CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

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CENTRAL TASAR RESEARCH AND TRAINING INSTITUTE
ISO 9001 : 2015 CERTIFIED, CENTRE OF EXCELLENCE

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Note: Information given in the present book is based on past and present R&D information along with recent advances; therefore, divergence in outlook is projected.

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(First Edition)

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CENTRAL TASAR RESEARCH & TRAINING INSTITUTE
(Central Silk Board, Ministry of Textiles Govt. of India)
Piska Nagari, Ranchi-835303, Jharkhand, India
We all know that tropical tasar silk is exclusive and unique in nature. Prominently, tasar silk industry based employment is mainly focused on women, tribal and poor people. This industry provides employment to around 3.5 lakhs peoples of India. Jharkhand, Odisha, Chhattisgarh, West Bengal, Telangana, Maharashtra are the core states for tasar silk production. Rearing of the tasar silkworm is conducted in outdoor conditions, therefore, its management is challenging for the researchers and primary producers. Several R&D initiative and farmers oriented technologies were developed for the elevation of production and productivity. I am contented to convey that implementation of various technologies at field level has minimized the hurdles of tasar culture which has played a key role in significant enhancement of raw silk production in many folds up to last one decade.

The CTR&TI Ranchi is an exclusive institute for key R&D support to tasar silk industry. Institute has developed many new technologies and performed the cutting edge need based research in recent past. Therefore, it is essential to document the current research and recent advances in the field of tasar. Recent past research findings, significant R&D achievements, need based research information as well as comprehensive informations have been highlighted in the present book. Therefore, this book will be very much useful for researchers, students, scholars, scientists, planners and entrepreneurs etc.

I am keen to divulge that the realistic research and crucial research information have been incorporated in the book entitled “Present Status & Recent Advances in Tasar Sericulture”. More importantly, present book includes key information linked to soil to silk, post cocoon, by-products, biotechnological aspects, tasar silkworm genomic information and seri-extension aspects of tasar silk industry in 15 vital book chapters. I convey my best wishes to the Director, contributors and editors for documentation of crucial findings in the form of book which will be highly beneficial for tasar silk industry as a whole.

Bangalore
18th March 2020.

(R.R. Okhandiar)
It is a great pleasure that Central Tasar Research & Training Institute, Ranchi is publishing an exclusive reference text book entitled “Current Status and Recent Advances in Tasar Sericulture”. Tasar culture is traditional culture of the poorest of the poor and different tribes of India. People used to do tasar culture in different parts of the country where other sources of income are scarce. Over the pasts decade the production of tasar silk has increased many folds due to collective approaches and active participation of CTR&TI, its R&D as well as its technology dissemination through States DOS. Jharkhand is the model state of tasar production which produces more than 70 percent of tasar silk and popularly known as the Tasar capital of the country. Several R&D achievements were made during the recent past and these are documented in the present book. We strongly believe that this will help the farmers, students and policy makers. Various technological interventions have been contributed in the areas of tasar silkworm rearing, host plant breeding, silkworm breeding, silkworm physiology, silkworm pathology, etc. Significant achievements in field of by-product utilization have also been documented in the present book which will create new dimension to Tasar silk industry. I would like to congratulate the research team and support staff for bringing this book for the benefit of the tasar industry as a whole.

It is believed that the Jharkhand state is the home of many indigenous tribes who practice Tasar sericulture since time immemorial. This culture is integrated in the lives of tribal people. Out of 3.5 lakhs people employed in India, around 2.3 lakhs peoples are associated with tasar culture in Jharkhand state. I’m happy to see the R&D progress of Central Tasar Research & Training Institute, Ranchi which has been working for the welfare of the poorest of poor through its R&D support, extension and training activities. This Institute looks after the various activities of tasar sericulture in 14 states. I thank team CTR&TI for the tremendous progress in the production of tasar silk since the last decade despite of various constraints.

As we know that, the Tropical Tasar Silkworm Antheraea mylitta Drury is grown mainly on Arjun, Asan and Sal. This sector is gaining popularity both in domestic and international markets. In this regard, there is an urgent need to have a concise text book on recent R&D developments carried out at Central Tasar Research & Training Institute, Ranchi. I would like to cite few recent developments in tasar sericulture that are incorporated in this book are sericin, cocoonase and other by-products utilization, modern biotechnological interventions for enhancing the quality and quantity of silk, soil health management, semi synthetic diet, pebrine visualizing solution for quick and easy detection of spores, recent reeling machine etc are highlighted in the present book.

I also extend my sincere thanks to farmers, precedent tasar researchers as well as key contributors of the present book. I express my sincere thanks to Editors and contributors for bringing out the text book “Current status and Recent Advances in Tasar Sericulture”. I also extend my sincere thanks to entire scientific fraternity of the tasar silk Industry for their valuable research. I believe that with effective dissemination of information CTR&TI will reach the greatest heights in the coming years.

I would also convey my deep thanks to present and precedent scientific/technical fraternity of Institute, whose recent developments are compiled and edited in this concise book which may act as reference book for the students, faculty, scholars & planners.

Best wishes

Ranchi
March 2020.

(Dr. Alok Sahay)
Director
India is the only country in the world which produces the 5 commercial variety of silks viz., mulberry, muga, tropical tasar, oak tasar and eri. Tasar silk is unique in world due to tremendous ethnic gaze and exclusive properties. The tasar silk is produced by tropical tasar silkworm, *Antheraea mylitta* and this culture provides employment to around 3.5 lakhs peoples in various parts of India. More importantly, Tasar silk industry based employment is mainly focused on women, tribal and poor people. The major tasar producing states are Jharkhand, Odisha, Chhattisgarh, West Bengal, Telangana, Maharashtra etc.

Interestingly, tasar occupies a distinctive position due to its outdoor rearing and its management is challenging for the researchers. Owing to many difficulties faced during the tasar culture, researchers have contributed significantly during the last 5 decades. However, the tasar production of India has taken a great leap during the last decade. Central Tasar Research & Training Institute is exclusive in the world, therefore, imperative need was felt to consolidate the present status and recent advancement in R&D activities. The text of this book is exclusive since the facts have been incorporated after practical research. The findings of the recent past, significant achievements were scored and these highlights have been documented in the present book entitled “Present status and Recent Advances in Tasar Sericulture”. This book is aimed for the researchers, students, scholars, Scientists, planners and entrepreneurs etc. Interestingly, this book not only focuses on the R&D of soil to silk, but also covers the by-products and seri- extension too by the experienced research contributors. Existent research scenario “Present Status and Recent Advances” of tasar silk industry has been documented in 15 crucial chapters of the present book. Chapter-1 Provides the overview of the tasar industry as a whole, Chapter-2 presents the recent advances in soil health & nutrient management, Chapter-3 emphasized the plant improvement efforts in *Terminalia arjuna* and *T. tomentosa*, Chapter-4 focused on the tasar silkworm host plant pest management, Chapter-5 deals with the tasar silkworm physiology, Chapter-6 documented the gynandromorphism in tasar silkworm, Chapter-7 deals with the tasar silkworm biodiversity, breeding, genetics & conservation, Chapter-8 provides details about the tasar silkworm rearing and seed technology, Chapter-9 deals with the tasar silkworm pest management, Chapter-10 elaborates the recent approaches in tasar silkworm disease management, Chapter-11 bio-technological approaches in tasar sericulture: Future prospective, Chapter-12 provides the recent developments in tasar silk post cocoon technology, Chapter-13 draws the attention towards tasar industry by-product utilization, Chapter-14 deals with the fundamentals of seri-extension education, Chapter-15 summarizes the outlook of CTR&TI Ranchi and outline of key R&D Initiatives.

I am sure this book will be highly beneficial for researchers, students, scholars, scientists, planners, entrepreneurs as well as tasar silk industry in totality.

Ranchi
March 2020

(Dr. Alok Sahay)
Chief-Editor
# CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULURE

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Introduction

India produces all the four commercially known varieties of silk viz; mulberry, tasar, eri and muga. These varieties were classified into mulberry and non-mulberry (Vanya silk). Non-mulberry sericulture is a vast field having enormous diversity and unique silk quality. Interestingly, this sort of sericulture is an ancient custom in India, mainly practiced by tribal people. Availability of the abundant nature grown plants are main unique resources for non-mulberry sericulture. Captivatingly, it is having high market demand at local as well as global level. It is a profitable traditional occupation that requires least investment to get good return. One of the key points of this industry is to employ the rural work-force gainfully. It provides them judicious earnings in different incline seasons of the year when they do not have crest-work in agriculture and other allied pursuits. (Arora and Gupta; 1979; Barua, et al., 2000; Geist and Lambin 2002; Jolly et al., 1969; Jolly, et al., 1976; Jolly, et al., 1968; Jolly, et al., 1979; Kakati and Chutia, 2009. Kar, et al.,2010; Kushwaha and Roy 2002; Reeta et al., 2016; Sahu 2005; Sinha et al., 2017; Singh, et al., 2005; Singh & Chakravorty, 2006; Singh, et al., 2005. Singh and Maheswari, 2003; Suryanarayana and Srivastava 2005; Thangavelu 1991). There are many basic and applied bio-molecular/bio-technological work conducted in the field of non-mulberry sericulture which played key role in production enhancements. Data on non-mulberry cocoon and raw silk production revealed a tremendous increase in production and productivity in last few decades which was more pronounced in last 12 years. More importantly, statistical analysis of production data 2007-08 to 2018-19 using Linear trend of the type Yt = a + b t based on Least square technique revealed the excellent favorable sign about growth rate and affirm future forecasting. Besides this, a ratio method technique was also applied to quantify the variety wise share in different plan period and state level in the total raw silk production in the country. Variety wise raw silk production at the end of IX to XII plan period along with their contribution to the total silk production indicate that the percentage share of mulberry and Muga silk in total raw silk has declined drastically, whereas, tasar, eri and Non-mulberry as a whole are in increasing trend after Xth plan period was noticed. The total raw silk production is 35468 MT of which present share of mulberry, non-mulberry, Tasar, Eri and Muga silk are 71.5 % (25345 mt), 28.54 % (10124 mt), 8.4 % (2981 mt), 19.48 % (6910 mt) and 0.66 % (233 mt) respectively. Tropical tasar silk is produced only in India. More importantly, tasar silk industry alone provides livelihood to nearly 3.5 lakhs families and having socio-economic relevance along with favour to ecology and environment. Recent data suggests that the raw silk production increased massively in last decade (Fig. 1).

Outline of Non-mulberry sericulture

India has a glorious sericulture tradition of its own, which no other country in the world can share; the Muga and tropical Tasar silk originated in India and Muga silk is exclusively confined to India; besides Muga and Tasar; Eri and mulberry silk are also cultivated in large quantity, making India the only producer of all the four types of commercial silk in the world and ranks only next to China in the global production of silk. India is also a largest user of silk and it has a very strong domestic market, which is the real strength of Indian sericulture. The commercial production of wild silk (non mulberry silk), Tropical Tasar (Antheraea mylitta), Muga (A. assama) and Eri silk (Samia cynthia ricinii) are not only the rich heritage of Indian sericulture but they make the distinction of Indian sericulture, therefore, greater emphasis and thrust for the overall development of non-mulberry sericulture in India should be given which will keep the Indian sericulture unique in the world silk market. India is the second largest producer of tasar silk after China, which produces temperate tasar obtained from Antheraea pernyi. India is still to catch ground in production of temperate tasar on commercial scale. India is the sole country producing tropical tasar silk by rearing of tropical tasar silkworm Antheraea mylitta. It harbours high potential for gainful rural employment and remunerative income to the tribal populace. It is a profitable traditional subsidiary occupation that requires least investment and high return. It has multi-tier earning potential to support rural enterprises/entrepreneurs, especially in the area of silkworm seed production, commercial cocoon production, yarn and fabric making and diversified products at the level of cocoon, yarn, fabric and wastes.

Fig.1: Production of the tasar raw silk in India during 2007-08 to 2019-20 data value is projected
Overview of Indian Non-Mulberry Sericulture Industry

The world of silk is mainly constituted by two distinct varieties—mulberry and non-mulberry. Non-mulberry sericulture is an age-old tradition in India, practiced mainly by the tribal people. It provides them with moderate earnings in different lean seasons of the year when they do not have any work in agriculture and other allied pursuits. Among the non-mulberry, Tasar, Muga, Eri, Anaphe, Fagara, Sinew, Mussel, Spider and Coan silks constitute “Wild Silk”. India has distinction of producing the commercially better known varieties viz; Tasar, Muga and Eri silks.

Indian Non-mulberry Production Scenario: Interestingly, India produces all the four commercially known varieties of silk viz; mulberry, tasar, eri and muga. These varieties were classified into mulberry and non-mulberry (Vanya silk). Mulberry forms the major share of silk production in India. Out of a total quantity of 35468 tones of raw silk produced in 2018-19, Mulberry raw silk was 25345 MT tones and non-mulberry 10123 MT tones accounting for 70.06 % and 29.94 % respectively. The variety-wise production of non-mulberry silk during 2018-19 was 10123 MT Tasar- 2981 MT (8.47 %), Eri-6910 MT (19.48 %) and Muga-233 MT (0.66 %). During XI and XII th plan period, higher growth rate was recorded in Non-mulberry silk in comparison to Mulberry silk which may be due to positive impact of developmental schemes implemented by Govt. of India.


Table 1: Production of Raw silk at the end of Plan period (IX to XII) and contribution over raw silk*

<table>
<thead>
<tr>
<th>Plan</th>
<th>Mulberry Qty (MT)</th>
<th>% Cont.</th>
<th>Tasar Qty (MT)</th>
<th>% Cont.</th>
<th>Eri Qty (MT)</th>
<th>% Cont.</th>
<th>Muga Qty (MT)</th>
<th>% Cont.</th>
<th>Non-Mulberry Qty (MT)</th>
<th>% Cont.</th>
<th>Total Raw Silk (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IX Plan (1997-02)</td>
<td>15842</td>
<td>91.30</td>
<td>249</td>
<td>1.44</td>
<td>1160</td>
<td>6.69</td>
<td>100</td>
<td>0.58</td>
<td>1509</td>
<td>8.70</td>
<td>17351</td>
</tr>
<tr>
<td>X Plan (2002-07)</td>
<td>16525</td>
<td>89.45</td>
<td>356</td>
<td>1.93</td>
<td>1485</td>
<td>8.04</td>
<td>115</td>
<td>0.62</td>
<td>1950</td>
<td>10.55</td>
<td>18475</td>
</tr>
<tr>
<td>XI Plan (2007-12)</td>
<td>18271</td>
<td>85.10</td>
<td>1590</td>
<td>7.41</td>
<td>3072.1</td>
<td>14.31</td>
<td>126.2</td>
<td>0.59</td>
<td>3198.3</td>
<td>14.90</td>
<td>21469</td>
</tr>
<tr>
<td>XII Plan (2012-17)</td>
<td>21203</td>
<td>70.06</td>
<td>3259</td>
<td>10.77</td>
<td>5629</td>
<td>18.60</td>
<td>171</td>
<td>0.57</td>
<td>9059</td>
<td>29.94</td>
<td>30262</td>
</tr>
</tbody>
</table>

Compound Growth Rate (%):

<table>
<thead>
<tr>
<th>Plan</th>
<th>IX Plan</th>
<th>X Plan</th>
<th>XI Plan</th>
<th>XII Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Cont.</td>
<td>-4.40</td>
<td>4.30</td>
<td>3.00</td>
<td>17.70</td>
</tr>
<tr>
<td>% Growth</td>
<td>7.30</td>
<td>2.40</td>
<td>15.00</td>
<td>11.70</td>
</tr>
<tr>
<td>% Cont.</td>
<td>10.00</td>
<td>2.40</td>
<td>1.50</td>
<td>11.70</td>
</tr>
<tr>
<td>% Growth</td>
<td>4.90</td>
<td>2.80</td>
<td>18.20</td>
<td>17.40</td>
</tr>
<tr>
<td>% Cont.</td>
<td>2.60</td>
<td>2.50</td>
<td>4.70</td>
<td>6.30</td>
</tr>
</tbody>
</table>

*Source: Central Silk Board
Interestingly, the linear trend fitted for tasar, eri and muga cocoon and raw silk production (Table 2) reveals that the tasar cocoon, eri cocoon and muga cocoon production were increasing annually by 2.41 Lakh (kahan), 582.99 MT and 378.20 Lakh, whereas tasar silk, eri silk and muga silk and total non-mulberry silk were increasing annually by 325.12 MT, 447.58 MT, 6.94 MT, and 751.87 MT respectively based on the period 2007-08 to 2016-17. The projected raw silk production for tasar, eri, muga and total non-mulberry silk have been estimated at 4508.48 MT, 7267.19 MT, 194.28 MT and 10596.82 MT respectively for the year 2020-21 based on linear trend of 10 years data under study. The compound growth rate for cocoon and raw silk production was calculated using exponential growth model of the type \( Y = \exp(a + bX) \). The compound growth rate for tasar cocoon, eri cocoon, and muga cocoon production were recorded 22.45 %, 15.10 % and 5.86 % annually, whereas growth for tasar raw silk, eri raw silk, muga raw silk and total non-mulberry raw silk were registered 25.23 %, 14.72 %, 5.14 % and 19.25 % annually. During the last two decades, the highest growth rate was recorded for tasar cocoon and raw silk production in comparison to other non-mulberry silk varieties. The regression coefficients \( b \) and coefficient of determination \( R^2 \) estimated from linear growth model indicated in Table 2 were found significant at \( p<0.01 \) level.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cocoon Production</th>
<th>Raw Silk Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tasar (Lakh Kahan)</td>
<td>Eri (MT)</td>
</tr>
<tr>
<td>2007-08</td>
<td>4.00</td>
<td>1982.9</td>
</tr>
<tr>
<td>2008-09</td>
<td>5.30</td>
<td>2593.0</td>
</tr>
<tr>
<td>2009-10</td>
<td>7.50</td>
<td>2800.7</td>
</tr>
<tr>
<td>2010-11</td>
<td>10.30</td>
<td>3526.7</td>
</tr>
<tr>
<td>2011-12</td>
<td>15.00</td>
<td>3899.0</td>
</tr>
<tr>
<td>2012-13</td>
<td>15.60</td>
<td>3945.4</td>
</tr>
<tr>
<td>2013-14</td>
<td>20.70</td>
<td>5464.0</td>
</tr>
<tr>
<td>2014-15</td>
<td>20.60</td>
<td>6087.0</td>
</tr>
<tr>
<td>2015-16</td>
<td>22.87</td>
<td>6623.0</td>
</tr>
<tr>
<td>2016-17</td>
<td>23.67</td>
<td>7060.0</td>
</tr>
<tr>
<td>CGR%</td>
<td>22.45</td>
<td>15.10</td>
</tr>
</tbody>
</table>

State wise production of non-mulberry raw silk (MT) in India: State wise and variety wise raw silk production for the year 2015-16 (Table 3) indicate that Jharkhand is leading state in tasar raw silk production with 2281 MT (80.92%) out of total tasar silk production (2819 MT) followed by Chhattisgarh (254 MT) and Odisha (107 MT). Among eri silk producing states, Assam placed at first position with 3143 MT (62.11%) followed by Meghalaya (824 MT) and Nagaland (622 MT). Whereas, Assam is only state which contributed 86% (142 MT) for Muga silk production followed by Meghalaya. On the other hand, based on combined data of all varieties, Assam is highest contributor with 40.83 % in non-mulberry silk production followed by Jharkhand with 28.35 %. As the XII plan was up to the 2017, there fore, the non-mulberry cocoon and raw silk production is mentioned and compared up to 2016-17, however the tasar production data is mentioned in the Figure 1.
### Table 3: State wise production of non-mulberry raw silk (MT) in India in 2015-16 and state wise contribution (%)*

<table>
<thead>
<tr>
<th>State</th>
<th>2015-16</th>
<th>% share of Non-mulberry silk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tasar</td>
<td>Eri</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>0.00</td>
<td>32.00</td>
</tr>
<tr>
<td>Assam</td>
<td>0.00</td>
<td>3143.00</td>
</tr>
<tr>
<td>Bihar</td>
<td>41.00</td>
<td>8.00</td>
</tr>
<tr>
<td>Chattisgarh</td>
<td>254.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Jharkhand</td>
<td>2281.00</td>
<td>0.00</td>
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<tr>
<td>Madhya Pradesh</td>
<td>56.00</td>
<td>1.00</td>
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<td>Maharashtra</td>
<td>0.00</td>
<td>370.00</td>
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<tr>
<td>Manipur</td>
<td>4.00</td>
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<tr>
<td>Meghalaya</td>
<td>0.00</td>
<td>824.00</td>
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<td>Mizoram</td>
<td>0.01</td>
<td>9.00</td>
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<tr>
<td>Nagaland</td>
<td>0.07</td>
<td>622.00</td>
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<tr>
<td>Orissa</td>
<td>107.00</td>
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<tr>
<td>Sikkim</td>
<td>0.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Telangana</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>20.00</td>
<td>36.00</td>
</tr>
<tr>
<td>Uttarakhand</td>
<td>34.00</td>
<td>0.00</td>
</tr>
<tr>
<td>West Bengal</td>
<td>0.00</td>
<td>6.00</td>
</tr>
<tr>
<td>Total</td>
<td>2819.00</td>
<td>5060.00</td>
</tr>
</tbody>
</table>

*Source: Central Silk Board

Among the non-mulberry silk, only the tasar silk fabrics are exported from India. There is practically least export of eri and muga silk products inspite of their better fiber qualities and textile properties. Non-mulberry (Tasar) export and its share in natural silk export (Table 4) speaks much about the dismal performance of non-mulberry silk export in the recent years and its share ranged from 2.46 to 11.33 % in the total natural silk export from India. The Non-mulberry (Tasar) silk goods exported by India to other countries was recorded a worth of Rs. 70.86 crore during 2004-05 and it reached upto level of 121.94 crore during 2013-14 with compound growth rate 5.58 % annually which shows significant achievement during last 10 years. The unit value realization is not encouraging; as compared to mulberry sector; since export of value added products lack in the non-mulberry category. The share of non-mulberry export in the silk export basket is in fluctuating nature. The highest 11.3% contribution of Non-mulberry silk export was registered during 2011-12, but subsequently the export trend does not indicate any favourable trend, may be due to poor workmanship, lack of product diversity, insufficient supply and poor publicity etc. As the non-mulberry plantation data was available till 2015-16, therefore, state-wise production of non-mulberry raw silk mentioned upto 2015-16 only (Table 3 and 5)

### Table 4: Export of Mulberry and Non-mulberry silk goods in India (Unit: Crore, Rs.)*

<table>
<thead>
<tr>
<th>Year</th>
<th>Mulberry</th>
<th>Non-Mulberry</th>
<th>Mixed Blended</th>
<th>Total</th>
<th>Raw Silk &amp; Silk Yarn</th>
<th>Silk Waste</th>
<th>Grand Total</th>
<th>Non-mulberry silk share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004-05</td>
<td>5452.32</td>
<td>70.86</td>
<td>30.61</td>
<td>2827.63</td>
<td>50.64</td>
<td>1.29</td>
<td>2879.56</td>
<td>2.46</td>
</tr>
<tr>
<td>2005-06</td>
<td>5896.74</td>
<td>118.62</td>
<td>39.10</td>
<td>3106.09</td>
<td>68.21</td>
<td>19.90</td>
<td>3194.20</td>
<td>3.71</td>
</tr>
<tr>
<td>2006-07</td>
<td>6183.26</td>
<td>143.21</td>
<td>34.97</td>
<td>3269.81</td>
<td>45.76</td>
<td>22.78</td>
<td>3338.35</td>
<td>4.29</td>
</tr>
<tr>
<td>2007-08</td>
<td>5067.58</td>
<td>118.92</td>
<td>17.63</td>
<td>2670.34</td>
<td>45.38</td>
<td>12.15</td>
<td>2727.87</td>
<td>4.36</td>
</tr>
<tr>
<td>2008-09</td>
<td>5815.84</td>
<td>208.67</td>
<td>21.29</td>
<td>3137.88</td>
<td>35.08</td>
<td>5.23</td>
<td>3178.19</td>
<td>6.57</td>
</tr>
<tr>
<td>2009-10</td>
<td>5209.10</td>
<td>211.53</td>
<td>22.02</td>
<td>2838.10</td>
<td>29.42</td>
<td>24.92</td>
<td>2892.44</td>
<td>7.31</td>
</tr>
<tr>
<td>2010-11</td>
<td>5137.38</td>
<td>192.54</td>
<td>27.01</td>
<td>2788.24</td>
<td>39.38</td>
<td>36.14</td>
<td>2863.76</td>
<td>6.72</td>
</tr>
</tbody>
</table>
The overall statistical analysis reveals that the trend of non-mulberry silk production in the recent past is highly encouraging particularly that of tasar silk which supply most of the raw materials for export production in the non-mulberry silk category. However the growth rate of food plant areas for all the non-mulberry varieties shows negative growth inspite of increasing raw silk production which may be due to impact of technologies and developmental schemes implemented by Govt. of India like MKSP, TSP, VCPP and NERTPs & IVCP respectively. Based on the recent 11 years data of non-mulberry plantation area (hec) at national level compiled by Central Silk Board for tasar, eri and muga (Table 5), it was found that share of tasar food plant ranged 65.67 % to 78.74 % out of total non-mulberry plantation areas followed by eri food plant area (15.05 to 28.42 %) and muga (4.48 to 9.91 %). During 2015-16, tasar food plant area was recorded 127718 hec, eri (40827 hec) and muga (17487 hec) which is comparatively better than previous year.

Table 5: Non-mulberry plantation area (ha.) at National level*

<table>
<thead>
<tr>
<th>Year</th>
<th>Tasar</th>
<th>Eri</th>
<th>Muga</th>
<th>Total Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (ha)</td>
<td>% share</td>
<td>Area (ha)</td>
<td>% share</td>
</tr>
<tr>
<td>2005-06</td>
<td>1,31,273</td>
<td>67.03</td>
<td>55,142</td>
<td>28.16</td>
</tr>
<tr>
<td>2006-07</td>
<td>1,44,073</td>
<td>67.10</td>
<td>61,023</td>
<td>28.42</td>
</tr>
<tr>
<td>2007-08</td>
<td>1,39,536</td>
<td>74.40</td>
<td>37,897</td>
<td>20.21</td>
</tr>
<tr>
<td>2008-09</td>
<td>1,46,849</td>
<td>79.21</td>
<td>28,218</td>
<td>15.22</td>
</tr>
<tr>
<td>2009-10</td>
<td>1,49,680</td>
<td>77.74</td>
<td>37,149</td>
<td>16.49</td>
</tr>
<tr>
<td>2010-11</td>
<td>1,61,490</td>
<td>77.49</td>
<td>33,610</td>
<td>16.13</td>
</tr>
<tr>
<td>2011-12</td>
<td>1,78,756</td>
<td>78.74</td>
<td>34,168</td>
<td>15.05</td>
</tr>
<tr>
<td>2012-13</td>
<td>1,05,949</td>
<td>65.67</td>
<td>39,397</td>
<td>24.42</td>
</tr>
<tr>
<td>2013-14</td>
<td>1,13,899</td>
<td>69.02</td>
<td>36,403</td>
<td>22.06</td>
</tr>
<tr>
<td>2014-15</td>
<td>1,10,262</td>
<td>69.02</td>
<td>36,403</td>
<td>22.06</td>
</tr>
<tr>
<td>2015-16</td>
<td>1,27,718</td>
<td>68.65</td>
<td>40,827</td>
<td>21.95</td>
</tr>
<tr>
<td>CGR (%)</td>
<td>-0.25</td>
<td>-2.70</td>
<td>5.77</td>
<td>-0.47</td>
</tr>
</tbody>
</table>

*Source: Central Silk Board

The constraints facing Tasar sericulture in India are manifold; and generally, they are of two types; manmade and inherent biological constraints, which are unique to wild silkworms. The scientists, planners and administrators should collectively plan the importance, intricacies and the socio economic relevance of tasar silk, in the back drop of ecology and environment. In fact the Tasar silk is the inherent strength of Indian sericulture. Often the undue importance given to mulberry silk overshadows the rightful place and importance of tasar silk in India. The planners and administrators often consider the immediate economic returns to the farmers from mulberry sericulture; but the long term effect of tasar sericulture on the ecological and environmental balance that accrue through tasar sericulture are seldom considered.

Therefore the planners invariably give top priority and make very heavy investment in mulberry silk as against the low investment and low priority in the non-mulberry silk. The opportunity, funds and infrastructure available for research in Tasar sericulture is highly inadequate and not commensurate with the manifold and numerous intricate and complex problems that are unique to Tasar silk, and these are the manmade problems.

The biological constraints include wild nature of the silkworms and their low amenability to human handling, outdoor rearing, unstable voltinism, high susceptibility to diseases, which are aggravated by adverse climatic conditions and poor quality of leaves of food plants, low fecundity, unstable crops, adverse climatic conditions, particularly during seed crops; non availability of sufficient quantity of quality silkworm seeds in right time, physiological and genetic...
The voltinism in wild silkworms are highly unstable. In economic point of view, which are the two most important commercial characters from potential of the wild silkworms in respect of fecundity and silk yield, the nutritional requirements of the wild silkworms are also not yet today. In this backdrop it is essential to mention that the nutritional loss of physiological vigour, which is confronting the scientists even successive multiplication of silkworm crops. This might be due to and genetic degeneration; the robustness of the cocoons, health and productivity of Raw silk in Tasar sector.

The characterization of tasar silkworms is more or less based on morphological and biochemical parameters of egg, larva, pupa, cocoon and moth; which often vary widely and not stable. The genetics of Non-mulberry silkworms are not yet studied in detail in a systematic way, which are essential to determine racial characters and evolve specific pure lines/races. Even after 35 years of research, the descriptors of tasar silkworms with race specific characters are not yet available. The non-mulberry silkworms available today for commercial exploitation are genetically mosaics with different genetic linkage groups and hence do not exhibit hybrid vigour when breeds from different seed stocks are crossed with. In other words, genetically distinct and character specific races are still not available for evolution of superior breeds / cross breeds/ hybrids, which will exhibit hybrid vigour. But when pure lines are isolated from the existing population of mosaic forms, such pure lines exhibit very low survival rate and are highly vulnerable to extremes of climatic condition and the onslaught of diseases and hence it is very difficult to maintain the pure lines in the germplasm for evaluation and breed evolution.

The Tasar silkworms are often reported to undergo physiological and genetic degeneration; the robustness of the cocoons, health of the worms and other quantitative characters often decline in successive multiplication of silkworm crops. This might be due to loss of physiological vigour, which is confronting the scientists even today. In this backdrop it is essential to mention that the nutritional status of the food plants are still not yet studied and subsequently the nutritional requirements of the wild silkworms are also not yet understood properly and hence we are unable to exploit the biofert potential of the wild silkworms in respect of fecundity and silk yield, which are the two most important commercial characters from economic point of view.

The voltinism in wild silkworms are highly unstable. In A. mylitta; voltinism depends on the altitude of the place and the photoperiod during the final instar stage prevailing in the rearing site. As a result, it is common phenomena that bivoltine races of tasar silkworm behave like trivoltine in hotter areas at low altitude and long photoperiod, whereas the reverse is true and trivoltine behave like bivoltine if the trivoltine races are reared in place of high altitude under short photoperiod condition. In A. assama some fragment of the natural wild population undergo diapause in their natural habitat, but when this population is shifted to low altitude area under long photoperiod conditions, such diapause population behave like non-diapause population. This indicate that voltinism is genetically not stable which is a major constrain in race fixation.

Reproductive biology is another area of neglect and concern; low fecundity and retention of eggs in the ovary, staggered oviposition and consequently the hatching of eggs over 3 to 4 days, low rate of fertilization and hatching of eggs are some of the problems which are responsible for low multiplication rate (i.e. seed to seed – or dff to dff) which affect the seed production sector in tasar sericulture. (Arora and Gupta; 1979; Barua, et al., 2000; Geist and Lambin 2002; Jolly et al., 1969; Jolly, et al., 1976; Jolly, et al., 1968; Jolly, et al., 1979; Kakati and Chutia, 2009. Kar, et al.,2010; Kushwaha and Roy 2002; Reeta et al., 2016; Sahu 2005; Sinha et al., 2017; Singh, et al., 2005; Singh & Chakravorty, 2006; Singh, et al., 2005. Singh and Maheswari, 2003; Suryanarayana and Srivastava 2005; Thangavelu 1991).

Future Research Strategies

While the potential for Tasar silk expansion is huge, projections of Inter-Governmental panel on climate change leading to more frequent hot extremes, floods, droughts, cyclones etc., would alter dynamics of pests and diseases, which may result in greater instability in Tasar host plant production and success rate of cocoon crop production. This would require increased adaptation and mitigation research, capacity-building and changes in policies. Developmental in molecular biology, biotechnology, nanotechnology, information technology and geo-spatial technology are expected to provide significant new opportunities for productivity enhancement. For expansion of Tasar sector following points needs to be taken care:

- Improvement & Development of Tasar breeds, field trial of higher fecundity Daba tasar ecorace line. Thermo-tolerant and disease resistant lines need proper improvement to increase the production and productivity of Raw silk in Tasar sector.
  - Conservation of indigenous germplasm of Tasar silkworms and host plants in situ and ex situ for their better use in developing high productive/ disease resistant / climate resilient silkworm breed / host plants.
  - Bio-pesticides and bio-control agents against silkworm pests and diseases to reduce production costs by increasing productivity.
  - Seed technology development and strengthening Seed sector: Working out appropriate preservation schedule as per ideal crop schedules,
  - Host plant improvement: Identification of high rooting, early sprouting and fast growing genotypes to reduce gestation period, development of dwarf and bushy genotypes to maximize leaf yield, tolerant towards biotic and abiotic stress, package of practices Lagerstroemia speciosa, integrated plant nutrient management & cost effective pest and disease control system, multi-cropping and intercropping need more attention for growth of Tasar sericulture.
  - Diversification of silk products and by-products: Apart from the regular use of silk as yarn to make fabrics, there are
ample avenues to utilize the by-products of Tasar sericulture, which if used prudently and judiciously can help to increase the value of sericulture products to maintain a healthy level of profitability. Owing to the recent advances in biomedical sciences, silk has increasingly been used as biomaterial to make scaffolds, sponges, films, gels, nano particles and nano fibrils. These high value products can definitely bring additional benefits to the tasar sericulture sector. Keeping this in view CTR&TI institutes should work in collaboration with reputed National and International Institutes to develop technologies to use silk as biomaterial in biomedical applications. Fusion proteins with antibacterial properties, nano particles of sericine for cosmetics and fibroin based scaffolds and gels shall be produced to utilize silk in biomedical applications.

Approach to increase Tasar silk production: Increase systematic plantation of tasar silks for controlled rearing: At present, majority of the rearings are taken up in natural host flora, which are depleting due to deforestation. In order to ensure better productivity and quality of cocoons, there is a need to converse the natural host flora and also taking up block plantations of tasar host plants in forest, revenue and private lands. Further, the block plantations are essentials to take up seed rearings to ensure disease free seed cocoon generation. On the other hand, though commercial rearing will continue to be taken up on natural flora, in order to minimize the mortality, tasar chawki silkworms need to be fed with better quality foliage, for which chawki gardens need to be developed so that the worms after chawki stage can be transferred to fringe forest areas. Based on earlier successful experience in few states, attempts would be made to bring in revenue, forest and private wastelands under tasar host plant economic plantations, availing the provisions available schemes of “Govt. of India keeping in view of the above strategy, a vision for producing 17,800 MT of Non-Mulberry raw silk out of 60,000 MT raw silk by 2030 has been proposed with strategic approach in critical areas as per Govt. of India’s focused areas.

Problems of Tasar Industry
Research by CTR&TI in the field of Tasar culture spans over 56 years. Many of the problems pertain to seed production, rearing technology, training and transfer of technology has been solved. Yet several problems still continue to check the growth of the industry, some important problems are listed:

- Non-utilization of sal flora though it is one of the primary food plant and are available in abundance.
- Environmental chances sometimes severely affect the seed preservation and production.
- Full linkage between breed development, breed maintenance and P4 to P1 continuity in seed sector is lacking.
- Development of high yielding plant varieties and its multiplication.
- Full proof disease control method and yardstick for identification of healthy stock are very much required.
- Introduction and termination of diapause to utilize the best option of suitable season.
- There is no consistency in cocoon yield per dfl. Present productivity ranges between 30 to 80 cocoons per dfls.
- Inadequate product diversification
- Modernization of reeling and weaving sector.
- No organized market for Tasar cocoons.

Priorities Areas for tasar silk Industry
- By-product utilization
- Genome sequencing and SNP Genotyping of tasar ecoraces
- Morpho-physio-molecular characterization of tasar host-plant and development of further true to type multiplication technique.
- Promoting conservation & characterisation of various available ecoraces.
- Genetic and molecular characterisation of ecoraces, promoting their conservation, development of productive breeds lines, evolution of thermotolerant breed of tassar silkworm.
- Development of disease resistant silkworm.
- Molecular characterisation of disease causing pathogens , development of disease resistant varities farm friendly method of disease detection and ecofriendly management.
- Development of bio-indicator.
- Evaluation of effective utilisation of developed tasar silkworm breeds.
- Indoor chowki rearing as a tool for improving cocoon productivity.
- Product diversification.
- Promotion of organic tasar fabrics for international productivity.
- Transfer of technology.
- Drudgury reduction.

Road Map by Year 2030 for tasar silk industry
- Development of technology for exploitation of sal flora and conservation of ecoraces.
- Development linkage of breed development in seed sector P4 to P1 system.
- Full proof technology for seed cocoon preservation in adverse condition.
- Introduction of New seed zone concept.
- Establishment of germ plasm station for tasar food plants and silkworm or germplasm station for tasar sector.
- Development of high yielding disease tolerant races in term of fecundity and silk yield and low denior through biotechnological tools.
- Development of indoor rearing technique for tasar ecoraces.
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

- Development of chowki rearing concept and introduction after establishment of CRC.
- Studies on diapause mechanism and preservation of eggs.
- Studies on termination of diapause in bivoltine stock.
- Studies on induction of diapause in egg storage.
- Developing bioindicators for pupal health.
- Characterisation of disease causing pathogens and their management.
- Domestication of sal based ecoraces for rearing and seed production.
- Development of vegetative propagation technique and superior varieties of food plant.
- Identification of desired genotype and genetic manipulation for enhancing productivity.
- Assessment of nutritional status of the leaf in view of food preference of silkworm.
- Identification of leaf, ingredients Amino acid combination, protein and other substance of silk production.
- Developing plants having such ingredients for enhancing silk production.
- Biotechnological intervention at host and silkworm stages maximization of production of identified ingredients at food plant level and its conversion by silkworm for silk production.
- Development of food plant variety wich can produce desired leaf quality on desired time with low gestation.
- Development of dwarf host plant with less gestation period.
- Embryo preservation of tasar embryo and semen for posterity.
- Improvement of productivity and quality in rearing sector.
- Product diversification.
- Higher return through value chain addition.
- Seri- waste utilisation and product diversification.

Conclusions

Non-mulberry sericulture is very vast field having enormous diversity and unique silk quality. It harbours high potential for gainful rural employment and remunerative income to the tribal populace. Tropical tasar silk is produced only in India. Availability of the abundant nature grown plants is main unique resources for tasar sericulture. It is having high market demand at local as well as global level. It is a profitable traditional occupation that requires least investment to get good return. One of the key points of this industry is to employ the rural work-forces gainfully. It provides them judicious earnings in different incline seasons of the year when they do not have crest-work in agriculture and other allied pursuits. There are many basic applied and bio-molecular/bio-technological work conducted in the field of non-mulberry sericulture which played key role in production enhancements. Data on Non-mulberry Cocoon and Raw silk production revealed a tremendous increase in production and productivity in last few decades which was more pronounced in last 10 years. More importantly, statistical analysis of production data using Linear trend of the type \( Y_t = a + b \cdot t \) based on Least square technique revealed the excellent favorable sign about growth rate and affirm future forecasting. Besides this, a ratio method technique was also applied to quantify the variety wise share in different plan period and state level in the total raw silk production in the country. Variety wise raw silk production at the end of IX to XII plan period along with their contribution to the total silk production indicate that the percentage share of mulberry and Muga silk in total raw silk has declined drastically, whereas, tasar, eri and Non-mulberry as a whole are in increasing trend after Xth plan period was noticed. More importantly, tasar sericulture provides huge livelihood to poor families and having socio-economic relevance along with favour to ecology and environment. Hence, more focus must be given to the tasar sector.

References


Soil Health and Nutrient Management
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Central Tasar Research & Training Institute, (Central Silk Board, Ministry of Textiles Govt. of India)
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* Corresponding author

Introduction
Soil is the thin top layer on the earth’s crust comprising rock particles mixed with organic matter. It is a marvelous gift of nature to mankind. Without the presence of this thin layer on the top of lithosphere, there would have been no life on the planet Earth. Kellogg (1938) expressed that soils and humans have evolved together. A priorly expressed ‘health of the soils a nation owns determines the quality of well-being of its people’. Humans for their own survival and for the sake of survival of their future generations, must not violate the quality of the soils inherited by them (Chief Seattle 1855). Hence it becomes incumbent on mankind to treat soil as part of their ‘community’ and not as a ‘commodity’. SOIL is derived from the Latin Word “SOLUM” Means FLOOR. Soil has been described in several ways; from solid ground (solum) to dirt and to the nurturer of the universe. Capturing the essence of definitions given by soil scientists, it is portrayed as:

Functions of soil
• It provides place and anchorage for plant growth and development.
• It serves as a medium for air and water circulation.
• It acts as a reservoir for water and nutrients.
• It provides space for beneficial microorganisms.

Soil can be compared to various systems of human body

<table>
<thead>
<tr>
<th>Functions of Soil</th>
<th>Digestive</th>
<th>Respiratory</th>
<th>Circulatory</th>
<th>Excretory</th>
<th>Brain</th>
<th>Colour</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>• a</td>
<td>- Matters decomposition</td>
<td>- Air circulation &amp; exchange of gases</td>
<td>- Water movement within the soil system</td>
<td>- Leaching out of excess salts</td>
<td>- Soil clay</td>
<td>- Soil colour</td>
<td>- Soil depth</td>
</tr>
</tbody>
</table>

Average composition of Earth’s soil crust (% by weight)

<table>
<thead>
<tr>
<th>Component</th>
<th>Non-metallic</th>
<th>Metallic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen O₂</td>
<td>46.60%</td>
<td>74.32% (3/4th)</td>
</tr>
<tr>
<td>Silica Si⁴⁺</td>
<td>27.72%</td>
<td></td>
</tr>
<tr>
<td>Aluminium Al³⁺</td>
<td>8.13%</td>
<td>1/4th of the total</td>
</tr>
<tr>
<td>Iron Fe²⁺</td>
<td>5.00%</td>
<td></td>
</tr>
<tr>
<td>Calcium Ca²⁺</td>
<td>3.63%</td>
<td></td>
</tr>
<tr>
<td>Sodium Na⁺</td>
<td>2.83%</td>
<td></td>
</tr>
<tr>
<td>Potassium K⁺</td>
<td>2.59%</td>
<td></td>
</tr>
<tr>
<td>Magnesium Mg²⁺</td>
<td>2.09%</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>1.41%</td>
<td></td>
</tr>
</tbody>
</table>

Eight elements are abundant – 98.6%

Components of Soil (volume basis)
• Soil is made up of 4 parts: mineral matter, organic matter, water, and air.
• Mineral matter and organic matter together form the solid part of soil. Soil air and soil water occupy the spaces between the solid particles. This space is the pore space. A good productive soil will be about half solid particles and half pore space.
• Conditions for root growth will be ideal when about half the pore space is filled with water and half is filled with air.

Fig 1: Composition of Soil
How is Soil Formed?

Soils are dynamic, forming continuously over a long period of time. Soil types differ, depending on the parent materials from which they came and from the surrounding environment. The way in which soil forms depends on: (i) parent material (ii) climate (iii) topography (iv) living organisms and (v) time.

Development of Soil Profile

The vertical section of the soil showing the various layers from the surface to the unaffected parent material is known as a soil profile. The various layers are known as horizons. A soil profile contains three main horizons. They are named as horizon A, horizon B and horizon C.

A hypothetical mineral soil profile will include O, A, B, C and R master horizons and all the possible sub-horizons.

**Fig 2: horizons of Soil**

- **O horizon** - It is called as organic horizon. It is formed in the upper part of the mineral soil, dominated by fresh or partly decomposed organic materials. The organic horizons are commonly seen in forest areas and generally absent in grassland, cultivated soils.
  - O1 - Organic horizon in which the original forms of the plant and animal residues can be recognized through naked eye.
  - O2 - Organic horizon in which the original plant or animal matter cannot be recognized through naked eye.

- **A horizon** - Horizon of organic matter accumulation adjacent to surface and that has lost clay, iron and aluminium.
  - A1 - Top most mineral horizon formed adjacent to the surface. There will be accumulation of humified organic matter associated with mineral fraction and darker in colour than that of lower horizons due to organic matter.
  - A2 - Horizon of maximum eluviation of clay, iron and aluminium oxides and organic matter. Loss of these constituents generally results in accumulation of quartz and other sand and silt size resistant minerals. Generally lighter in Colour than horizons above and below.
  - A3 - A transitional layer between A and B horizons with more dominated properties of A1 or A2 above than the underlying B horizon. This horizon is sometimes absent.

- **B horizon** - Horizon in which the dominant features are accumulation of clay, iron, aluminium or humus alone or in combination. Coating of sesquioxides will impart darker, stronger of red colour than overlying or underlying horizons.
  - B1 - A transitional layer between A and B. More like A than B.
  - B2 - Zone of maximum accumulation of clay, iron and aluminium oxide that may have moved down from upper horizons or may have formed in situ. The organic matter content is generally higher and colour darker than that of A2 horizon above.
  - B3 - Transitional horizon between B and C and with properties more similar to that of overlying B2 than underlying C.

- **C horizon** - It is the horizon below the solum (A + B), relatively less affected by soil forming processes. It is outside the zone of major biological activity. It may contain accumulation of carbonates or sulphates, calcium and magnesium.

- **R horizon** - Underlying consolidated bed rock and it may or may not be like the parent rock from which the solum is formed.

**Soil Health**

The term ‘Soil health’ invariably crosses roads with other name ‘soil quality’. The pioneer textbook on Soil Science, ‘Nature and Properties of Soils’ 14th Edition (Brady and Weil 2013) describes the concepts of soil health and soil quality. According to the text “Although these terms are often used synonymously, they involve two distinct concepts.

The soil health refers to self-regulation, stability, resilience, and lack of stress symptoms in a soil as an ecosystem.

**Soil health** describes the biological integrity of the soil community - the balance among organisms within a soil and between soil organisms and their environment”. Soil health concept involves integration of physical, chemical and biological properties of a soil and role of this harmonious blend in sustaining productivity growth and environmental security.

**Soil quality**, therefore, in contrast is the term that more often is used to illustrate physical and chemical attributes of a soil and their place in plant growth and environmental regulatory functions. These characteristics range between a simple trait like soil colour to more complex properties like fertility, erodibility and compactability.

**Soil health indicators**

1. Soil provides adequate levels of macro- and micronutrients to plants and soil microbes. This reflects the ability of the soil to mineralize nutrients and a moderate pH (~6.0–7.0) that allows the nutrients to be both held in the soil and available to plants as needed.
2. Soil has good “tilth.” This includes a good structure that resists degradation (e.g., erosion and compaction), provides adequate aeration and rapid water infiltration, and accepts, holds, and releases water to plants and groundwater.
3. Soil promotes good root growth and maintains good biotic habitat that sustains high and diverse populations of beneficial organisms and low populations of pests and pathogens.
4. Soil has low salinity levels and low levels of potentially toxic elements (e.g., boron, manganese, and aluminum).

Soil health is established through the interactions of soil’s physical, chemical, and biological properties.

**Physical Properties**

Physical properties (mechanical behaviour) of a soil greatly influence its use and behaviour towards plant growth. The plant support, root penetration, drainage, aeration, retention of moisture, and plant nutrients are linked with the physical condition of the soil.

Important physical properties of soils are i) Soil texture, ii) Soil structure, iii) Soil density iv) Soil porosity, v) Soil colour, vi) Soil consistence & vii) Soil Moisture.

**Soil Texture**

Soil texture refers to the relative proportion of particles or it is the relative percentage by weight of the three soils separates viz., sand, silt and clay or simply refers to the size of soil particles.

Particles less than 2 mm in diameter are considered as soil material. Stones and gravels may influence the use and management of land because of tillage difficulties but these larger particles make little or no contribution to soil properties such as water holding capacity and capacity to store plant nutrients and their supply.

Gravels: 2 – 4 mm; Pebbles: 4 – 64 mm; Cobbles: 64 – 256 mm; Boulders: > 256 mm

**Classification of soil**

<table>
<thead>
<tr>
<th>Soil separates</th>
<th>ISSS system (mm)</th>
<th>USDA system (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Coarse Sand</td>
<td>-</td>
<td>2.00-1.00</td>
</tr>
<tr>
<td>Coarse Sand</td>
<td>2.00-0.20</td>
<td>1.00-0.50</td>
</tr>
<tr>
<td>Medium Sand</td>
<td>-</td>
<td>0.50-0.25</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>0.20-0.02</td>
<td>0.25-0.10</td>
</tr>
<tr>
<td>Very Fine Sand</td>
<td>-</td>
<td>0.10-0.05</td>
</tr>
<tr>
<td>Silt</td>
<td>0.02-0.002</td>
<td>0.05-0.002</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
</tr>
</tbody>
</table>

**Soil Colour**

Soil color, as such, does not have any influence on plant growth, but through its influence on soil temperature and soil moisture, it indirectly influences the plant growth.

Practically all colours occur in soils, except pure blue and pure green. Predominantly, soil colors are not pure but mixtures, such as grey, brown and rust. Frequently, two or three colours occur in patches, which are called “mottling”.

The colour of the soil is a composite of the colours of its components. Humus – brown or dark brown; Iron oxides – red, rust – brown, or yellow depending upon degree of hydration; Reduced iron – blue green; Quartz – white; Lime stones – white, gray or sometimes olive green.

**Soil Moisture**

Water contained in soil is called soil moisture. The water is held within the soil pores. Not all the water, held in soil, is available to plants. Much of water remains in the soil as a thin film. Soil water dissolves salts and makes up the soil solution, which is important as medium for supply of nutrients to growing plants.

**Importance of Soil water**

- Soil water serves as a solvent and carrier of food nutrients for plant growth
- Yield of crop is more often determined by the amount of water available rather than the deficiency of other food nutrients
- Soil water acts as a nutrient itself and regulates soil temperature
- Soil water helps in chemical and biological activities of soil
- Water is essential for photosynthesis.

**In-situ conservation of rain water**

As rearing of tasar silkworm is mostly done in forest patches or the plantation which are totally under rain fed conditions, proper rain water conservation measures have to be adopted to maintain the moisture level in the soil.

Digging of staggered trenches of size 6’×2’×1’ (lxbxd) across land at 6’ distances/ circular basin of one meter diameter around plants/ semicircular bunds with 2m diameter to a height of 15-20 cm across the slope helps check the run off loss of top soil.

Semicircular bunds should be prepared as per the slope of the land. For sloppy land, only semicircular bunds should be preferred.

**Soil Air**

The degree of continuity of both soil water and the soil air is of great importance in determining the physical properties of soil.

**Composition**

The composition of soil air is not the same as that of the atmosphere. The plant life and microorganism cause the soil atmosphere to become dynamic with respect to the ratio of O₂ to CO₂.

<table>
<thead>
<tr>
<th>Gases</th>
<th>Soil air (%)</th>
<th>Atmospheric air (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>79.20</td>
<td>79.00</td>
</tr>
<tr>
<td>Oxygen</td>
<td>20.60</td>
<td>20.97</td>
</tr>
<tr>
<td>Carbon di-oxide</td>
<td>0.50 (Variable)</td>
<td>0.033</td>
</tr>
<tr>
<td>Other gases</td>
<td>Traces</td>
<td></td>
</tr>
</tbody>
</table>

CO₂ content vary from 10-10000 times to that of atmospheric air.

**Effect of soil air on plant growth, soil properties and nutrient availability**

- Soil air with its constituents plays a vital role in modifying soil properties
• Under poor aerated conditions development of plant roots will be restricted or inhibited.
• Absorption of water and nutrients will be decreased. Toxic substances will be formed.
• Soil aeration influences the activity of soil micro organism
• Many nutrients like Fe and Mn will be at their toxic levels under poorly aerated soil.
• Many toxic organic acids like lactic, butyric and citric acid etc., will be found under anaerobic conditions and cause injury to plant roots thereby minimize the ability of roots to absorb nutrients and water.

Based on their texture, the soil is basically classified into four types:

- Sandy soil
- Silt Soil
- Clay Soil
- Loamy Soil

**Sandy Soil**

- Sandy soil consists of small particles of weathered rock which may be rounded or irregular with quite jagged surfaces.
- Usually consists of quartz but may also contain fragments of feldspar, mica and occasionally heavy minerals viz., zircon, Tourmaline and hornblende.
- Sandy soils have very low nutrient content and poor water holding capacity and high percolation rate, which makes it hard for the plant’s roots to absorb water.
- They Exhibit no plasticity and stickiness and less influenced by changes in moisture content.
- Low water holding capacity and high percolation rate, good drainage and air movement.
- They are one of the poorest types of soil for growing plants.

**Silt Soil**

- Silt soils are the smooth and quite fine quality of the soil which have much smaller particles compared to the sandy soil and is made up of rock and other mineral particles which are Intermediate between sand and clay in size and irregular in shape.
- Silt particles greatly resemble sand particles, but since they are smaller and have a greater surface area per unit mass
- Silt is dominated by quartz and micas like primary minerals and posses some plasticity, cohesion and adsorption as compared to sand but lesser than the Clay.
- The silt soil is more fertile compared to the other three types of soil. Therefore it is also used in agriculture.

**Clay Soil**

- Clay is the smallest particles amongst the other two types of soil, fraction is less than 0.002 mm in size and having poor drainage properties.
- Clay particles are characteristically plate like or needle like in shape and are tightly packed together with each other with very little or no airspace providing very little space for plant roots to flourish.
- This soil has very good water storage qualities and making hard for moisture and air to penetrate into it.
- Clay particles adsorb water and hydrate.
- They are very plastic and sticky in moist condition, and become hard and cloddy when dry.

**Loamy Soil**

- Loam is the fourth type of soil. It is actually a combination of sand, silt, & clay and thus having the beneficial properties of each one.
- Due to presence of all the three types of soil particles, it has the ability to retain moisture and nutrients; hence, it is more suitable for farming.
- This soil is also called as agricultural soil, as it also contains hummus. Because of its inorganic origins, it shows higher pH levels and high calcium content.
- Its composition is about 40%-40%-20% concentration of sand-silt-clay, respectively. However, based on variations in their proportions loam soils may be of different types viz., sandy loam, silty loam, clay loam, sandy clay loam, silty clay loam, and loam.
soil is known before the brushing of silkworm, it provides a sound basis for determining the nutrient requirements for the desired tasar silk production. For providing a comprehensive details of soil fertility and productive of tasar host plants growing regions, soil samples from different locations of major tasar growing regions were collected and analysed to prepare the soil health cards for the purposes of optimum nutrient inputs, better utilization of soil nutrients and higher nutrient use efficiency.

**Fig 4: Soil Health Card prepared for tasar farmers (Front page)**

**Fig 5: Soil Health Card prepared for tasar farmers (Back page)**

[soil health card images]
Soil Health Card records showed that pH of the soils of tasar growing areas ranges between 3.63-7.58 with a mean value of 5.96, i.e., according to classification of soil reaction suggested by Brady (1985) are generally acidic. Electrical conductivity of the soils was in the range of 0.01-0.66 dS m⁻¹ with a mean value of 0.087 dS m⁻¹. On the basis of limits suggested by Muhr et al. (1965), the soils are in normal range indicating that the soils are free from salinity. Organic carbon % in the tasar growing areas ranges between 0.03-2.01% with a mean value of 0.69% against the critical limit of 0.50 %. The high organic content in the soils is due to luxuriant availability of organic matter like litters, grasses along with slow seasonal decomposition of organic matter (Kavitha and Sujatha, 2015).

Available nitrogen in the study area ranges from between 40.20-532.25 kg ha⁻¹ with an mean average value of 168.92 kg ha⁻¹. On the basis of the rating suggested by Subbiah and Asija (1956), available nitrogen content of all the soil shows deficient range (<280 kg ha⁻¹). Being mobile in nature and low uptake recovery due to its losses through various mechanism like NH₃ volatilization, succeeding, de-nitrification, chemical and microbial fixation, leaching and runoff results in residual/available N becomes poor in soils (De Datta and Buresh 1989). Soils of these areas are having available Phosphorus in the range between 1.6-68.3 kg ha⁻¹ with a mean value of 13.23 kg ha⁻¹. On the basis of the limits suggested to Muhr et al. (1965), most of the soil samples are low (<10 kg ha⁻¹) in available phosphorus status. Available K content in selected areas ranged from 53.8-557.8 kg ha⁻¹ with an average value of 246.55 kg ha⁻¹. Considering the critical limit of 110 kg ha⁻¹ most of the soils have medium to high available potassium content. The available sulphur status varied from 0.23 to 96.98 ppm with a mean value of 11.04 ppm. As per the categorization given by Hariram and Dwivedi (1994), majority of soil in all the tasar growing states soils are under deficient category. The contents of available Zn in the tasar growing areas ranged from 0.12 ppm to 15.85 ppm with a mean value of 2.68 ppm. Based on the critical limits of 0.5 mg kg⁻¹ given by Takkar and Mann (1975), prevalence of Zn deficiency is common in most of the tasar sericulture states except in Jharkhand. The content of available DTPA-B in soils ranges from 0.38 ppm to 39.10 ppm with a mean value of 6.24 ppm. Results, illustrated on available DTPA-B in soil samples indicated that soils of all the tasar growing areas have sufficiency in DTPA- B content with 0.50 ppm as the critical limit proposed by Lindsay and Novel (1978). The DTPA-Fe in the soil samples varied from 0.10 ppm to 157.8 ppm with the mean value of 30.62 ppm, considering 4.8 ppm as critical limit for Fe deficiency (Sakal et al., 1985), most of soils under tasar cultivation are sufficient in available Fe, except in certain pockets of Chhattisgarh and West Bengal. Fe deficiency is very unlikely in acid soils, as it is known to be soluble under relatively acid and reducing conditions (Chestworth, 1991). DTPA-Mn in the studies soils ranged from 5.70 ppm to 235.94 ppm with an average value of 65.59 ppm. Considering 2.0 ppm as critical limit for Mn deficient (Sakal et al., 1985), soils from almost all the areas are sufficient in Manganese availability. The DTPA extractable Cu in soils of selected sites ranged from 0.10 to 13.40 ppm with a mean value of 2.26 ppm. Considering 0.2 ppm as critical limit for Cu (Lindsay and Novel, 1978), most of the soils are found to be adequate in DTPA-extractable Cu (Katyal and Randhawa 1983) as 0.2 ppm Cu of soil is considered as the threshold value.

### Table 1: Classification for Available Nutrients in Soil

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Available Nutrients</th>
<th>Rating of availability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>1.</td>
<td>Nitrogen (kg/ha)</td>
<td>280&lt;</td>
</tr>
<tr>
<td>2.</td>
<td>Phosphorous (kg/ha)</td>
<td>10&lt;</td>
</tr>
<tr>
<td>3.</td>
<td>Potassium (kg/ha)</td>
<td>110&lt;</td>
</tr>
<tr>
<td>4.</td>
<td>Exchangeable Calcium (oil)</td>
<td>1.5</td>
</tr>
<tr>
<td>5.</td>
<td>Exchangeable Magnesium (%)</td>
<td>1.0</td>
</tr>
<tr>
<td>6.</td>
<td>Sulphur (ppm)</td>
<td>10&lt;</td>
</tr>
<tr>
<td>7.</td>
<td>Iron (ppm)</td>
<td>4.5</td>
</tr>
<tr>
<td>8.</td>
<td>Manganese (ppm)</td>
<td>2.00</td>
</tr>
<tr>
<td>9.</td>
<td>Zinc (ppm)</td>
<td>0.60</td>
</tr>
<tr>
<td>10.</td>
<td>Boron (ppm)</td>
<td>0.50</td>
</tr>
<tr>
<td>11.</td>
<td>Molybdenum (ppm)</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Table 2: Soil Characteristics and nutrient status of soil of different Tasar growing areas:

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Locations/ States</th>
<th>Jharkhand (Santhal Pargana)</th>
<th>Jharkhand (Kolhan)</th>
<th>Chhattisgarh</th>
<th>West-Bengal</th>
<th>Odisha (Mayurbhanj)</th>
<th>Odisha (Kendujhar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>5.18-7.58</td>
<td>5.01-7.05</td>
<td>3.90-7.10</td>
<td>4.46-6.8</td>
<td>3.63-7.10</td>
<td>5.07-6.49</td>
</tr>
<tr>
<td>EC (ds m⁻¹)</td>
<td></td>
<td>0.01-0.13</td>
<td>0.02-0.24</td>
<td>0.024-0.328</td>
<td>0.02-0.66</td>
<td>0.01-0.66</td>
<td>0.05-0.62</td>
</tr>
<tr>
<td>Organic Carbon (%)</td>
<td></td>
<td>0.41-1.97</td>
<td>0.12-0.58</td>
<td>0.21-1.29</td>
<td>0.21-1.29</td>
<td>0.03-2.10</td>
<td>0.21-2.01</td>
</tr>
<tr>
<td>Available N (kg ha⁻¹)</td>
<td></td>
<td>92.9-327.6</td>
<td>95.40-532.25</td>
<td>66.5-342.7</td>
<td>124.3-246.0</td>
<td>40.2-531.0</td>
<td>86.62-233.49</td>
</tr>
<tr>
<td>Available P (kg ha⁻¹)</td>
<td></td>
<td>1.9-43.3</td>
<td>1.7-53.2</td>
<td>1.6-68.3</td>
<td>6.30-38.10</td>
<td>1.9-29.0</td>
<td>3.4-24.7</td>
</tr>
<tr>
<td>Available K (kg ha⁻¹)</td>
<td></td>
<td>95.2-616.0</td>
<td>100.8-358.4</td>
<td>111-347</td>
<td>95.2-481.6</td>
<td>53.8-537.6</td>
<td>53.8-557.8</td>
</tr>
<tr>
<td>Available S (mg kg⁻¹)</td>
<td></td>
<td>0.23-96.98</td>
<td>1.1-41.28</td>
<td>1.60-37.5</td>
<td>2.0-23.18</td>
<td>0.48-48.63</td>
<td>9.18-35.55</td>
</tr>
<tr>
<td>Available Fe (mg kg⁻¹)</td>
<td></td>
<td>3.25-35.72</td>
<td>7.65-118.90</td>
<td>0.10-35.95</td>
<td>2.30-19.70</td>
<td>0.95-157.8</td>
<td>18.55-157.8</td>
</tr>
<tr>
<td>Available Cu (mg kg⁻¹)</td>
<td></td>
<td>0.23-0.84</td>
<td>1.07-16.37</td>
<td>0.10-7.53</td>
<td>0.26-9.87</td>
<td>0.15-13.40</td>
<td>0.73-13.40</td>
</tr>
<tr>
<td>Available Zn (mg kg⁻¹)</td>
<td></td>
<td>0.83-8.58</td>
<td>1.28-6.75</td>
<td>0.12-8.22</td>
<td>0.37-15.85</td>
<td>0.13-6.38</td>
<td>0.65-5.77</td>
</tr>
<tr>
<td>Available Mn (mg kg⁻¹)</td>
<td></td>
<td>5.7-85.9</td>
<td>37.45-178.85</td>
<td>3.13-62.35</td>
<td>9.05-81.05</td>
<td>8.40-235.94</td>
<td>19.05-235.94</td>
</tr>
<tr>
<td>Available B (mg kg⁻¹)</td>
<td></td>
<td>0.47-2.67</td>
<td>2.76-24.24</td>
<td>0.38-35.02</td>
<td>0.76-17.82</td>
<td>1.08-39.10</td>
<td>4.63-15.10</td>
</tr>
</tbody>
</table>

Table 3: Soil Characteristics and nutrient status of different Tasar growing areas (Mean value)

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Locations/ States</th>
<th>Jharkhand (Santhal Pargana)</th>
<th>Jharkhand (Kolhan)</th>
<th>Chhattisgarh</th>
<th>West-Bengal</th>
<th>Odisha (Mayurbhanj)</th>
<th>Odisha (Kendujhar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>7.40</td>
<td>5.89</td>
<td>5.74</td>
<td>5.49</td>
<td>5.52</td>
<td>5.72</td>
</tr>
<tr>
<td>EC (ds m⁻¹)</td>
<td></td>
<td>0.05</td>
<td>0.06</td>
<td>0.092</td>
<td>0.12</td>
<td>0.098</td>
<td>0.10</td>
</tr>
<tr>
<td>Organic Carbon (%)</td>
<td></td>
<td>0.93</td>
<td>0.55</td>
<td>0.59</td>
<td>0.59</td>
<td>0.67</td>
<td>0.85</td>
</tr>
<tr>
<td>Available N (kg ha⁻¹)</td>
<td></td>
<td>196.5</td>
<td>173.86</td>
<td>154.6</td>
<td>173.4</td>
<td>159.7</td>
<td>155.48</td>
</tr>
<tr>
<td>Available P (kg ha⁻¹)</td>
<td></td>
<td>9.9</td>
<td>11.19</td>
<td>20.6</td>
<td>17.79</td>
<td>9.30</td>
<td>10.6</td>
</tr>
<tr>
<td>Available K (kg ha⁻¹)</td>
<td></td>
<td>300.6</td>
<td>203.7</td>
<td>249.0</td>
<td>254.8</td>
<td>177.7</td>
<td>293.5</td>
</tr>
<tr>
<td>Available S (mg kg⁻¹)</td>
<td></td>
<td>8.38</td>
<td>8.81</td>
<td>11.1</td>
<td>13.10</td>
<td>8.53</td>
<td>16.34</td>
</tr>
<tr>
<td>Available Fe (mg kg⁻¹)</td>
<td></td>
<td>15.93</td>
<td>33.18</td>
<td>9.07</td>
<td>19.70</td>
<td>43.42</td>
<td>62.41</td>
</tr>
<tr>
<td>Available Cu (mg kg⁻¹)</td>
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<td>0.74</td>
<td>3.35</td>
<td>0.99</td>
<td>1.49</td>
<td>3.43</td>
<td>3.58</td>
</tr>
<tr>
<td>Available Zn (mg kg⁻¹)</td>
<td></td>
<td>2.29</td>
<td>3.09</td>
<td>2.98</td>
<td>4.10</td>
<td>1.72</td>
<td>1.92</td>
</tr>
<tr>
<td>Available Mn (mg kg⁻¹)</td>
<td></td>
<td>42.81</td>
<td>80.89</td>
<td>31.15</td>
<td>41.33</td>
<td>79.09</td>
<td>118.27</td>
</tr>
<tr>
<td>Available B (mg kg⁻¹)</td>
<td></td>
<td>0.90</td>
<td>6.47</td>
<td>10.07</td>
<td>4.65</td>
<td>6.61</td>
<td>8.74</td>
</tr>
</tbody>
</table>

Soil Chemistry
It deals with the chemical constitution of the soil, the chemical properties and the chemical reactions in soils. It is the study of chemical composition of soil in relation to requirement of the crop. The overall goal of soil chemistry is a more fundamental understanding of chemical and biochemical reactions in soils related to plant growth, sustainability while maintaining soil and environmental quality.

Soil Reaction
Soil pH is defined as negative logarithm of hydrogen ion concentration is called pH. The scale of acidity or alkalinity is called pH scale. This scale runs from 0 to 14. The neutral point in this scale is at pH 7. All the values above pH 7 represent alkalinity and below 7 denote acidity.

There are three types of soil reactions: i) Acidic, ii) Alkaline and iii) Neutral.

i. Acidic: It is common in region where precipitation is high. The high precipitation leaches appreciable amounts of exchangeable bases from the surface layers of the soils; so that the exchange complex is dominated by H⁺ ions. Acid soils, therefore, occur widely in humid regions and affect the growth of plants markedly.
ii. **Alkaline**: Salts like carbonates of calcium, magnesium and sodium give a preponderance of OH⁻ ions over H⁺ ions in the soil solution.

iii. **Neutral**: Neutral soils occur in regions where H⁺ ions just balance OH⁻ ions.

---

### Influence of Soil Reaction on Availability of Nutrients

The unproductiveness of acid and alkali soils is very often due to the lack of available plant nutrients. In highly acid soils (low pH), the availability of some of the nutrients such as aluminum, iron, manganese etc., is increased to a point to become toxic to the plant. At the same time the supplies of available calcium, nitrogen, phosphorus etc., are reduced to starvation level (become unavailable). Most microorganisms function at their best within a pH range 6.0 to 7.5. If soil reaction is changed beyond this range, the availability of some of the nutrients such as aluminum, iron, manganese etc., is increased to a point to become toxic to the plant. At the same time the supplies of available calcium, nitrogen, phosphorus etc., are reduced to starvation level (become unavailable). Most microorganisms function at their best within a pH range 6.0 to 7.5. If soil reaction is changed beyond this range, the microorganisms become functionless.

#### 1. **Nitrogen**:
- Plant absorbs most of their nitrogen in the form of nitrate of which availability depends on the activity of nitrifying bacteria. The micro-organisms responsible for nitrification are most active when the pH is between 6.5 and 7.5. They are adversely affected if the pH falls below 5.5 and rises above 9.0. The decomposition of organic matter which is the primary source of nitrogen is also slowed down under acidic condition.

#### 2. **Phosphorus**:
- Its availability is at its highest when the reaction is between 6.5 and 7.5. When the reaction is above or below this range, availability is reduced.

#### 3. **Potassium**:
- The availability of potassium does not influence by soil reaction to any great extent. In acid soil potassium is lost through leaching. The unavailability of K is due to the conversion of exchangeable to non-exchangeable potassium in alkaline soil.

#### 4. **Calcium and magnesium**:
- Acid soils (base unsaturated) and above pH 8.5 are poor in available calcium and magnesium.

#### 5. **Iron, aluminum and manganese**:
- At pH below 5.5, the solubility of these compounds considerably increased with the result that they may have a toxic influence on plant growth. At the pH range 5.5 to 7.0, iron and manganese are present in the soluble ferrous (Fe²⁺) and Manganous (Mn²⁺) forms. Under neutral and alkaline conditions, iron and manganese are usually present in ferric (Fe³⁺) and manganese (Mn⁴⁺) states. Hence in soils with pH 7.5 and above, they become unavailable and sometimes produce deficiency diseases like chlorosis in plants.

#### 6. **Sulphur**:
- The availability of sulphur is not affected by soil reaction as sulphur compounds are soluble in low pH range. Acid conditions, which retard the decomposition of organic matter, therefore, retard the release of available sulphur.

#### 7. **Micronutrients**:
- In general, the availability of boron, copper and zinc is increased in acidic range but reduced below pH 5.5 and alkaline soils. The availability of molybdenum is reduced under acid soils. It is more available in neutral and alkaline soils.

### Soils of most of the tasar growing areas are Acid Soils

Acid soils are those having high degree of adsorbed Aluminium and Hydrogen. Acid soils in India distributed mostly in North eastern states and hilly area of other state. A special acid soil is seen in Kerala which is acid sulphate soils having low pH i.e. < 3.5 and high amount of sulphates.

### Genesis of acid soils

Following are the factors responsible for formation/genesis of acid soils.

1. **Parents Materials**:
   - Soil formed from acid parent root is usually acidic in nature is: granite, Rhyolite etc.

2. **High rainfall**:
   - High rainfall leaches the bases from the soil and becomes reason for accumulation of H⁺ ion at exchange complex. Bases like Ca, Mg, K, Na etc are removed from the soil by the water in high rainfall areas.

3. **Organic Matter**:
   - Decomposition of organic matter released weak organic acids (Carbanic acid → CO₂ + H₂O → H₂ CO₃), strong organic acids. Further decomposition of nitrogen containing materials release nitric acid and sulphur compounds release sulphonic acid.

4. **Acid Forming Fertilizer**:
   - Application of acid forming fertilizers like elemental sulphur, Ammonium sulphate, Ammonium chloride etc continuously over a period to soils become a reason for the acid soil formation. Ammonical fertilizers on oxidation release free hydrogen ion.

\[
\text{NH}_4^+ + 2\text{O}_2 \rightarrow 2\text{H}^+ + \text{NO}_3^- + \text{H}_2\text{O}
\]

### Effect of acidity

1. Injury to the growing plants.
2. In acid soils (low pH) Fe, Al and Mn are solubilised and available excessively. This causes toxicity effect on the growing plants.
3. Growth of microorganisms is restricted particularly bacteria multiplication reduced.
4. Nutrients availability in acid soils is reduced. Calcium and Magnesium are in low levels. Further poor decomposition of organic matter due to low microbes in acid soils leads to low availability of nitrogen and sulphur. Phosphorus is converted into Al and Fe phosphates which are insoluble hence P is deficient in acid soils. Molybdenum is another element available in low level in acid soils.
Reclamation
Acids soils can be reclaimed to normal soil by introducing suitable base cation and thereby removing excess H⁺ and Al³⁺ at exchange complex. The commonly used liming materials (supply Ca to remove H⁺ + Al³⁺) to reclaim acid soils are

a) Quick / Burnt / Oxide of lime (CaO)
b) Hydrated lime (Ca COH)₂

c) Lime / Calcite (CaCO₃)
d) Dolomite [Ca Mg (CO₃)₂]
e) Marl/Oyster shells/ Basic slay etc)

Among the above calcite (Lime-CaCO₃) and Dolomite [Ca Mg (CO₃)₂] are mostly used and for reclamation of acid soils.

Finess of lime:
At least 50 per cent lime material should pass through 60 mesh sieve as coarser particles are less effective than finer particles.

Soil / Cultural Management
Mulching soil prevents evaporation which reduces accumulation of salts due to capillary rise of water ate surface of soils.

Fertilizer Management
Addition of extra dose of nitrogen to the tune of 20 – 25% of recommended level will compensate the low availability of N in these soils. Addition of organic manures like, FYM, compost, etc helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition. Green manuring (sunnhemp, Daincha) and / or green leaf manuring also counteracts the effects of salinity.

Nutrient Management

Nutrient management is an approach to increase production on one hand and to safeguard the environment on the other. It is essential for proper growth of plants together with effective crop, water and soil management.

Effective nutrient management involves meeting the nutrient requirements for expected yield from the nutrient reserves in soil and additional supplementation of nutrients by chemical fertilizers and organic manures. It involves application of nutrients, their conservation and rendering them available to the plants.

Maintenance of nutrient reserve in soil does not necessarily require heavy application of inorganic fertilizers. Loss of nutrients can be minimized by adopting various planting practices such as terracing, intercropping and low till forming. Other practices, such as application of FYM, biofertilizers, vermicomposting and crop mulching can improve nutrient reserves of the soil and consequently enhance its fertility.

Making the uptake of nutrients more efficient by the plants is also one of the major aspects of nutrients management. Adopting techniques such as deep placement of fertilizers, proper timing of application, applying them in split doses and use of more concentrated fertilizers, it is possible to improve the nutrient uptake efficiency of the plants to some extent.

Terminology

Soil Fertility
“Soil fertility is the ability of the soil to supply essential plant nutrients during growth period of the plants, without toxic concentration of any nutrients”. i.e. “the capacity of soil to supply nutrient in available form to crop”. It also indicates the nutrient supplying capability of soil. Moreover fertility of soil is subject to man’s control (Deshmukh, 2012). The conventional fertilizing method is not scientifically appropriate and efficient because soil fertility varies between regions. Overuse of fertilizers can indeed lead to a waste of fertilizer resources and a serious environmental pollution (Clay, 2002; Yang and Zhang, 2008). Hence, a comprehensive knowledge of soil fertility provides a better understanding in the current situation and for identifying soil nutrient distribution and trends (Dafonte et al., 2010).

Soil Productivity

“Soil productivity is ability of soil to produce a particular crop or sequence of crops under a specified management system” i.e. “the crop producing of soil”.

“All the productive soils are fertile but all the fertile soils need not to be productive”, because they are subjected to drought or other unsatisfactory growth factors or management.

Study indicated that depletion in nutritive value of zinc occurs in leaves of tasar food plant, T. tomentosa on conducting successive rearing over the years. It was also found that the tasar producing areas have low level of available Nitrogen and Phosphorous in the soil. Availability of Potassium is in medium range. Soil organic carbon ranges from low to medium in tasar rearing fields. Hence, development of in-situ soil health by adopting rain water conservation, mulching of biomass and inoculation of Phosphate Solubilizing Bacteria (PSB) are the effective means to improve leaf quality of tasar host plant as nutritive value and quantity of foliage enhanced due to in-situ nutrient management. (Giri et al., 2017)

Soil Management

Imbalanced fertigation does not help in increasing the yield but it increases the cost of production. This may lead to Luxury consumption. “Luxury consumption is defined as the nutrient concentration range in which added nutrient will not increase yield but can increases nutrient concentration”.

1. Excess elements may be toxic e.g. Mo, Cu, Fe.
2. Excess of one element may cause deficiency of other elements.
   a. Excess of N may cause K deficiency
   b. Excess of K may cause Mn deficiency
   c. Excess of P may cause Zn deficiency
   d. Excess of Ca may cause Fe deficiency

Plant Nutrition:

Plant nutrition is defined as the supply and absorption of chemical...
compounds required for plant growth and metabolism. It is the process of absorption and utilization of essential elements for plant growth and reproduction.

Nutrient:
Nutrient may be defined as the chemical compound or ion required by an organism. The mechanism by which the nutrients are converted to cellular material or used for energetic purposes are known as metabolic processes.

Beneficial Elements:
The elements, the essentiality of which for growth and metabolism has not been unequivocally established, but which are shown to exert beneficial effects at very low concentrations are often referred to as beneficial elements, or potential micronutrients. They may be essential only for certain plant species or under specific conditions, e.g. Si, CO, Na and Va.

Level of nutrient element in plants are defined as
1. Deficient: When an essential element is at low concentration that severely limits yield and produces more or less distinct deficiency symptoms.
2. Toxic: when the concentration of either essential or other element is sufficiently high to inhibit the plant growth to a great extent.

<table>
<thead>
<tr>
<th>Table 4: Forms of nutrient elements absorbed by plants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Absorbed as single nutrient ion</strong></td>
</tr>
<tr>
<td>Nutrient element</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>Potassium</td>
</tr>
<tr>
<td>Calcium</td>
</tr>
<tr>
<td>Magnesium</td>
</tr>
<tr>
<td>Iron</td>
</tr>
<tr>
<td>Manganese</td>
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<tr>
<td>Copper</td>
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<tr>
<td>Zinc</td>
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<tr>
<td>Chlorine</td>
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<tr>
<td>Silicon</td>
</tr>
<tr>
<td>Cobalt</td>
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<tr>
<td>Sodium</td>
</tr>
</tbody>
</table>

On the basis of the amounts of these nutrients taken by plants they are classified as: (i) macronutrients and (ii) micronutrients.

Macronutrients (taken up in large amounts, generally in kg per hectare). These can be further sub-divided as (i) Primary nutrients (taken up in large amounts): N, P, K. (ii) Secondary nutrients (taken up in lesser amounts than N and K): Ca, Mg, S

Micronutrients: These are taken up in very small amounts, generally expressed in g or mg per hectare, these include Fe, Mn, Zn, Cu, B, Mo, Cl.

Criteria of essentiality—Arnon and stout 1939.
a. The plant must be unable to grow normally or complete its life cycle in the absence of the element.
b. The element is specific and cannot be replaced by other.
c. The element plays a direct role in the metabolism of the plant.

<table>
<thead>
<tr>
<th>Table 5: Classification of plant nutrients based on biochemical function</th>
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</thead>
<tbody>
<tr>
<td><strong>Essential plant nutrient</strong></td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>1st group</td>
</tr>
<tr>
<td>C, H, O, N, S</td>
</tr>
<tr>
<td>2nd group</td>
</tr>
<tr>
<td>P, B, Si</td>
</tr>
<tr>
<td>3rd group</td>
</tr>
<tr>
<td>K, Na, Mg, Ca, Mn, Cl</td>
</tr>
<tr>
<td>4th group</td>
</tr>
<tr>
<td>Fe, Cu, Zn, Mo</td>
</tr>
</tbody>
</table>
Classification of plant nutrients based on mobility in plant

<table>
<thead>
<tr>
<th>Mobile</th>
<th>Partly mobile</th>
<th>Immobile</th>
</tr>
</thead>
<tbody>
<tr>
<td>N, P, K, Mg</td>
<td>Fe, Zn, Cu, Mo</td>
<td>Ca, S, B</td>
</tr>
</tbody>
</table>

Mobile nutrient: Mobile nutrients are those when deficient in the plant, move from the matured tissue (older leaves) to the young meristems thus the deficiency symptoms are manifested on the older tissue.

Immobile nutrient: Immobile nutrients are those which under the situation of deficiency in the soil cannot move from older to younger tissue and hence the deficiency symptoms appear first on the younger leaves.

Nitrogen
The ultimate source of nitrogen used by the plants is the inert gas nitrogen, which constitutes about 78% (by volume) of the earth’s atmosphere. Among all the essential nutrients, nitrogen is the extensively studied one and still receiving much attention. The ploughed layer of majority of cultivated soils contains about 0.02 – 0.04% nitrogen.

Functions of N
- N is an essential constituent of proteins and is present in many other compounds of great physiological importance in plant metabolism. Nitrogen is an important constituent of chlorophyll, amino acids, proteins, protoplasm, nucleotides, phosphatides & alkaloids and is a part of many vitamins, enzymes and hormones also.
- N is an integral part of chlorophyll, which is primary absorber of light energy needed for photosynthesis.
- It increases vegetative growth and produces good quality foliage by promoting carbohydrate synthesis and encouraging succulence.
- It enhances the green colour and delays maturity in plants.
- It governs the utilization of K, P and other elements.

Deficiency of N:
1. Plants are stunted and yellow in appearance.
2. In older leaves produces the yellowing or chlorosis. It appears first on the lower leaves, the upper leaves remain green, while under severe N deficiency lower leaves will turn brown and die.
3. The necrosis begins at the leaf tip and progress along the midrib until the leaf is dead.

C. Excess of Nitrogen (Toxicity of nitrogen)
Causes excess vegetative growth, dark green leaves, lodging, maturity is delayed with increases susceptibility to pest and disease. Air is the primary source of nitrogen for plants but only leguminous crops can use this free nitrogen directly with the help of symbiotic bacteria belonging to genus *Rhizobium*. Other plants take their nitrogen from the soil in the form of nitrates and ammonium, which are produced in the soil by the action of microorganisms of the soil organic matter.

Forms of soil nitrogen

<table>
<thead>
<tr>
<th>Inorganic forms</th>
<th>Organic forms of soil N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium $\text{NH}_4^+$</td>
<td>Amide form (NH$_2$)</td>
</tr>
<tr>
<td>Nitrite $\text{NO}_2^-$</td>
<td>Plant absorbs N as both $\text{NH}_4^+$, $\text{NO}_3^-$</td>
</tr>
<tr>
<td>Nitrate $\text{NO}_3^-$</td>
<td></td>
</tr>
<tr>
<td>Elemental N (No)</td>
<td></td>
</tr>
</tbody>
</table>

Phosphorus
Phosphorus occurs in most plants in concentrations between 0.1 and 0.4%. Plants absorb either $\text{H}_2\text{PO}_4^-$ or $\text{HPO}_4^{2-}$ ortho $\text{PO}_4^{3-}$ ions. Absorption of $\text{H}_2\text{PO}_4^-$ is greatest at low pH values, where as uptake of $\text{HPO}_4^{2-}$ is greater at higher values of soil pH, plant uptake of $\text{HPO}_4^{2-}$ is much slower than $\text{H}_2\text{PO}_4^-$.

Functions of P
Phosphorus is a part of all living cells and is an essential constituent of cell nucleus. Phosphorus strengthens the root system of plants and helps in development of lateral and fibrous roots, which increases the absorbing surface for nutrients uptake.
1. Phosphorus has been called “The key to life” as it is directly involved in most of the life processes of plants.
2. It is a constituent of nucleic acid, phytin and phospholipids.
3. It promotes cell division and the development of meristematic tissues in growing plants.
4. Phosphorus has the unique property of forming bonds of more than one energy levels. This makes possible the storage, transfer and release of energy within the plant through such energy carriers as ATP and ADP.
5. Transfer of the energy rich $\text{PO}_4^{3-}$ molecules from ATP to energy requiring substances in the plant is known as “Phosphorylation”.
6. It stimulates early root development and growth and there by helps to establish seedlings quickly.
7. It is essential for seed formation because larger quantities of P are found in seed and fruit- phytic acid is the principle storage from of phosphorus in seeds.
8. It increases the activity of Rhizobia and increases the formation of root nodules.

Deficiency symptoms
- Development of root system is not satisfactory and growth is stunted.
- It arrests metabolism resulting in reduction of total N of plants.
- Reduced sugar content and premature leaf fall.
- Leaves become smaller in size and their natural luster is lost.
- Sometimes they show red pigmentation in the leaf bases and in the dying leaves.

Toxicity of phosphorus
- Profuse root growth i.e. laterals and fibrous root lets.
- It develops normal growth having green leaf colour.
• It may cause in some cases trace elements deficiencies i.e. Zinc and Iron.

**POTASSIUM**

The potassium ion (K⁺) is actively taken up soil solution by plant roots. The concentration of K⁺ in vegetative tissue ranges from 1 to 4% on dry matter basis.

**Functions of potassium**

1. Potassium is not a constituent of plants but it plays an important role in the synthesis of amino acids and proteins from NH₄⁺ ions, which are absorbed from the soil.
2. Essential for photosynthesis, development of chlorophyll.
3. It improves vigour of the plants to enable to with stand adverse climatic conditions.
4. Reduces lodging in cereal crops.
5. It regulates stomata opening and closing.
6. It regulates the movement of ions within the plants and hence it is called “traffic policeman” of the plant.
7. Activation of enzymes, enzyme synthesis and peptide bonds synthesis.
8. Regulates H₂O imbalance within the plant.

**Deficiency symptoms**

1. Plant becomes stunted in growth with shortening of internodes and busy in appearance.
2. K deficiency in plants show reduced rate of photosynthesis.
3. Deficiency is seen in the margin and bottom of leaves.
4. Chlorosis, yellowing of leafs and leaf scarch in case of trees.

**Sources of K**

The micas and fieldspars constitute the major K bearing minerals which on weathering slowly release K to the soil. (Muscovite and biotite) (Orthoclase and microline)

**Forms of potassium in soils**

- H₂O soluble K.
- Readily exchangeable K.
- Fixed K.

The different forms are in dynamic equilibrium with one another and represented as follows.

\[
\text{Fixed K} \xrightarrow{\text{slow}} \text{Readily exchange} \xrightarrow{\text{fast}} \text{H₂O soluble K}
\]

**Calcium**

Calcium is absorbed by plants as Ca²⁺ and its concentration ranges from 0.2 to 1.0% and it is supplied through mass flow method.

**Functions of calcium**

1. It is a constituent of cell wall and increases in stiffness of plants.
2. It regulates the activity of soil bacteria related with the fixation of free nitrogen and promotes formation of nitrates from organic forms of nitrogen. It also helps in the.
3. Promotes development of a good root and growth of plants, root elongation and cell division.
4. Helps to translocate the sugar in the plants.
5. It involves chromosome stability and that it is a constituent of chromosome structure.
6. Encourages seed production.
7. Activates enzyme phosphate and kinease.
8. Accumulated protein during respiration by mitochondria and it increases their protein content.
9. It binds DNA to protein molecules.

**Deficiency of calcium**

a. In calcium deficiency, the cells do not grow to normal position and fail to maintain their shape.

b. It is immobile in plants and hence the deficiency is observed in younger leaves.
c. The leaves may be irregular in shape. Normal unfurling of leaves does not take place due to sticking of tips of leaves or leaf blades.
d. Normal growth in affected and root may become short, stubby and brown.
e. Causes acidity of soil.
f. Cell may become rigid and brittle.

**Sources of soil calcium**

Earth crust contains about 3.64% calcium. The important source of calcium is anorthite (Ca₂Al₂Si₂O₇). Generally arid region soils contain high amount of Ca regard less of texture, low rainfall and little leaching.

In arid and semiarid regions: Calcite (CaCO₃), Dolomite (Ca, Mg, Ca₂(OH)₂) and Gypsum (CaSO₄·2H₂O) are found.

**MAGNESIUM**

Magnesium is absorbed as Mg²⁺ and the concentration in crop varies between 0.1 and 0.6%. It was taken by plant by Mass flow and diffusion.

**Functions of Mg**

1. Primary constituent of chlorophyll and imports green colour in leaves.
2. It activates a number of enzymes and is a part of carboxylase enzyme, which fixes carbon dioxide.
3. Serves as structural components in ribosomes and stabilizing the ribosome configuration for protein synthesis.
4. It is also a component of peptidases enzyme, which activates hydrolysis of simple proteins. It also helps in metabolism of fat.
5. Involves numbers of physiological and biochemical function.
6. Increases the oil content of oil seed crops.

**Deficiency of Magnesium**
1. The symptoms of magnesium deficiency in plants first appear in older leaves showing its mobility in the plant.
2. Deficiency is indicated by rugged outline and interveinal chlorosis of the leaf in which only the leave veins remain green.
3. Characteristic yellowing or reddening of leaves which appears first at the tips and spreads between the veins, especially in older leaves.

**Sources of Soil Magnesium**
It constitutes 1.93% of earth crust.
Primarily minerals (a) Biotite (b) Dolomite (c) Hornblende (d) olivine (e) serpentine. Secondary minerals (a) Chlorite (b) Jomite (c) Montmorillonite.
In arid region substantial amount of Mg present as Epsomite (Mg SO₄ 7H₂O)

**Functions of Mg in the soil**
1. It occurs predominately as exchange and solution Mg.
2. Coarse text soil exhibits the greatest potential for Mg deficiencies.
3. Competition between NH₄⁺ and Mg²⁺ also lower the Mg²⁺ availability to crops.

**Sulphur**

Sulphur is absorbed by plant roots as SO₄²⁻ ions. Concentration of S in plants range between 0.1 and 0.4%.

**Functions of Sulphur**
1. Essential for synthesis of S-containing aminoacids cystine, cysteine and methionine.
2. Essential for synthesis of other metabolites including Coenzyme A., Biotin, Thiamin of vitamin B and Glutathione.
3. It is a vital part of ferredoxins i.e Fe – S – protein occurring in the chloroplasts.
4. Responsible for the characteristic odor and taste of mustard, onion and Garlic. (Pungent smell)
5. It helps in the formation of nodules on the roots of the leguminous plants.
6. Increasing root growth, stimulate seed formation,

**Deficiency of sulphur**

a. Stunted growth pale green to yellow colour.
b. Immobile in plants and plants symptoms start first at younger leaves.
c. Deficiency of sulphur limits the plant growth and causes poor seed set.
d. The symptoms show uniform chlorosis, which affects all portions of leaves except the tips.
e. Its deficiency may affect the protein synthesis in leaves as it is also involved in the formation of amino acids which are essential for protein synthesis.

**Sources of sulphur**
1. Amount has <0.05 ppm in the form of SO₂; Earth crust contains 0.06 to 0.10%.
2. Sulphur bearing minerals
   - Gypsum - CaSO₄ 2 H₂O.
   - Epsomite - MgSO₄ 7H₂O.
   - Mirabilite - Na₂SO₄ 10 H₂O.
   - Pyrite - FeS₂.
3. Silicate mineral contains <0.01% S.
4. Igneous rocks 0.02 to 0.07%
5. Sedimentary rocks 0.02 to 0.22%

**Iron**

Fe is absorbed by plants roots as Fe³⁺, Fe²⁺ and chelated iron. Sufficiency range of Fe in plant tissue is 50-250 ppm.

**Functions of Iron**
- Although iron is not a constituent of chlorophyll, it acts as a catalyst and helps in the synthesis of chlorophyll.
- It is essential for the synthesis of protein and several metabolic reactions.
- Structural component of porphyrin molecules like cytochromes, hematin, hemes, ferrichrome and hemoglobin. These substances are involved in oxidation-reduction reactors in respiration and photosynthesis.
- Structural component of non-hemine compounds like ferredoxins.
- Component of flavoprotein like FMN = Flavin mono nucleotides; FAD=Flavin Adinosine Dinudeotide.

**Deficiency Symptoms**
- Deficiency symptoms occur in younger leaves since Fe is immobile element within plant.
- It occurs in soils of calcareous or alkaline soils and poorly drained H₂O logged soils.
- Younger leaves develop interveinal chlorosis with progresses rapidly over the entire leaf. Severe cases entire leaf turns yellowish to papery whitish colour.
- Plants show lack of vigour, are often shunted and generally become unproductive.

**Sources of Iron**
- Earth crust contains about 5% Primary and secondary minerals such as 1. Olivenite, 2. Pyrite, 3. Hematite, 4. Goethite, 5. Magrulite and 6. limestone
Manganese
Mn concentration in plant ranges from 20 to 500 ppm

Functions of Mn
1. Manganese along with iron helps in the synthesis of chlorophyll. It increases the sugar and chlorophyll content in the plants.
2. Involves in photosynthesis, particularly in evolution of O₂.
3. It improves the water holding capacity of tissues and reduces transpiration.
4. Involves in oxidation - reduction - process in decarboxylation and hydrolysis reactions.
5. Involves in enzyme systems and various enzyme reactions in the citric acid cycle.
6. It is a substitute for Mg²⁺ in many of the phosphorylating and group transfer reactions.

Deficiency of Mn
• Immobile in plant and deficiency starts in the younger leaves.
• Deficiency of manganese results in chlorosis in the interveinal tissues of the leaves. The veins become dark green and the colour persists even when chlorotic parts are dead.
• Deficiency increases asparatic acid and decreases glutamine.
• Increases respiration.
• Accumulation of N compounds mainly in form of amines.

Sources of Mn
Earth crust contains 1000 ppm. Various oxides and hydroxides. Manganite MnO (OH) and Braunite Mn₂O₃

Zinc
Normal concentration in plant 25 to 150 ppm; Deficiency level is < 20 ppm; Toxic level is > 400 ppm. Zn is present in all parts of the plants. In general roots contain more zinc than fruits.

Functions of Zn
Zinc is an essential constituent of several enzymes, which regulate various metabolic activities in plants.
• Essential to formation of growth hormones.
• Zinc is also essential for the formation of the growth promoting substances, auxins in plants.
• Influence the activity of dehydrogenase enzymes.

Deficiency of Zn
• Light yellow or white areas between the veins of leaves particularly older leaves.
• Death of tissue, discolored and Mal formation of fruits.
• Reduced growth hormone production.

Sources of zinc
Soil: 10-300 ppm; Igneous rock: >10 ppm; Sedimentary: > 95 ppm

Copper
Copper is absorbed by plants as cupric ion Cu²⁺. Normal concentration in plants is 5-20 ppm.

Functions of Copper
• Essential for the synthesis of vitamin-A
• Copper is an important coenzyme and is required for activating several plant enzymes. It is Constituent of chlorophyll and also supposed to be involved in formation of chlorophyll.
• Copper has important functions in root metabolism.
• Copper is also needed for the utilization of ammonium nitrate by plants and for the utilization of proteins in the growth processes of plants.
• Act as a catalyst in respiration and acts as an “electron carrier” in enzyme which brings about oxidation reduction reactions in plants.

Deficiency of Copper
• Leaves of copper deficient plants have been found to have an abnormally low rate of photosynthesis.
• Chlorosis, withering and distortion of terminal buds.
• Curling of leaf margins is caused by copper deficiency as dead tissue appears along the tips and edges of leaves.
• Multiple bud formation in the leaf axil and mal formation of leaves.
• Heavy liming, excessive application of N and P - induces Cu deficiency
• Splitting of fruits & die back of shoot.

Sources of Copper
• Igneous rock contains 10-100 ppm of Cu and Sedimentary rock contains 4-45 ppm.
• Primary minerals are Chalcopyrite, Chalcocite and Bornite.
• Sedimentary minerals are Oxides, Carbonates, Silicates, Sulphates and Chlorides.

Forms of Soil Copper
• Soil solution - ionic and completed
• Cation exchange sites of clay and organic matter
• Occluded and co-precipitated in soil oxide material.

Boron
Boron concentration in mono cotyledons and dicotyledons (20-60 ppm) varies between 6 and 18 ppm. It is absorbed by plants as undissociated boric acid (H₃BO₃).

Functions of Boron
• Pollination, fruit / seed set.
• Translocation of sugars, starches, N and P;
• Synthesis of proteins and amino acids and regulation of CHO metabolism
• Boron is related with flowering and fruiting processes, pollen germination cell division, metabolism of carbohydrates, nitrogen & pectic substances.
• It helps in new cell development in meristematic tissues.
• It regulates active salt absorption, hormonal movement and action.
• It influences the protein & nucleic acid and is also necessary
for the development of new cell membrane.

Deficiencies of Boron
- Since it is immobile, deficiency Symptoms occurs in terminal bud growth.
- Flowering and fruit development are restricted.
- Sterility and mal formation of reproductive organs.
- Thickened and curled leaves. Breakdown of the basal tissues occurs and if growth continues, the leaves have a one sided or twisted appearance.
- Usually the leaves die and terminal growth ceases.
- Discoloration, cracking or rotting of fruit, tubers or roots.

Sources of Boron
- Non metal among the micronutrient
- Low concentration in earth crust igneous rocks (<10 ppm)
- Tourmaline and borosilicate contains B.

Molybdenum
- Non metal anion absorbed as molybdate (MoO$_4$). It is weak acid and form complex poly anions such as phosphomolybdate. Plant contains <1 ppm Mo.

Functions of Mo
- Essential component of enzyme NO$_3$ reductase, which catalyses NO$_3$ to NO$_2$.
- Structural component of nitrogenase enzyme - involved in N fixation.
- Essential for absorption and translocation of Fe in plant

Deficiency of Mo
- Inhibits flower formation
- Imbalances various Amino Acids in plants.
- Reduce activity of symbiotic and non symbiotic N fixation.

Sources of Mo
- Earth crust 2 ppm : and range from 0.2 to 5 ppm.

Chlorine
- Normal concentration in plant is about 0.2-2.0%. Absorbed by plants as Cl$^-$ through roots and aerial parts.

Functions of Chloride
- Essential for biochemical reactions Osmotic cation neutralization reactors.
- Act as a counter ion during rapid K fluxes.
- Involves in the evaluation of O$_2$ in photosynthesis.
- Creates disease resistant by increase osmotic pressure in cell sap.

Deficiency of Cl
- Partial wilting and loss of turgidity.
- Necrosis, leaf bronzing and reduction in growth.

Sources of Cl
- Igneous and metamorphic rocks
- Soluble salts such as NaCl, CaCl$_2$ and MgCl$_2$.
- Earth crust 0.02-0.05%.
  It is mobile within the plant it can be rapidly recycled through soil systems.
Biofertilizers

Biofertilizers are defined as preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil.

**Advantages of Biofertilizers:**

i) Biofertilizers are environment friendly and reduces use of chemical fertilizers.

ii) They increase absorption of the nutrients.

iii) They convert complex organic material into simple compounds making them readily available to the plants.

iv) They improve the physical, chemical and biological properties of the soil.

v) Enhance root proliferation due to release of certain growth promoting hormones.

vi) They are not costly and are affordable.

**Different types of biofertilizers**

**Rhizobium**

Rhizobium is a soil habitat bacterium, which colonize the legume roots and fixes the atmospheric nitrogen symbiotically. They have seven genera and highly specific to form nodule in legumes, referred as cross inoculation group.

**Azotobacter**

Of the several species of Azotobacter, *A. chroococcum* happens to be the dominant inhabitant in arable soils capable of fixing N₂ (2-15 mg N₂ fixed /g of carbon source) in culture media. The bacterium produces abundant slime which helps in soil aggregation. The numbers of *A. chroococcum* in Indian soils rarely exceeds 10⁵/g soil due to lack of organic matter and the presence of antagonistic microorganisms in soil.

**Azospirillum**

*Azospirillum lipoferum* and *A. brasilense* (*Spirillum lipoferum* in earlier literature) are primary inhabitants of soil, the rhizosphere and intercellular spaces of root cortex of graminaceous plants. They perform the associative symbiotic relation with the graminaceous plants.

Five species of *Azospirillum* have been described to date *A. brasilense*, *A. lipoferum*, *A. amazonense*, *A. halopraeferens* and *A. irakense*. The organism proliferates under both anaerobic and aerobic conditions but it is preferentially micro-aerophilic in the presence or absence of combined nitrogen in the medium. Apart from nitrogen fixation, growth promoting substance production (IAA), disease resistance and drought tolerance are some of the additional benefits due to *Azospirillum* inoculation.

**Phosphate solubilizing microorganisms (PSM)**

Several soil bacteria and fungi, notably species of *Pseudomonas*, *Bacillus*, *Penicillium*, *Aspergillus* etc. secrete organic acids and lower the pH in their vicinity to bring about dissolution of bound phosphates in soil.
**Arbuscular Mycorrhiza (AM) fungi**
The transfer of nutrients mainly phosphorus and also zinc and sulphur from the soil *milleu* to the cells of the root cortex is mediated by intracellular obligate fungal endosymbionts of the genera *Glomus, Gigaspora, Acaulospora, Sclerocystis* and *Endogone* which possess vesicles for storage of nutrients and arbuscles for funneling these nutrients into the root system.

**Plant Growth Promoting Rhizobacteria (PGPR)**
The group of bacteria that colonize roots or rhizosphere soil and beneficial to crops are referred to as plant growth promoting rhizobacteria (PGPR).

The PGPR inoculants currently commercialized that seem to promote growth through at least one mechanism; suppression of plant disease (termed Bioprotectants), improved nutrient acquisition (termed Biofertilizers), or phytohormone production (termed Biostimulants). Species of *Pseudomonas* and *Bacillus* can produce as yet not well characterized phytohormones or growth regulators that cause crops to have greater amounts of fine roots which have the effect of increasing the absorptive surface of plant roots for uptake of water and nutrients. These PGPR are referred to as Biostimulants and the phytohormones they produce include indole-acetic acid, cytokinins, gibberellins and inhibitors of ethylene production.

**Table 6: Different groups of Biofertilizers**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Groups</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen fixing biofertilizers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Free- living</td>
<td><em>Azotobacter, Beijerinckia, Clostridium, Klbsella, Anabaena, Nostoc</em></td>
</tr>
<tr>
<td>2.</td>
<td>Symbiotic</td>
<td><em>Rhizobium, Frankia, Anabaena azollae</em></td>
</tr>
<tr>
<td>3.</td>
<td>Associative symbiotic</td>
<td><em>Azospirillum</em></td>
</tr>
<tr>
<td>Phosphorus solubilizing biofertilizers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Bacteria</td>
<td><em>Bacillus megaterium var. phosphaticum, Bacillus subtilis, Bacillus circulans, Pseudomonas striata</em></td>
</tr>
<tr>
<td>2.</td>
<td>Fungi</td>
<td><em>Penicillium sp, Aspergillus awamori</em></td>
</tr>
<tr>
<td>Phosphorus – mobilizing biofertilizers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Ectomycorrhiza</td>
<td><em>Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.</em></td>
</tr>
<tr>
<td>3.</td>
<td>Ericoid mycorrhizae</td>
<td><em>Pezizella ericae</em></td>
</tr>
<tr>
<td>4.</td>
<td>Orchid mycorrhiza</td>
<td><em>Rhizoctonia solani</em></td>
</tr>
<tr>
<td>Potassium – mobilizing biofertilizers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Bacteria</td>
<td><em>Frateuria aurantia</em></td>
</tr>
<tr>
<td>Biofertilizers for micronutrients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Silicate and zinc solubilizers</td>
<td><em>Bacillus sp</em></td>
</tr>
<tr>
<td>Plant Growth Promoting Rhizobacteria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Pseudomonas</td>
<td><em>P. fluorescens</em></td>
</tr>
</tbody>
</table>

**Green Manures**
Green manures, also referred to as fertility building crops, may be broadly defined as crops grown for the benefit of the soil. They have been used in traditional agriculture for thousands of years but conventional farming systems largely rejected them as the use of fertilizers and pesticides became more common.

**Green manure crops:** Crops grown for the purpose of restoring or increasing the organic matter content in the soil are called Green manure crops.

**Green Manuring:** Use of Green manure crops in cropping system is called ‘Green Manuring’ where the crop is grown *in situ* or brought from outside and incorporated when it is purposely grown.

**Advantages**
- Adding organic matter to the soil
- Increasing biological activity
- Improving soil structure
- Reduction of erosion
- Increasing the supply of nutrients available to plants (particularly by adding nitrogen to the system by fixation)
- Reducing leaching losses
- Suppressing weeds
- Reducing pest and disease problems
- Providing supplementary animal forage
- Drying and warming the soil
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

Table 7: Classification of green manures

<table>
<thead>
<tr>
<th>Legumes</th>
<th>Non-legumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green manure</td>
<td>Green leaf manure</td>
</tr>
<tr>
<td>Non-legumes</td>
<td>Green manure</td>
</tr>
<tr>
<td>Gomphrena</td>
<td>Gliricidia</td>
</tr>
<tr>
<td>Gliricidia</td>
<td>Sunflower</td>
</tr>
<tr>
<td>Calotropis</td>
<td>Buck wheat</td>
</tr>
<tr>
<td>Daincha</td>
<td>Pongamia glabra</td>
</tr>
<tr>
<td>Sunhemp</td>
<td>Thespesia</td>
</tr>
<tr>
<td>Kolinji</td>
<td></td>
</tr>
</tbody>
</table>

Characteristics desirable in legume green manure crops

1. Multipurpose use
2. Short duration, fast growing, high nutrient accumulation ability
3. Tolerance to shade; flood, drought and adverse temperatures.
4. Wide ecological adaptability and efficiency in use of water
5. Early onset of biological nitrogen fixation and high N accumulation rates
6. Timely release of nutrients and High N sink in underground plant parts.

7. Photoperiod insensitivity
8. High seed production and seed viability
9. Ease in incorporation and ability to cross-inoculate or responsive to inoculation
10. Pest and disease resistant

Leguminous green manures

Sesbania, Daincha, Sunnhemp, Wild Indigo, Pillipesara, Cowpea, Cluster bean (Guar), Green gram (Mung bean), Berseem, Madras Indigo

Table 8: Common shrubs and trees used as green leaf manures

<table>
<thead>
<tr>
<th>Shrubs</th>
<th>Trees</th>
<th>Green Leaf Manures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassia auriculata</td>
<td>Thespesia populnea</td>
<td>Leucaena leucocephala</td>
</tr>
<tr>
<td>Derris indica</td>
<td>Neem</td>
<td>Calotropis gigantea</td>
</tr>
<tr>
<td>Ipomoea cornea</td>
<td>Glyricidia</td>
<td>Delonix regia</td>
</tr>
<tr>
<td>Jatropha</td>
<td>Cassia tora</td>
<td>Cassia Occidental</td>
</tr>
<tr>
<td>Tephrosia candida</td>
<td>Vitex negundu</td>
<td>Hibiscus viscosa</td>
</tr>
</tbody>
</table>

Ideal nutritional status in leaf and soil of tasar plantation sites

Nutritional status of soil has significant impact on the reproductive and commercial traits of tasar silkworms. In a study to find out the most suitable nutrient status available in soil and leaf of tasar plantations, rearing conducted at Goelkera forest patch (West Singhbhum Distt.) has shown more than 50% enhancement in fecundity whereas shell wt. and filament length were almost double in comparison to the control (Muru, 2015). Hence, the soil and leaf nutritional status were considered ideal for tasar silkworm rearing.

Table 9: Ideal Nutritional status of Soil and Leaf

<table>
<thead>
<tr>
<th>Soil</th>
<th>Leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>Availability</td>
</tr>
<tr>
<td>S.N.</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>pH</td>
</tr>
<tr>
<td>2.</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>3.</td>
<td>Phosphorus</td>
</tr>
<tr>
<td>4.</td>
<td>Potassium</td>
</tr>
<tr>
<td>5.</td>
<td>Sulphur</td>
</tr>
<tr>
<td>6.</td>
<td>Zinc</td>
</tr>
<tr>
<td>7.</td>
<td>Manganese</td>
</tr>
<tr>
<td>8.</td>
<td>Copper</td>
</tr>
</tbody>
</table>

Enrichment of nutrients in the plantation sites:

Leguminous plants like Mucuna bracteata or wild Tephrosia, Cassia tora etc may be taken as per local availability. Seeds @ 20 kg/ha can be sown and the whole biomass is to be mulched before start of fruiting. Enrichment of nutrients in the soil should be done by mulching the biomass in every consecutive year after rearing.

Experiments have shown that digging of trenches in the plantation area along with growing of leguminous plants and mulching the biomass increases the available nitrogen content in the soil up to 19%, whereas available potassium increases up to 11% besides increasing the moisture content of the soil.

Inoculation of phosphate solubilizing bacteria in the land of
plantation site should be done after mixing @ 200 g PSB with fine sandy soil of 4-5 kg. The same soil mixture@ 100g should be applied around the plant and should be covered with soil. Phosphate solubilizing Bacteria (PSB) of species Pseudomonas should be taken. Experiments have shown significant improvement in available phosphorus (up to 70%) content in the soil.

**Leaf Constituents of Tasar Food Plants and Quality of Leaf Required for Early and Late Instar Silkworms**

Tasar silkworm is poly-phagous in nature and feeds on several host plants. However, it has food preference. The host plants, which silkworm normally prefers are known as primary host plants. Other host plants, where the silkworm can sustain its life, but do not prefer much, are called secondary host plants. Jolly et al. (1968) have found that *Terminalia arjuna* (Arjun), *Terminalia tomentosa* (Asan) and *Shorea robusta* (Sal) are best among all other food plants and are considered as primary food plants for commercial rearing which have since been adopted for large scale exploitation for Tasar rearing in the country. Among the secondary food plants *Syzygium cuminii* (Jamun), *Dalbergia sissoo* (Seesam), *Zyziphus jujuba* (Ber) and *Bauhinia variegata* (Kachnar) are the common one. During the rearing, it is wise to provide the worms suitable leaves as per the stages/instars they are in. Leaves with high nutrition, high succulence and low percentage of crude fibre are suitable for young stage larvae. For late age larvae, the leaves should be a bit mature, rich in protein or nitrogen content as development of silk gland and formation of silk takes place during the 4th & 5th stage. Crude fibre content should also be higher as compared to those suitable for early stage worms. Succulence or moisture % should not be much for the late stage worms as it may cause grasserie in them. A high nutritive value in the leaf increases the resistance of silkworm as well as cocoon production and raw silk quality. Hence, we must have an idea about the nutritive value of the leaves of tropical tasar food plants for harvesting good quality of tasar cocoons in optimum quantities. Visual examination of the leaf before the rearing is generally done in the field and at the farmer’s level in order to have an idea about the suitability of leaf for feeding them to the silkworm as foliar analysis of leaf of every rearing patch is practically not possible.

Chemical analysis of the leaves reveal useful information on the nutritional values of the food plants of silkworms. This paves the way for selection of suitable food plants species and their varieties. The foliar constituents in the three primary and some secondary tasar food plants have been given in table 10.

**Table 10: Chemical analysis of leaves of different food plants**

<table>
<thead>
<tr>
<th>Food plants</th>
<th>Moisture (%)</th>
<th>Total nitrogen (%)</th>
<th>Crude Protein (%)</th>
<th>Total mineral (%)</th>
<th>Crude fibre (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary food plants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Terminalia tomentosa</em></td>
<td>72.84</td>
<td>1.85</td>
<td>10.93</td>
<td>8.24</td>
<td>13.41</td>
</tr>
<tr>
<td><em>Terminalia arjuna</em></td>
<td>71.86</td>
<td>1.72</td>
<td>10.12</td>
<td>6.91</td>
<td>9.77</td>
</tr>
<tr>
<td><em>Shorea robusta</em></td>
<td>66.12</td>
<td>1.59</td>
<td>9.94</td>
<td>3.89</td>
<td>19.37</td>
</tr>
<tr>
<td><strong>Secondary food plants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Syzygium cuminii</em></td>
<td>69.81</td>
<td>1.79</td>
<td>11.19</td>
<td>5.95</td>
<td>12.80</td>
</tr>
<tr>
<td><em>Bauhinia variegata</em></td>
<td>73.95</td>
<td>3.40</td>
<td>21.25</td>
<td>6.00</td>
<td>10.90</td>
</tr>
<tr>
<td><em>Zyziphus jujuba</em></td>
<td>64.19</td>
<td>2.46</td>
<td>15.38</td>
<td>6.67</td>
<td>16.80</td>
</tr>
<tr>
<td><em>Dalbergia sissoo</em></td>
<td>73.27</td>
<td>3.70</td>
<td>23.13</td>
<td>7.65</td>
<td>11.70</td>
</tr>
</tbody>
</table>

There exists considerable variation among the food plants in their nutritional constituents. The leaf moisture and nitrogen contents of the leaves decrease with age whereas total mineral and crude fibre % increases with maturer of leaves.

Nitrogen is an important constituent of chlorophyll, amino acids, proteins, many vitamins, enzymes and hormones. Hence it is essential nutrient for plant growth. As photosynthetic activity in plants is controlled by the amount of chlorophyll present in it, nitrogen also controls the assimilation of carbohydrates. Since, silk is also a kind of protein, nitrogen is one of the most important leaf constituent for formation of silk by the silk glands of the silkworms.

Nitrogen contents are highest in Asan leaf (1.85 %) followed by Arjun leaf (1.72 %). The lowest contents of nitrogen have been found in Sal leaf (1.59 %). Nitrogen contents of leaf decreases with the maturity of leaf. It may be due to rapid growth, higher content of nitrogen could be accumulated in tender leaves.

Intake of crude fibre with diet is essential because of its regulatory function that helps to maintain the peristaltic movement of the intestine to remove waste products from it. Reduction in fibre content has an advantage for better silkworm crop yield. Amongst the three primary tasar host plants, with respect to crude fibre, Arjun is better because its leaf contains lowest quantity of crude fibre (9.77%). Sal leaf contains highest crude fibre (19.37%) followed by Asan (13.41%). further, crude fibre increases with the maturity of leaf in all the food plants of tasar silkworm.

Suculent leaf with lesser fibre and higher mineral contents stimulate the metabolic activities in silkworm resulting in quantitative improvement of cocoon and silk. Highest content of total mineral is found in Asan (8.24%) followed by Arjun (6.91%) and Sal (3.89%). This constituent also increases gradually with the maturity of leaf.
The gradual increase in mineral and crude fibre contents may be attributed to the translocation of minerals from the soil and synthesis of cellulose and consequently their increased deposition in comparatively older leaves.

High nutritive value in the leaf increases the ‘resistance’ in the silkworm besides enhancing the cocoon production and raw silk quality. Here high moisture content in the leaf has favourable effect on the palatability and assimilability of nutrients, Arjun (71.86% moisture) and Asan (72.84% moisture) are palatable to the silkworm thus it may be inferred that 70% or more moisture content is optimum for silkworm rearing. Nitrogen is the most important leaf constituent for growth and survival of silkworm and a major constituent of cocoon shell or more precisely silk itself. Silk is a kind of protein and nitrogen present in the leaf is converted into silk by the silkworm. Thus leaves rich in nitrogen are the prerequisite for quality cocoons. In Arjun and Asan nitrogen is in the range of 1.6-2.0 % . Hence, this range can be considered suitable for growth and survival of silkworm and better yield of quality cocoons. High mineral content also indicates towards the better nutritional status of the food plants. Arjun and Asan have better mineral content in comparison to other food plants (primary and secondary) except D. sissoo. Hence, 6-10 % mineral content is supposed to be more suitable for proper development of silkworms and thus for a good crop.

Intake of crude fibre with diet is essential because of regulatory function that helps to maintain the peristaltic movement of the intestine to remove waste products from it. Reduction in fibre content has an advantage for better silkworm crop yield. Amongst the three primary tasar host plants, with respect to crude fibre, Arjun is better because its leaf contains lowest quantity of crude fibre (9.77%). Sal leaf contains highest crude fibre (19.37%) followed by Asan (13.41%). further, crude fibre increases with the maturity of the three primary tasar host plants, with respect to crude fibre, Arjun is better because its leaf contains lowest quantity of crude fibre (9.77%). Sal leaf contains highest crude fibre (19.37%) followed by Asan (13.41%). Further, crude fibre increases with the maturity of the leaf in all the food plants of tasar silkworm.

Here Asan and Arjun have shown comparatively low percentage of crude fibre, together with high percentage of total minerals & nitrogen and sufficient moisture adding to the nutritional qualities of leaves which result in better tasar silk production in commercial Daba. However, Daba found in wild thrive well on Sal trees also.

**Recommendations by C.T.R. & T.I., Ranchi**

**Application of NPK fertilizers**
- The recommended dose of NPK is 150-50-50 kg /ha/year to be added to the soil.
- NPK application is 48 g Urea (3 split doses) + 46 g SSP + 12 g MOP plant/year.
- FYM @ 1kg/ plant /year should also be applied.

**Foliar application of individual micronutrients:**
- To avoid fixation of manganese it is advisable to spray Manganese sulphate (MnSO₄) @ 6.14 kg/ha./crop dissolved in 1000 liters of water.
- Foliar application of zinc has also been effective in correcting the zinc deficiency, especially in tree crops. Zinc sulphate (Zn SO₄) @ 10.9 kg/ha./crop can be applied by dissolving the salt in 1000 liters of water and spraying 3-4 weeks before commencement of the rearing.
- Foliar application of aqueous solution of Copper sulphate (CuSO₄) @ 1.97 kg ha. /crop dissolved in 1000 liters of water is recommended for correction of copper deficiency in *Terminalia arjuna* plants with 4' X 4' spacing.
- Aqueous solution of Ferrous sulphate (FeSO₄) @ 2.48 kg /ha/ crop dissolved in 1000 liters of water is recommended for iron deficiency in 4' X 4' *Terminalia arjuna* plantation.
- Borax (Sodium tetraborate - Na₂B₄O₇) is the most commonly used boron fertilizer. Foliar spray of Borax @ 4.37 kg/ha./crop dissolved in 1000 liters of water on *Terminalia arjuna* plant is recommended for 4’ X 4’ spacing to correct the boron deficiency.
- Foliar application of Ammonium molybdate ([NH₄]₆Mo₇O₂₄) @ 0.09 kg/ha./crop dissolved in 1000 liters of water is recommended for *Terminalia arjuna* plantation with 4’ X 4’ spacing.

All the above sprays should be done 3-4 weeks before commencement of the rearing.

**Foliar application of micronutrients mixture**
- A mixture of six micronutrients viz. [Manganese sulphate (MnSO₄) 4.6 kg + zinc sulphate (ZnSO₄) 1.09 kg + Copper sulphate (CuSO₄) 0.2 kg + Ferrous sulphate (FeSO₄) 0.25 kg + Borax (Na₂B₄O₇) 0.5 kg + Ammonium molybdate ([NH₄]₆Mo₇O₂₄) 0.0036 kg.] per hectare per crop may be applied on *Terminalia arjuna* plants with 4’ x 4’ spacing by dissolving the above said mixture in 1000 liter of water and spraying 3 – 4 weeks before commencement of the rearing. For the plants with 6’ x 6’ spacing the amount of micronutrients should be halved and dissolved in 500 liters of water (Chaudhary et al., 2002, Sinha et al., 2005 & 2009).

**Foliar application of NPK fertilizers**
- In a bid to reduce the quantity of NPK fertilizers that should be added to the soil, aqueous solution of 1% Urea + 1% DAP + 1% MOP may be sprayed on *Terminalia arjuna* plants, 3-4 weeks before commencement of the rearing with the application of half of the recommended basal dose of NPK i.e. 150-50-50 kg ha⁻¹ year⁻¹ (Das et al, 2004 & 2005).

**Use of organic manure**
- To improve the soil fertility 12 mt vermicompost along with 75-25- 25 kg ha⁻¹ year⁻¹ (50% of the recommended dose) is advisable to be added to the soil (Kumar et al., 2002).

**Use of biofertilizers**
- Combined application of Azotobacter + Azospirillum + *phosphobacterin* @ 20 kg each is recommended to improve leaf yields and soil fertility (Kumar et al., 2002).

**Incorporation of green manure**
- Sowing of Sunnhemp or Daincha seeds @ 30 kg ha⁻¹ during the onset of monsoon and incorporates the biomass after 45 days or before flowering initiation can be practiced for
improving crop yield and soil fertility (Kumar et al., 2002).

**Application of Secondary nutrients**

For increasing the quantity and quality of leaves of *T. arjuna*, application of secondary nutrients combination, SM₅ₖ comprising of Basal application of slaked lime @ 45 g/plant, on onset of monsoon and foliar application 2% aqueous solution of Magnesium sulphate in three equal split doses with an interval of fifteen days after sprouting of leaves has been found very effective. It also improves the commercial characters of the cocoons produced. In each split dose, 100 g Magnesium sulphate should be dissolved in 15 liters of water (total 300 g/100 plants or 20 kg/ha). (Sinha et al., 2008, 2009, 2009, 2010, 2012, 2013).

**In-situ soil health and nutrient management**

- Conservation of rainwater through small catchments i.e., circular basin trenches of size 6’ x 2’ x 1’ (l x b x d) for plain land and semicircular for sloppy land along with growing & incorporation of *Cassia tora* or other locally available leguminous plants and inoculation of Phosphate Solubilizing Bacteria (PSB) in plantation sites significantly improves the N, P & K content in soil as well as leaf of *T. tomentosa* besides improving the leaf yield, cocoon yield and S.R% as compared to the control.
- This technique is eco friendly and can also be adopted for producing Organic tasar cocoons. (Giri et al., 2015, 2015, 2016)

**Future Strategies:**

**Concept of Organic Silk**

Most of the tasar silk produced in the country is organic as tasar culture is mainly forest based with no or little use of fertilizers. For rearing conducted in economic plantations and in peripheral forest patches, maintaining the nutrient status of soil and leaf, crop after crop (rearing) and to improve the quality and yield of the produce (cocoons & yarn) with a target to reduce the use of chemical fertilizer is posing a challenge. To overcome these constraints, switching from inorganic fertilizers to organic bio-fertilizers and nutrient management through practices like bio-mulching of nitrogen fixing plants, application of PGPR and proper soil moisture conservation by adopting suitable and recommended practices can establish the organic status of cultivated tasar also.

**References**


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Plant improvement efforts in *Terminalia arjuna* and *T. tomentosa*

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Introduction

In recent decades tasar culture has taken new dimension of rearing under systematic plantation unlike previous forest based cocoon collection and thus changing subsistence tasar culture to commercial tasar rearing. In commercial rearing, host plants viz., Arjun (*Terminalia arjuna*) and Asan (*T. tomentosa*) are planted systematically, upon which tropical tasar silkworm are reared to get more number of cocoons per unit area. Owing to its potential in tribal livelihood, planting of tasar host plants has been promoted in forest areas, government land, marginal and poor fertile lands, non-agricultural lands etc. through various government schemes like RKVY, MGNREGA, MKSP, TSP etc. Therefore, over years area under block plantation is being increasing, at the same time several challenges are also being posed to the tasar industry. Among them availability of improved host plant varieties is of great concern in the establishment of block plantations. This chapter emphasizes the recent achievements made in tasar silkworm host plant breeding, current requirement of tasar industry and breeding strategies to achieve this.

Establishment of Field Gene Bank

To initiate plant breeding, availability of germplasm is pre-requisite. Hence a systematic germplasm conservation was initiated from 2000 under National Agriculture Technology Project. Central Tasar Research and Training Institute (CTR&TI), Ranchi has surveyed and collected genetic variability of primary and secondary food plants of tasar silkworm from different parts of the country. These are being conserved in field gene bank (Fig. 1) under *ex-situ* condition at CTR&TI, Ranchi, Jharkhand, India (230 4’ N and 850 88’ E, altitude-708 m SL). At present a total of 341 germplasm accessions are being maintained in field gene bank, covering nine species viz., *Terminalia arjuna* (190), *Terminalia tomentosa* (94), *T. belerica* (22), *T. chebula* (17), *T. myriocarpa* (4), *Lagerstroemia speciosa* (6), *L. parviflora* (4), *L. indica* (3) and *Anogeissus latifolia* (1). This field gene bank has also been identified as the ‘National Active Germplasm Site (NAGS)’ of various tasar silkworm food plants by National Bureau of Plant Genetic Resources (NBPGR), New Delhi.

Using germplasm maintained in field gene bank several breeding initiatives were made to address several issues of tasar industry.

Fig. 1: Tasar food plant field gene bank maintained at CTR&TI, Ranchi.
of germplasm accession was undertaken (Kumar et al., 2009; Kumar et al., 2010). A total of 180 accessions were characterized, which includes T. arjuna (83), T. tomentosa (50) T. belerica (20) and T. chebula (17). A total of 50 characters were recorded, including morphological (15), anatomical (13), growth parameters (12) and biochemical traits (10). Bioassay was also performed in 85 selected germplasm accessions of T. arjuna, T. tomentosa, T. belerica and T. chebula during July-August for three consecutive years. These germplasm have been registered in NBPGR, the passport data of each germplasm accession is available in the database.

Some of the important characteristics of germplasm accessions are briefed hereafter. In acc. 141 of T. tomentosa stomata were present on adaxial leaf surface also in fewer numbers, while in all other genotypes stomata were present only on abaxial surface. The IC 326377 of T. tomentosa, IC 355550 of T. arjuna, IC 410848 and IC 326377 of T. chebula had higher density of trichome, while acc. 724 of T. arjuna had poor population of trichome. The number of epidermal outgrowths on abaxial surface varied from 0/mm² in IC 410766 of T. belerica to 276.4/mm² in IC 410764 of T. tomentosa. The acc. 331855 and 141 of T. tomentosa had very long epidermal hairs. The leaves of IC 410768 of T. belerica had a dense covering of papillae on either surface, and their stomata were hidden amidst the papillae.

The detailed passport data of all the 180 germplasm accessions are given in the previously published book entitled “Monograph on Indian Tropical tasar silkworm food plants (Terminalia spp.)” (Suryanarayanan et al., 2005). However, in this chapter emphasis is given to T. arjuna and T. tomentosa as these are primary food plants of tasar silkworm. Detailed characterization of 50 accessions of T. arjuna and 50 accessions of T. tomentosa are described as follow.

Analysis of variance showed significant difference for all the characters and indicates the presence of substantial amount of genetic variability among the accessions. The mean values for leaf length ranged from 12.82 cm in T. arjuna to 19.83 cm in T. belerica, whereas mean value for leaf width was maximum in T. tomentosa (8.03 cm). Single leaf weight was maximum in T. tomentosa (6.36 g) followed by T. belerica (6.15 g), T. arjuna (4.08 g) and the least mean value for T. chebula (3.02 g). Similarly the mean value for moisture per cent and moisture retention capacity in per cent was highest in T. tomentosa (69.25% and 67.48 %, respectively) followed by T. belerica (68.96 and 67.29 %). Lowest (7.89) and highest (8.45) chloroplast in guard cells were recorded in T. chebula and T. arjuna. Number of stomata/mm² was lowest in T. belerica (215.27) and highest in T. arjuna (414.46). The pore size of stomata on which the rate of transpiration depends, was minimum in T. chebula (91.57 µm) and maximum in T. arjuna (102.63 µm). Mean value for thickness of palisade tissue the seat for photosynthesis was maximum in T. arjuna (138.76 µm) followed by T. belerica (131.18 µm), T. tomentosa (129.35 µm) and T. chebula (100.72 µm). Total leaf thickness was maximum in T. belerica (380.7 µm) and minimum in T. chebula (300.3 µm).

The values for CV also differ significantly for the traits studied. The maximum CV (47.00%) was for the ratio of leaf length to petiole length. Coefficient of variation was also high for thickness of upper epidermis (42.76%) and number of stomata/mm² (40.68%). The mean value for total chlorophyll contents was maximum in T. chebula (1.86 mg/g) followed by T. arjuna (1.82 mg/g), T. belerica (1.80 mg/g) and least in T. tomentosa (1.65 mg/g). Total phenol and proline contents in leaf were highest in T. chebula (2.33 µg/g and 51.04 µmol/g respectively). Protein, the major part of the silk was maximum in T. belerica (30.53 mg/g) followed by T. chebula (21.89 mg/g), T. tomentosa (19.61 mg/g) and least in T. arjuna (18.21 mg/g). Among biochemical traits high CV values were recorded for total phenol (54.93%), followed by non-reducing sugar (43.14%) whereas moderate CV values were observed for proline (35.97%),protein (34.53%) and chlorophyll a (36.03%). Low CV was recorded for stomata conductance (20.06%).

The detailed passport data of all the 180 germplasm accessions are given in the previously published book entitled “Monograph on Indian Tropical tasar silkworm food plants (Terminalia spp.)” (Suryanarayanan et al., 2005). However, in this chapter emphasis is given to T. arjuna and T. tomentosa as these are primary food plants of tasar silkworm. Detailed characterization of 50 accessions of T. arjuna and 50 accessions of T. tomentosa are described as follow.

Analysis of variance revealed significant differences among T. arjuna and T. tomentosa accessions for most of the traits. The mean, range and coefficient of variation (CV) of 36 characters in T. arjuna and T. tomentosa are tabulated in Table 1. The highest coefficient of variation (CV) was observed for leaf phenol content in both T. arjuna (67.93%) and T. tomentosa (53.21%) accessions and for proline content (49.2%) in T. arjuna accessions, which are the indicators of water stress tolerance. These germplasm lines could be explored in development of drought/stress tolerant varieties. Similarly, high CV was observed for protein and moisture contents in T. tomentosa.

Table 1: Range, mean and coefficient of variation among 50 Terminalia arjuna and T. tomentosa germplasm accessions for morpho-physio-anatomical traits.

<table>
<thead>
<tr>
<th>#</th>
<th>Parameters</th>
<th>Terminalia arjuna accessions</th>
<th>Terminalia tomentosa accessions</th>
</tr>
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<tr>
<td>1</td>
<td>Lamina length(cm)</td>
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<td>8.10 - 23.13</td>
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<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
<td>CV (%)</td>
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<td>13.68</td>
<td>17.03</td>
<td>23.68</td>
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<tr>
<td>#</td>
<td>Parameters</td>
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<td>Terminalia tomentosa accessions</td>
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<td>----</td>
<td>------------------------------------------</td>
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<td>--------------------------------</td>
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<td>2</td>
<td>Lamina width (cm)</td>
<td>3.66-14.06</td>
<td>4.35-13.7</td>
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<td>3</td>
<td>Petiole length (cm)</td>
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<td>0.25-1.11</td>
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<td>4</td>
<td>Lamina length/petiole length (ratio)</td>
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<td>10.57-59.74</td>
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<td>5</td>
<td>Leaf weight (g)</td>
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<td>2.07-11.72</td>
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<tr>
<td>6</td>
<td>Petiole weight (g)</td>
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<td>0.04-0.25</td>
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<td>7</td>
<td>Lamina weight (g)</td>
<td>2.1-7.28</td>
<td>2.03-11.51</td>
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<td>8</td>
<td>Leaf weight/Petiole weight (ratio)</td>
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<td>33.50-118.57</td>
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<td>Laminar index</td>
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<td>96.96-99.15</td>
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<td>10</td>
<td>Internodal distance (cm)</td>
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<td>1.52-3.53</td>
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<td>11</td>
<td>Moisture (%)</td>
<td>62.58-78.57</td>
<td>62.65-84.06</td>
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<td>12</td>
<td>Moisture retention capacity (%)</td>
<td>61.44-76.64</td>
<td>58.90-83.10</td>
</tr>
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<td>13</td>
<td>Stomata/mm²</td>
<td>186.76-625.07</td>
<td>169.9-617.70</td>
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<td>14</td>
<td>Length of stomata (µm)</td>
<td>21.81-31.3</td>
<td>15.50-30.85</td>
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<td>15</td>
<td>Width of stomata (µm)</td>
<td>10.46-19.48</td>
<td>11.98-26.56</td>
</tr>
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<td>16</td>
<td>Pore length of stomata (µm)</td>
<td>13.39-22.30</td>
<td>13.00-21.94</td>
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<td>17</td>
<td>Pore width of stomata (µm)</td>
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<td>3.81-6.94</td>
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<td>Stomata Pore area (µm)</td>
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<td>Number of chloroplast in guard cell</td>
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<td>Cuticle thickness (µm)</td>
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<td>5.73-28.06</td>
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<td>Upper epidermis thickness (µm)</td>
<td>12.61-31.98</td>
<td>10.54-28.04</td>
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<td>22</td>
<td>Palisade thickness (µm)</td>
<td>96.57-185.22</td>
<td>85.98-195.35</td>
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<tr>
<td>23</td>
<td>Spongy parenchyma thickness (µm)</td>
<td>88.5-281.60</td>
<td>103.02-296.78</td>
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<td>24</td>
<td>Lower epidermis thickness (µm)</td>
<td>6.45-32.30</td>
<td>10.56-32.20</td>
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<td>25</td>
<td>Total thickness (µm)</td>
<td>256.08-496.29</td>
<td>256.11-502.80</td>
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<tr>
<td>26</td>
<td>Ratio of palisade /spongy tissue</td>
<td>0.49-1.42</td>
<td>0.41-1.36</td>
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<td>27</td>
<td>Chlorophyll a (mg/g)</td>
<td>0.66-1.72</td>
<td>0.25-1.94</td>
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<tr>
<td>28</td>
<td>Chlorophyll b mg/g</td>
<td>0.42-1.76</td>
<td>0.18-1.30</td>
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<tr>
<td>29</td>
<td>Chlorophyll a / Chlorophyll b</td>
<td>0.64-2.33</td>
<td>0.75-3.64</td>
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<tr>
<td>30</td>
<td>Total chlorophyll (mg/g)</td>
<td>1.24-3.49</td>
<td>1.49-2.66</td>
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<tr>
<td>31</td>
<td>Phenol (µg/mg)</td>
<td>0.23-5.63</td>
<td>0.51-4.94</td>
</tr>
<tr>
<td>32</td>
<td>Reducing sugar (µg/mg)</td>
<td>2.64-20.8</td>
<td>3.06-17.35</td>
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<tr>
<td>33</td>
<td>Non-reducing sugar (µg/mg)</td>
<td>3.6-14.75</td>
<td>3.64-17.45</td>
</tr>
<tr>
<td>34</td>
<td>Proline (µmol/g)</td>
<td>7.83-84.25</td>
<td>8.61-84.38</td>
</tr>
<tr>
<td>35</td>
<td>Protein mg/g</td>
<td>12.26-36.11</td>
<td>8.95-41.90</td>
</tr>
</tbody>
</table>
The genetic distance among all the accessions was assessed by using Mahalanobis D² analysis (Mahalanobis, 1936) and clustering by Tocher method (Rao, 1952). A total of 50 Arjun accessions were grouped into 12 clusters (Table 2), where Cluster II (23) is the largest followed by cluster I (11). The maximum inter-cluster distance was recorded between cluster XI and XII (821.48) indicating high genetic divergence between these two group accessions. Minimum inter-cluster distance (66.51) was observed between III and IV cluster showing their close proximity. The cluster means showed substantial variation, where maximum lamina length (19.48 cm) was observed in cluster VI, highest single leaf weight (4.69 g) in cluster VII, minimum Stomata/mm² (248.33) in cluster III, minimum total phenol contents (0.61 mg/g) in cluster VI and highest protein contents (25.52 mg/g) in cluster I. The Arjun accessions from respective trait cluster could be explored in breeding program to improve respective traits.

The cluster analysis in *Terminalia tomentosa* accessions has grouped 50 accessions in to 7 clusters (Table 3), where cluster-I the largest (21). Maximum inter-cluster distance was recorded between cluster VI and VII (49.63), these highly divergent accessions could be explored in hybridization breeding. In case of cluster mean maximum lamina length was recorded in cluster VI and VII. Whereas, the leaf weight, moisture content and moisture retention capacity were highest in cluster VI. Minimum stomata/mm² and high protein contents were recorded in cluster X. On the other hand, reducing and non-reducing sugar and proline contents were highest in cluster VII and phenol contents were low in the same cluster.
Silkworm rearing performance of *T. arjuna* and *T. tomentosa* accessions

The silkworm rearing performance was conducted on 79 accessions covering *T. Arjuna* (50) and *T. tomentosa* (29) for two years (2008 and 2009). Cocoon assessment revealed similar mean performance of silkworm in both the host plants. However accessions of both species showed wide variation for different traits. Range for cocoon weight in *T. arjuna* was 9.74 to 15.37 g and in *T. tomentosa* it is 10.11 to 15.79 g. Highest Shell ratio was observed on *T. tomentosa* (14.97%) as compared to *T. arjuna* (14.30%). Correlation study on effect of host plant biochemical on cocoon traits revealed that, silk ratio is positively correlated with reducing sugar (r = 0.111) and protein contents (0.486). On the other hand, it was negatively correlated (r = - 0.174) with phenol contents in the leaf.

Variable rearing performance was observed across host plant species, where mean larval duration ranged from 29.1 days in *T. arjuna* to 33.7 days in *T. chebula* and single mature larvae weight was 38.85g in *T. arjuna* followed by *T. tomentosa* (38.69 g) and *T. chebula* (33.82 g). On the other hand, mean value for single cocoon weight was highest (12.61g) in *T. arjuna* and least (10.82 g) in *T. chebula*. However, the mean values for silk ratio varied from 12.10% in *T. tomentosa* to 11.96% in *T. arjuna*, and 11.23% in *T. chebula*.

Molecular diversity among *T. arjuna* and *T. tomentosa* accessions

As the expression, morphological traits is highly influenced by environment, genetic diversity based on these traits is less reliable. Hence an attempt was made to study molecular diversity in selected accessions of host plants using DNA markers, which are insensitive to environment and plant growth stages. Random Amplified Polymorphic DNA (RAPD), a multi-loci markers were used for the molecular diversity. A total of 37 reproducible RAPD primers were screened on 18 accessions of *T. arjuna* and generated 641 RAPD bands, of which 589 bands were polymorphic (91.89%). Whereas in *T. tomentosa* 16 accessions were screened using 37 reproducible RAPD primers and thus generated 719 RAPD bands, out of which 693 bands were polymorphic (96.38%) (Kumar et al., 2009b). Unweighted Pair Group Method with Arithmetic Mean (UPGMA) based dendrogram (Fig. 2a & 2b) had grouped 18 accession of Arjun and 16 accession of Asan in three major clusters respectively. Both Arjun and Asan accessions have shown geographical clustering, as depicted in dotted circles in Figure1a & b.
Analysis of genetic parameters

The estimates for phenotypic coefficient of variation (PCV) were almost similar to genotypic coefficient of variation (GCV) for most of the characters. This indicates the little effect of environmental factors on these traits. High GCV was found for leaf weight, total chlorophyll, phenol, reducing sugar, proline and protein contents. Moderate value of GCV were recorded for stomata /mm$^2$ (33.20) stomata pore area (31.26), cuticle thickness (38.71), total leaf thickness (20.15) and non-reducing sugar (25.43). The estimate for heritability ranged from 97% for stomata conductance to 100% for total leaf thickness. For remaining characters it varied from 98 to 99 per cent. The genetic advance as per cent of means at 1% ranged from 53.19 for leaf thickness to 143.43 for protein contents.

Under simultaneous selection indices analysis, desirable accessions from undesirables ones has been discriminated on the basis of their phenotypic performances assuming that all the 13 characters are economically important and accordingly economic weight was assigned one for each character. Finally, on the basis of these selection criteria, the accessions (individuals) were arranged in the order of merit and then best 10% were selected (selection intensity 328.70). The expected gain through selection was predicted for each character, which ranges between -0.381 to 118.477. The highest genetic gain was recorded for stomata conductance (63.44%) followed by stomata /mm$^2$ (23.04%) and total leaf thickness (8.86%). The results based on D$^2$ analysis grouped the top 20 accessions into five clusters which indicated that geographical distribution and genetic divergence did not follow the same pattern. The inference drawn from the inter cluster distances can be used to select genetically diverse and superior genotypes. Intercrossing of accessions from these diverse clusters may result in wide array of variability for having effective selection for these traits. Intercrossing divergent groups would lead to greater opportunity for crossing over, which may release hidden variability by breaking linkage. The magnitude of heritability in broad sense was high for most of the traits under study thus, suggesting that high heritable traits were least affected by environmental variation and selection based on phenotypic performance would be reliable.

Based on the above study 10 accessions of $T$. arjuna were selected. Two accession of $T$. arjuna i.e. Acc. 102 and Acc. 123 were selected as superior for the multi-location field trial.

Collection place | Accession
--- | ---
Andhra Pradesh | IC410747
Chhattisgarh | IC410862
Jharkhand | Acc.217, IC410782
Maharashtra | IC326382
Madhya Pradesh | IC560468
Uttarakhand | IC326394, IC382318, IC382330, IC410846

Development of clonal seedling orchard

Development of uniform plantation of genetically superior varieties is essential to achieve superior and uniform quality of tasar silk. Based on morphological and biochemical traits superior accessions of $T$. tomentosa (Acc.501 and 531) and $T$. arjuna (701, 702 and 722) were selected. Establishment of seedling orchard of improved accessions is essential to developed large number of seedlings, which can meet the seedling demand. Hence a clonal seedling orchard has been established at CTR&TI, Ranchi. This seedling orchard will be used as source for developing seedlings of superior accessions in both Arjun and Asan host plants.

Development of superior hybrids of $Terminalia$ arjuna and $T$. tomentosa

The growing areas under block plantation is in demand for superior
host plant varieties/hybrids. In view of this a project was framed to develop superior hybrids for high leaf yield and quality. Arjun accessions showing fast growth, short internodal distance, high moisture and protein contents and better rooting (more than 80%) and Asan accessions showing better rearing performance were selected as parents to develop hybrids superior in terms of fast growth, leaf quality and quantity, good rooting behavior to raise feasible economic plantations at farmers' level. The selected parents were crossed by following suitable crossing technique as depicted in figure 3. A total of 16 cross combinations were made during 2012 (first batch) and 9 combinations during 2014 (second batch) and thus developed 29 and 33 F1 hybrid plants, respectively.

In first batch hybrids leaf yield attributing characters were recorded at four different growth stages i.e. September 2014, May 2015, September 2015 and August 2016. Data across growth stages were averaged out (Table 4) and cumulative scoring was performed across all the characters. Hybrids were ranked based on their cumulative scores. Hybrid plant acc. 501 (T. tomentosa) x acc. 533 (T. arjuna) (P2) is first rank hybrid, securing highest cumulative score of 247. Morphological performance of hybrid over different growth stages are, plant height (188 cm), number and length of primary branches (15 & 279 cm), number and length of secondary branches (21 & 625 cm), total leaf number per plant (196), leaf moisture (65.7 %), leaf yield per plant (415 g) and internodal distance (3.5 cm).

Similarly in second batch hybrids, based on pooled data from August 2016, November 2016 and August 2017 hybrids were ranked. Among 33 hybrids, 533 (T. arjuna) x 702 (T. arjuna) (P1) hybrids has outperformed in different growth stages for growth and leaf yield related traits. Across three growth stages, on an average this hybrid has shown highest plant height (161 cm), maximum number of branches (41.3), longest total branches length (1390 cm), shorter internode distance (3.92 cm) and specifically high leaf yield per plant (374 g) and highest number of leaves per plants (2090) (Table 5). Typically this hybrid has more branching ability, which has resulted in more number of leaf, thus more leaf yield. It was clearly noticed that top ranking hybrids have more branching ability, more number of leaves and leaf yield per plant. Third rank hybrid shown highest leaf yield per plant (432 g) followed by first rank (374 g), 12th (350 g) rank and 4th rank (340 g) hybrid, respectively. Leaf biochemical analysis was performed for carbohydrate, protein and chlorophyll content. Hybrids having high biochemical content are tabulated in table 6.

![Fig. 3: Crossing technique followed in Terminalia hybrid development. Inflorescence of female parent having un-open florets (b) was bagged with cotton cloth bag (a) to avoid foreign pollen contamination. During anthesis bagged inflorescence was pollinated with pollens of male parent inflorescence (c) to effect cross pollination. Seed set was observed in crossed female inflorescence (d), after maturity seeds were raised to develop hybrid plants for the evaluation (e).](image-url)
Table 4: Average growth performance of *Terminalia* hybrids of 1st batch over different growth stages (mean data recorded over September 2014, May 2015 September 2015 and August 2016).

| #   | Cross combination | Plant No. | Plant Height (cm) | Number of primary branches | Length of primary branches (cm) | Number of secondary branches | Length of secondary branches (cm) | Total leaf number/plant | Leaf moisture content (%) | Leaf yield/plant (g) | Inter nodal distance (cm) | Total value | Rank |
|-----|-------------------|-----------|-------------------|-----------------------------|---------------------------------|-----------------------------|----------------------------------|----------------------------|--------------------------|--------------------------|--------------------------|-------------------------|--------------|------|
| 1   | 501x533           | 1         | 153               | 12                          | 274                             | 20                          | 537                              | 183                         | 65.5                     | 200                     | 4.4                      | 173         | 12   |
| 2   |                   | 2         | 188               | 15                          | 279                             | 21                          | 625                              | 196                         | 65.7                     | 415                     | 3.5                      | 247         | 1    |
| 3   |                   | 3         | 167               | 9                           | 361                             | 20                          | 615                              | 207                         | 63.5                     | 335                     | 3.6                      | 184         | 9    |
| 4   |                   | 4         | 166               | 11.3                        | 372                             | 36                          | 686                              | 263                         | 64.3                     | 387                     | 4.7                      | 204         | 7    |
| 5   |                   | 5         | 217               | 7                           | 300                             | 25                          | 557                              | 105                         | 62.2                     | 290                     | 4.8                      | 181         | 11   |
| 6   |                   | 6         | 227               | 11                          | 465                             | 20                          | 734                              | 228                         | 61.0                     | 412                     | 4.1                      | 215         | 4    |
| 7   | 501x702           | 1         | 228               | 8.3                         | 308                             | 18                          | 350                              | 134                         | 60.6                     | 342                     | 3.7                      | 141         | 20   |
| 8   |                   | 2         | 109               | 6.7                         | 136                             | 22                          | 411                              | 175                         | 67.4                     | 107                     | 5.0                      | 97          | 28   |
| 9   | 701x531           | 1         | 193               | 12.0                        | 374                             | 15                          | 565                              | 186                         | 62.4                     | 487                     | 3.8                      | 206         | 5    |
| 10  |                   | 2         | 192               | 11.7                        | 348                             | 14                          | 550                              | 178                         | 63.4                     | 426                     | 4.7                      | 204         | 6    |
| 11  | 615x531           | 1         | 169               | 12.7                        | 321                             | 20                          | 449                              | 246                         | 64.6                     | 491                     | 4.3                      | 188         | 8    |
| 12  |                   | 2         | 163               | 8.3                         | 241                             | 12                          | 379                              | 144                         | 60.9                     | 217                     | 4.1                      | 74          | 29   |
| 13  |                   | 3         | 179               | 10.7                        | 287                             | 21                          | 504                              | 219                         | 62.0                     | 298                     | 3.1                      | 163         | 16   |
| 14  |                   | 4         | 209               | 7.7                         | 265                             | 14                          | 439                              | 76                          | 64.3                     | 398                     | 3.7                      | 130         | 23   |
| 15  |                   | 5         | 199               | 9.0                         | 340                             | 10                          | 342                              | 103                         | 62.4                     | 476                     | 3.9                      | 169         | 14   |
| 16  |                   | 6         | 207               | 15.3                        | 300                             | 23                          | 584                              | 242                         | 61.5                     | 456                     | 3.8                      | 233         | 2    |
| 17  |                   | 7         | 165               | 11.0                        | 386                             | 23                          | 591                              | 176                         | 62.4                     | 561                     | 4.0                      | 216         | 3    |
| 18  |                   | 8         | 181               | 8.7                         | 275                             | 12                          | 470                              | 130                         | 61.8                     | 317                     | 4.5                      | 118         | 27   |
| 19  | 501 x 615         | 1         | 216               | 8.3                         | 349                             | 8                           | 319                              | 65                          | 65.5                     | 790                     | 4.9                      | 184         | 10   |
| 20  | 501 x 701         | 1         | 179               | 11.0                        | 443                             | 15                          | 411                              | 78                          | 65.3                     | 566                     | 4.8                      | 171         | 13   |
| 21  | 533 x 531         | 1         | 189               | 9.3                         | 337                             | 10                          | 271                              | 80                          | 62.8                     | 414                     | 4.3                      | 143         | 19   |
| 22  | 531 x 702         | 1         | 198               | 6.7                         | 260                             | 19                          | 470                              | 112                         | 61.3                     | 324                     | 3.8                      | 154         | 17   |
| 23  | 531 x 701         | 1         | 204               | 7.7                         | 309                             | 17                          | 460                              | 107                         | 62.9                     | 448                     | 3.7                      | 164         | 15   |
| 24  | 531 x 615         | 1         | 171               | 7.0                         | 291                             | 12                          | 299                              | 103                         | 61.0                     | 372                     | 5.0                      | 118         | 26   |
| 25  | 531 x 533         | 1         | 150               | 6.7                         | 268                             | 14                          | 351                              | 67                          | 63.6                     | 436                     | 5.5                      | 122         | 25   |
| 26  | 235 x 615         | 1         | 165               | 7.7                         | 277                             | 16                          | 408                              | 92                          | 64.3                     | 480                     | 5.0                      | 137         | 21   |
| 27  | 123 x 533         | 1         | 201               | 11.3                        | 248                             | 16                          | 589                              | 123                         | 60.8                     | 273                     | 4.8                      | 144         | 18   |
| 28  | 702 x 531         | 1         | 166               | 7.7                         | 240                             | 19                          | 473                              | 139                         | 64.2                     | 220                     | 4.4                      | 133         | 22   |
| 29  | 701 x 501         | 1         | 194               | 8                           | 238                             | 15                          | 407                              | 123                         | 64.8                     | 227                     | 3.5                      | 126         | 24   |
Table 5: Average growth performance of *Terminalia* hybrids of 2nd batch over different growth stages (mean data recorded over August 2016, November 2016 and August 2017).

<table>
<thead>
<tr>
<th>#</th>
<th>Combination</th>
<th>Plant height (cm)</th>
<th>Number of branches/plant</th>
<th>Length of all branches/plant (cm)</th>
<th>Inter nodal distance (cm)</th>
<th>Leaf yield/ plant (g)</th>
<th>Total # of leaves</th>
<th>Total score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>614 x 701(P1)</td>
<td>141</td>
<td>12</td>
<td>552</td>
<td>4.8</td>
<td>280</td>
<td>594</td>
<td>54</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>614 x 701(P2)</td>
<td>122</td>
<td>15</td>
<td>597</td>
<td>4.0</td>
<td>262</td>
<td>614</td>
<td>67</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>614 x 701(P3)</td>
<td>130</td>
<td>24</td>
<td>847</td>
<td>3.9</td>
<td>96</td>
<td>1320</td>
<td>107</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>614 x 701(P4)</td>
<td>141</td>
<td>30</td>
<td>779</td>
<td>3.0</td>
<td>432</td>
<td>1088</td>
<td>143</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>533 x 342(P1)</td>
<td>149</td>
<td>15</td>
<td>493</td>
<td>4.0</td>
<td>280</td>
<td>724</td>
<td>79</td>
<td>23</td>
</tr>
<tr>
<td>6</td>
<td>533 x 342(P2)</td>
<td>150</td>
<td>24</td>
<td>848</td>
<td>4.0</td>
<td>284</td>
<td>1184</td>
<td>128</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>533 x 342(P3)</td>
<td>139</td>
<td>24</td>
<td>756</td>
<td>3.8</td>
<td>254</td>
<td>1234</td>
<td>115</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>533 x 342(P4)</td>
<td>133</td>
<td>21</td>
<td>745</td>
<td>4.3</td>
<td>316</td>
<td>1368</td>
<td>117</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>533 x 342(P5)</td>
<td>161</td>
<td>26</td>
<td>921</td>
<td>4.3</td>
<td>340</td>
<td>1168</td>
<td>143</td>
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<td>10</td>
<td>533 x 342(P6)</td>
<td>117</td>
<td>28</td>
<td>880</td>
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<td>1366</td>
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<td>629</td>
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<td>533 x 342(P10)</td>
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<td>1024</td>
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</tr>
<tr>
<td>15</td>
<td>533 x 702(P1)</td>
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<td>41</td>
<td>1390</td>
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<td>374</td>
<td>2090</td>
<td>175</td>
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<td>533 x 702(P2)</td>
<td>152</td>
<td>23</td>
<td>784</td>
<td>3.7</td>
<td>300</td>
<td>968</td>
<td>126</td>
<td>10</td>
</tr>
<tr>
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<td>819 x 132(P1)</td>
<td>149</td>
<td>34</td>
<td>1031</td>
<td>4.0</td>
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<td>1406</td>
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<tr>
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<td>15</td>
<td>457</td>
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<td>192</td>
<td>198</td>
<td>53</td>
<td>29</td>
</tr>
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<td>701 x 614(P1)</td>
<td>166</td>
<td>34</td>
<td>1137</td>
<td>4.4</td>
<td>300</td>
<td>818</td>
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<tr>
<td>20</td>
<td>701 x 614(P2)</td>
<td>187</td>
<td>20</td>
<td>663</td>
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<tr>
<td>21</td>
<td>701 x 614(P3)</td>
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<td>928</td>
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<td>124</td>
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<td>701 x 614(P5)</td>
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<td>16</td>
<td>619</td>
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<td>122</td>
<td>616</td>
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<tr>
<td>24</td>
<td>701 x 614(P6)</td>
<td>161</td>
<td>19</td>
<td>620</td>
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<td>234</td>
<td>608</td>
<td>65</td>
<td>27</td>
</tr>
<tr>
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<td>701 x 614(P7)</td>
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<td>20</td>
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<td>936</td>
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<td>17</td>
</tr>
<tr>
<td>26</td>
<td>216 x 502(P1)</td>
<td>157</td>
<td>8</td>
<td>391</td>
<td>4.8</td>
<td>181</td>
<td>342</td>
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<td>216 x 502(P2)</td>
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<td>537</td>
<td>4.6</td>
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<td>554</td>
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<td>12</td>
<td>501</td>
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<tr>
<td>29</td>
<td>504 x 707(P1)</td>
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<td>11</td>
<td>436</td>
<td>4.4</td>
<td>285</td>
<td>422</td>
<td>72</td>
<td>26</td>
</tr>
<tr>
<td>30</td>
<td>504 x 707(P2)</td>
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<td>19</td>
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<td>1104</td>
<td>122</td>
<td>12</td>
</tr>
<tr>
<td>31</td>
<td>531 x 701(P1)</td>
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<td>9</td>
<td>310</td>
<td>3.9</td>
<td>308</td>
<td>184</td>
<td>56</td>
<td>30</td>
</tr>
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<td>32</td>
<td>819 x 716(P1)</td>
<td>161</td>
<td>33</td>
<td>1057</td>
<td>4.4</td>
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</tr>
<tr>
<td>33</td>
<td>701 x 531(P1)</td>
<td>123</td>
<td>16</td>
<td>672</td>
<td>4.3</td>
<td>218</td>
<td>1328</td>
<td>83</td>
<td>22</td>
</tr>
</tbody>
</table>

Table 6: List of hybrids having high biochemical content.

<table>
<thead>
<tr>
<th>Hybrids with high chlorophyll content</th>
<th>Total Chl (mg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>501 x 533 (P3)</td>
<td>2.386</td>
</tr>
<tr>
<td>501 x 533 (P4)</td>
<td>1.981</td>
</tr>
<tr>
<td>501 x 533 (P5)</td>
<td>1.935</td>
</tr>
<tr>
<td>701 x 614 (P3)</td>
<td>1.926</td>
</tr>
<tr>
<td>615 x 531 (P1)</td>
<td>1.814</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Hybrids with high chlorophyll content</th>
<th>Total Chl (mg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrids with high protein content</td>
<td>mg/g (dry basis)</td>
</tr>
<tr>
<td>533x342(P2)</td>
<td>207</td>
</tr>
<tr>
<td>701x614(P4)</td>
<td>179</td>
</tr>
<tr>
<td>533x342(P3)</td>
<td>168</td>
</tr>
<tr>
<td>533x702(P2)</td>
<td>165</td>
</tr>
<tr>
<td>Hybrids with high carbohydrate</td>
<td>mg/g (dry basis)</td>
</tr>
<tr>
<td>501x533(P4)</td>
<td>344</td>
</tr>
<tr>
<td>533x702(P1)</td>
<td>340</td>
</tr>
<tr>
<td>614x701(P4)</td>
<td>334</td>
</tr>
<tr>
<td>501x533(P2)</td>
<td>325</td>
</tr>
<tr>
<td>615x531(P7)</td>
<td>323</td>
</tr>
</tbody>
</table>

**Screening of germplasm accessions for disease resistance**

An attempt was made by Gargi *et al.*, 2010 to screen 140 accessions of *Arjun* (83) & *Asan* (57) for their tolerance against Leaf spot (Causal organism-*Pestalotiopsis palmarum*; Class-Ascomycetes), Black nodal girdling (Causal organism- *Uredo* spp. Class-Basidiomycetes) and Powdery mildew diseases (Causal organism–*Phyllactinia terminaliae*; Class-Ascomycetes). It was found that 78 accessions were resistant to black nodal girdling disease and 68 accessions were resistant to powdery mildew disease. Based on artificial inoculation of leaf spot disease pathogen + PDI for black nodal girdling disease under natural conditions, it is inferred that about 20 accessions of *T. arjuna* (Acc. No. 101, 106,122, 210, 204, 203, 115, 211, 201, 123, 202, 125, 102, 301, 117, 131, 215, 112, and 124) and 12 accessions of *T. tomentosa* (Acc. No. 139, 129, 144, 241, 219, 121, 120, 313, 314, 310, 229, and 226) were considered as major fungal foliar diseases tolerant/resistant. It was noticed that the Percent Disease Index (PDI) for foliar diseases in *T. tomentosa* accessions was found higher than the *T. arjuna* accessions, which could be attributed to higher succulence and pubescence of leaves.

**Identification of alternate host plant for block plantation**

The production of tropical tasar silk is very low as compared to mulberry silk, which could be attributed to two reasons (i) traditional method of silkworm rearing on tall trees in natural habitat, which exposes the larvae to a number of predators, parasites and diseases apart from natural vagaries (ii) Slow growing nature of host plants which support only one rearing in a year (Anonymous, 2013). At this juncture a host plant which is fast growing, easily propagated having low gestation period (2/3 year) and can support two consecutive rearing is needed. *Lagerstroemia speciosa*, a secondary food plant (Fig. 4) was found to cater these needs, because of its excellent features viz., wider adaptability, drought tolerance (due to its dense and wide spreading root system), fast growing nature, logging tolerance. Therefore, systematic studies were conducted (Deka *et al.*, 2015; Gargi *et al.*, 2014 a & b; 2015 a & b) on raising *Lagerstroemia speciosa* saplings, plantation, silkworm rearing and grainage behaviour. The package for the cultivation of *Lagerstroemia speciosa* was standardized as follow.

<table>
<thead>
<tr>
<th>Cultural practices</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raising of seedlings (March-October)</td>
<td>Soft wood cuttings with three nodes, treat with 0.2 % Carbendazim and plant in sand bag (30 x 15 cm). After rooting (30-45 days) transplant to growth medium (soil:sand:FYM in 1:1:1 ratio).</td>
</tr>
<tr>
<td>Plantation (onset of monsoon)</td>
<td>Ploughing of land, transplant one year old seedlings in pit (1’x1’x1’) filled with sand and FYM (1:1) under 10’x5’/6’ spacing. Maintain plant height of 3-4’, Pruning: last week of May (first crop) and clips during silkworm transfer (second crop).</td>
</tr>
<tr>
<td>Management of soil moisture and fertility and rain water harvesting</td>
<td>Bund formation (2’ width x 1’ height) Pre-, and post monsoon conservation tillage. FYM @ 400cf/ha (alternate year), NPK @50:25:25 kg/ha/year</td>
</tr>
<tr>
<td>Plant protection measures</td>
<td>During sprouting spray Rogor @ 0.3% and Bavistin @ 0.2% at 15-20 days interval</td>
</tr>
<tr>
<td>Intercropping in the field</td>
<td><em>L. speciosa</em> + Ground nut/Pigeon pea/Green gram/Black gram/Mustard/ Black gram + Pigeon pea/Cowpea/Cowpea+ Pigeon pea/Horse gram/ Ginger/Ginger/Turmeric/Any of above during rainy season.</td>
</tr>
<tr>
<td>Silkworm rearing</td>
<td>First crop silkworm rearing: July – Mid August Second crop silkworm rearing September – October.</td>
</tr>
</tbody>
</table>

It is evident from the Table 8 that days taken for rooting varies in different season and maximum days taken for rooting was 45 days in *L. speciosa* and 60 days in *T.arjuna* in the cuttings planted during December. The rooting percentage did not differ much during various seasons in *L. speciosa* but the days taken for rooting increased significantly during December. However, the rooting percent in *T. arjuna* reduced drastically (52 %) in the cuttings planted during December (Table 8).

Overall growth performance along with total leaf yield/plant of two year old plants of *L. speciosa* was higher than *T. arjuna* under 10’ x 5’ spacing (Table 9). Observations taken for the trees as well as in the bushes planted in the field also reveal that *L. speciosa* is fast growing and early sprouting plant as compared to *T. arjuna* and *T. tomentosa*.

Biochemical studies in the leaf shows that total protein, the main constituent of silk, was 28.75mg/g in *T.arjuna* whereas it was 20.00mg/g in *L. speciosa* (Table 9). Total phenols were maximum (5.6 µg/mg) in *L. speciosa* and minimum in *T.arjuna* (0.45 µg/mg). Proline contents, indicator of tolerance to water stress conditions, were maximum in *L.speciosa* (70.00 µmol/mg) followed by...
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

_T. tomentosa_ (56.80 µmol/mg) and _T. arjuna_ (25.30 µmol/mg). In the Field Gene Bank, 06 _L. speciosa_ accessions (3 from Uttarakhand, 01 from Maharashtra and 02 from Andhra Pradesh) are being maintained.

The grainage performance of the silkworm was found to be better in _L. speciosa_ as compared to _T. arjuna_. The silkworm rearing performance conducted during first and second crop of 2015 (Table 10) was almost similar on the plants of _L. speciosa_, _T. arjuna_ and _T. tomentosa_ except for larval duration. Silk ratio and filament length were almost similar in all the species which may be due to the similar level of leaf protein and moisture content. High Phenols and proline content in _L. speciosa_ and _T. tomentosa_ indicates their wider adaptability and stress tolerance.

Results of this study recommends the use of _L. speciosa_ for the development of block as well as forest plantation.

**Table 7**: Comparative rooting performance of cuttings in _L. speciosa_ and _T. arjuna_ in different seasons.

<table>
<thead>
<tr>
<th>Planting season</th>
<th>Cuttings planted (Number)</th>
<th>Days taken for root initiation</th>
<th>Rooting percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>L. speciosa</em></td>
<td><em>T. arjuna</em></td>
<td><em>L. speciosa</em></td>
</tr>
<tr>
<td>March</td>
<td>100</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>May</td>
<td>100</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>July</td>
<td>100</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>October</td>
<td>100</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>December</td>
<td>100</td>
<td>45</td>
<td>60</td>
</tr>
</tbody>
</table>

**Table 8**: Growth parameters in first and second year plantation of _L. speciosa_ and _T. arjuna_ under 10’x5’ spacing.

<table>
<thead>
<tr>
<th>Growth parameters</th>
<th><em>L. speciosa</em></th>
<th><em>T. arjuna</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st year</td>
<td>2nd year</td>
</tr>
<tr>
<td>Plant height (cm)</td>
<td>148.66</td>
<td>152</td>
</tr>
<tr>
<td>Leaf yield/plant (kg)</td>
<td>0.988</td>
<td>1.5</td>
</tr>
<tr>
<td>Number of primary branches</td>
<td>-</td>
<td>3.88</td>
</tr>
<tr>
<td>Total length of primary branches (cm)</td>
<td>-</td>
<td>295</td>
</tr>
<tr>
<td>Number of secondary branches</td>
<td>-</td>
<td>12.66</td>
</tr>
<tr>
<td>Total length of secondary branches (cm)</td>
<td>-</td>
<td>265.77</td>
</tr>
<tr>
<td>Internodal distance (cm)</td>
<td>1.15</td>
<td>1.12</td>
</tr>
<tr>
<td>Leaf moisture (%)</td>
<td>Young 72.16</td>
<td>71.95</td>
</tr>
<tr>
<td></td>
<td>Medium 70.02</td>
<td>69.25</td>
</tr>
<tr>
<td></td>
<td>Mature 69.63</td>
<td>69</td>
</tr>
</tbody>
</table>

**Table 9**: Leaf biochemical parameters in leaf of _Terminalia arjuna_, _T. tomentosa_ and _Lagerstroemia speciosa_.

<table>
<thead>
<tr>
<th>Species</th>
<th>Acc. No.</th>
<th>Total chlorophyll (mg/g)</th>
<th>Phenol (µg/mg)</th>
<th>Reducing sugar (µg/mg)</th>
<th>Non reducing sugar (µg/mg)</th>
<th>Protein (mg/g)</th>
<th>Proline µmol/mg</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>T. arjuna</em></td>
<td>102</td>
<td>3.04</td>
<td>0.84</td>
<td>5.64</td>
<td>6.09</td>
<td>22.05</td>
<td>22.50</td>
</tr>
<tr>
<td><em>T. arjuna</em></td>
<td>135</td>
<td>1.54</td>
<td>0.45</td>
<td>6.63</td>
<td>14.75</td>
<td>28.75</td>
<td>25.30</td>
</tr>
<tr>
<td><em>T. tomentosa</em></td>
<td>501</td>
<td>2.03</td>
<td>0.89</td>
<td>6.03</td>
<td>11.78</td>
<td>21.05</td>
<td>45.00</td>
</tr>
<tr>
<td><em>T. tomentosa</em></td>
<td>531</td>
<td>1.90</td>
<td>3.27</td>
<td>6.05</td>
<td>6.67</td>
<td>22.90</td>
<td>56.80</td>
</tr>
<tr>
<td><em>L. speciosa</em></td>
<td>630</td>
<td>0.96</td>
<td>1.60</td>
<td>9.50</td>
<td>10.40</td>
<td>20.00</td>
<td>55.80</td>
</tr>
<tr>
<td><em>L. speciosa</em></td>
<td>631</td>
<td>1.07</td>
<td>5.60</td>
<td>6.10</td>
<td>6.80</td>
<td>17.00</td>
<td>70.00</td>
</tr>
<tr>
<td>Mean</td>
<td>1.75</td>
<td>2.10</td>
<td>6.65</td>
<td>9.41</td>
<td>21.95</td>
<td>45.90</td>
<td>45.90</td>
</tr>
<tr>
<td>SE±</td>
<td>0.31</td>
<td>0.80</td>
<td>0.58</td>
<td>1.41</td>
<td>1.59</td>
<td>1.85</td>
<td>1.85</td>
</tr>
<tr>
<td>SD±</td>
<td>0.76</td>
<td>1.98</td>
<td>1.42</td>
<td>3.47</td>
<td>3.90</td>
<td>8.25</td>
<td>8.25</td>
</tr>
<tr>
<td>Range</td>
<td>0.96-3.04</td>
<td>0.45-5.6</td>
<td>5.64-9.5</td>
<td>6.09-14.75</td>
<td>17.0-28.75</td>
<td>22.50-70.00</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>43.42</td>
<td>94.28</td>
<td>21.35</td>
<td>36.87</td>
<td>17.76</td>
<td>17.97</td>
<td></td>
</tr>
</tbody>
</table>
Table 10: Comparative rearing performance of *A. mylitta* D. on *T. arjuna*, *T. tomentosa* and *L. speciosa* (2015)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Species</th>
<th>First crop (July – August 2015)</th>
<th>Second crop (October-November 2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>T. arjuna</em></td>
<td><em>T. tomentosa</em></td>
<td><em>L. speciosa</em></td>
</tr>
<tr>
<td>Larval duration (days)</td>
<td>32</td>
<td>32</td>
<td>35</td>
</tr>
<tr>
<td>Single mature larvae weight (g)</td>
<td>37.10±0.23</td>
<td>39.00±0.26</td>
<td>34.30±0.30</td>
</tr>
<tr>
<td>ERR (%)</td>
<td>93.17±0.17</td>
<td>94.21±0.18</td>
<td>93.05±0.10</td>
</tr>
<tr>
<td>Single cocoon weight (g)</td>
<td>14.11±0.31</td>
<td>16.19±0.31</td>
<td>14.26±0.27</td>
</tr>
<tr>
<td>Single shell weight (g)</td>
<td>1.66±0.06</td>
<td>1.91±0.09</td>
<td>1.81±0.03</td>
</tr>
<tr>
<td>Silk ratio (%)</td>
<td>11.85±0.45</td>
<td>11.85±0.67</td>
<td>12.64±0.20</td>
</tr>
<tr>
<td>Total cocoon shell production</td>
<td>154.66±8.88</td>
<td>179.94±9.88</td>
<td>168.42±7.21</td>
</tr>
<tr>
<td>Filament length (m)</td>
<td>743.00±44.46</td>
<td>674.40±47.14</td>
<td>644.90±45.55</td>
</tr>
<tr>
<td>Number of breaks</td>
<td>2.80±0.29</td>
<td>2.20±0.44</td>
<td>2.40±0.31</td>
</tr>
<tr>
<td>Silk weight (g)</td>
<td>0.94±0.05</td>
<td>0.90±0.07</td>
<td>0.73±0.06</td>
</tr>
<tr>
<td>Waste weight (g)</td>
<td>0.32±0.06</td>
<td>0.29±0.02</td>
<td>0.34±0.04</td>
</tr>
<tr>
<td>Non-breakable filament length (m)</td>
<td>233.97±23.09</td>
<td>315.34±68.95</td>
<td>232.20±27.22</td>
</tr>
<tr>
<td>Denier</td>
<td>11.41±0.20</td>
<td>11.64±0.27</td>
<td>10.57±0.23</td>
</tr>
</tbody>
</table>

± Indicates standard error

Fig. 4: *Lagerstroemia speciosa* plant.

Requirements of tasar industry in view of climate change

1. **Varieties with low gestation period:** Due to paradigm shift in tasar culture from forest based cocoon collection to silkworm rearing in block plantation, area under plantation is being increasing. Several farmers are showing interest in commercial based tasar culture, but due high gestation period of host plants (4 year for Arjun and 6 year for Asan) farmer has to wait for 4-6 years to initiate silkworm on newly established plantation. Because of long waiting period several farmers are not coming forward to establish block plantation despite having interest. Development of varieties having low gestation period is most appropriate to solve this issue.

2. **Varieties tolerant to abiotic stress:** As block plantations are finding its place in marginal lands not fit for agriculture and forest area which are completely dependent on rainfall for their survival. Hence, to cope up with this condition development of drought tolerant varieties/hybrid plants is need of the hour.

3. **Low input responsive variety:** The block plantations are mainly established in marginal unfertile soils, plantations hardly gets manures and fertilizers due to poor economic status of tasar farmers. Under this situation development of low input responsive, high yielding varieties under marginal low fertile soil is of utmost requirement of tasar industry.

4. **Varieties resistant to Gall insect and other diseases:** Tasar host plants are affecting with several diseases (Leaf spot, powdery mildew and black nodal girdling) and insect pests (gall insect, leaf roller, defoliators, stem bores and bark eating caterpillars). These are not causing significant yield loss causing except gall insect. Gall insect (*Trioza fletchery minor*) causing 10-15% damage to the foliage rendering the leaves unsuitable for silkworm rearing. The control of gall insect requires repeated spray of pesticide, which is non-economical to the poor farmers. On the other hand gall insects
are becoming pesticide tolerant due to continuous pesticide application. The best environment friendly and economic approach is to develop varieties/hybrids resistant to gall insect.

5. Development of hybrids/varieties for high leaf yield and quality: It is the foremost requirement of tasar industry to increase the production and productivity of tasar silk. Leaf nutrient content of host plays key role in quality of silk yarn and hence variety with high nutritional quality has to be taken care in development of varieties.

6. Selection of superior germplasm having high rooting ability in vegetative propagation: Despite lot of effort in vegetative propagation in tasar host plants limited success have been achieved. In juvenile cuttings up to 80% rooting was observed and hence varieties/accession with high rooting ability is required.

Breeding strategies to meet the requirements
Unlike agricultural crops breeding of in Terminalia sp. is difficult because of its Perennial and heterozygosity nature, besides smaller flower size also restricts hybridization. Keeping in view of these difficulties following breeding approaches are being proposed to achieve above objectives.

1. Development of varieties with low gestation period: Screening of germplasm for high seedling vigour in available germplasm of Terminalia species, and related genera is foremost approach. In case of non-availability creation of new variability is essential, could be achieved by following approaches.
   a. Mutation breeding: Clonally propagated improved variety can be used for mutagen treatment. The treated material can be screened for early vigour by following clonal selection method. Which can be directly used as a variety or as donor parent in hybridization breeding.
   b. Distant hybridization: Explore related genera having early vigour character, if available distant hybridization would be preferred due to cross incompatibility between distant genera. Since Terminalia is perennial plant use of bridging species for distant hybridization is not practicable and hence protoplast fusion technique is an appropriate technique to achieve the hybridization. This necessitates standardization of cell culture, tissue culture and protoplast fusion in Terminalia and respective genera. These techniques demands sophisticated laboratory.

2. Varieties tolerant to abiotic stress: Preliminary characterization of germplasm accessions showed wide variability for drought responsive traits viz., proline content, cuticle thickness, number stomata, stomatal pore size, and phenol content. Accessions having high proline content, thick cuticle can be evaluated for other drought tolerance characters. Superior lines could be used as parental lines in hybridization breeding.

3. Low input responsive variety: The germplasm lines need to be evaluated in marginal and unfertile lands, based on their performance superior germplasm can be selected. These lines can be further evaluated in different agro-climatic zones to observe for their stability.

4. Varieties resistant to Gall insect and other diseases: Systematic screening of available germplasm lines for gall insect for tolerant/resistant lines. If found which would be used as a variety directly or parent in hybridization breeding. If not found resistant gene can be explored in related species/genera. These resistant genes can be transferred using special technologies like protoplast fusion, somatic hybridization, genetic engineering.

5. Development of hybrids for high leaf yield and quality: Due to perennial nature as well as heterozygous nature of Terminalia species development of inbreds for hybrid development is impractical. However an attempts are being made to develop hybrids in Terminalia species by using heterozygous parents (Project is in progress). In principle higher heterosis in hybrid is the result of higher heterozygosity, which can be achieved by crossing highly homozygous parents (inbreds). Conventional development of inbreds in Terminalia spp. requires several decades due to its perennial nature. Development of haplo-diploid plants is most appropriate technique to develop 100% homozygous inbred plants. These inbreds would be crossed to get more heterotic hybrids. Haploid plants can be generated from anther/ovule culture as achieved in several other crops (rice, wheat, tobacco), which is followed by doubling of chromosomes to get halo-diploids. In Terminalia spp. protocol of anther culture need to be standardized, which again demands high through put tissue culture laboratory.

6. Development of polyploids: Polyploids offer three major advantages over diploid viz., heterosis, gene redundancy and asexual reproduction. Heterosis causes polyploids to be more vigorous than their diploid progenitors, whereas gene redundancy shields polyploids from the deleterious effect of mutations (Luca, 2005). Generally polyploids show gigantism i.e. large cell size, vegetative organs like leaf, root and flower and high biomass. They show increased heterozygosity; increase in chromosome number results in an increase in the number of alleles per locus and consequently more alleles in a state of heterozygosity.

7. Selection of superior germplasm having high rooting ability in vegetative propagation: Genetic variation for rooting ability was observed in germplasm accessions maintained in field gene bank. This variability need to be explored to identify varieties/accessions having high rooting ability. This will meet large demand of seedlings for growing area under block plantation.
Proposals for future host plant breeding

- Whole genome sequencing of primary tasar host plant species to increases precision of breeding.

- Development of markers: Despite advancement in marker technology till now no marker systems are developed for Terminalia species. Hence development of Terminalia species specific markers is need of the hour to assist host plant breeding.

- Gene mapping: Mapping of genes/QTLs controlling yield, quality and drought responsive traits is foremost important to assist marker assisted selection.

- Marker assisted selection: As morphological traits expressions are influenced by the environment, selection based on these traits decrease the precision of selection in plant breeding. Therefore DNA markers linked to desired traits will assist in precise selection and speed up the genetic improvement programs.

- Study on host plant-silkworm interaction: As silk quality is depends on host-silkworm interaction, study on critical metabolites/nutrients deciding silk quality is of paramount significance. Which can be unraveled by studying host-silkworm interaction at genomic/transcriptomic/metabolomics level.

- Somatic hybridization: The Sal (Shorea robusta) fed tasar silkworm produces very high quality silk (high filament length) as compared to silk produced on Asan and Arjun host plants. This could be attributed to unique nutrient composition/metabolites in Sal leaf. Distant hybridization between Terminalia spp. X Shorea robusta through somatic hybridization would be tried to develop new species having Terminalia character with unique metabolite(s) of Sal.

Acknowledgement
For the preparation of this chapter information has been collected from final reports of various projects conducted in CTR&TI, Ranchi. Contribution of concerned scientists to the projects is greatly acknowledged.

References:


Introduction
The primary food plants of tasar silkworm *A. Mylitta* are *Terminalia arjuna* and *Terminalia tomentosa* commonly known as Arjun and Asan, respectively. The food plants health depends mainly on two factors i.e. host plant management and host plant pest management. Effective management of both practices in tasar food plants not only increases the quality and quantity of leaf but also the cocoon yield and the income of tasar farmers.

Insects are diversified creatures on the earth. Their innate and acquired mechanisms improve their fitness (either individual or population) against the man-made challenges like insecticide molecules, transgenic plants, microorganisms & their toxins, pollutants, climate change, production practices and fragmented landscapes (Chakravarthy, 2015). Due to these reasons the risk of pest-outbreak is increasing regularly in agriculture, veterinary and medical fields. Since, tasar silkworm is reared on host plants which are raised under in-situ condition; the success in terms of productivity is highly influenced by both biotic and abiotic factors. In recent time, the improved production practices along with the climate change (delayed monsoon and prolonged dry spells) have drastically escalated the insect-pests problem on host plants of tasar-silkworm in a subtle and oblivious fashion.

Host Plant Pest Management
Tasar silk is produced by *Antheraea mylitta* which is polyphagous in nature. The primary food plants of tasar silkworm *A. Mylitta* are *Terminalia arjuna* and *Terminalia tomentosa* commonly known as Arjun and Asan, respectively. A large number of pests are reported to attack the host plants causing loss to the tune of 15 – 90%. The major pests are gall insect (*Trioza fletcheri minor*), Vapourer tussock moths, May-June beetle (*Anomala blanchardi*), ash weevils (*Myllocerus viridanus, M. Undecim-pustulatus, M. transmarinus*) and Red beetles (*Tricliona picea, T. variables*), stem borers (*Psiloptera fatuosa, Sphenoptera koenbiereni, Aeolesthes holoseracea*) and Bark eating caterpillars, *Indarbella* sp. Besides these insect pests like thrips, *Rhipiphorothrips cruentatus* Hood (Thysanoptera: Thripidae), spittlebug, *Clovia* sp. (Hemiptera: Aphrophoridae) and leaf hoppers (LH), *Hishimonus indicus* (Sohi) and *H. viraktamathi* Knight (Hemiptera: Cicadellidae) are also observed infested tasar host plants. (Jolly etal,1974; Singh etal 1992, Thangavelu and Singh, 1991, Thangavelu, 2000; Chandrashekharaiah etal, 2018 and Preeti Tirkey etal,2019).

Seasonal abundance of pest:
The occurrence of pest depends upon three components viz., host, pest and environment. These three components are responsible for high and low production tasar cocoon. When all three components are present in favorable condition, severity of pest reaches high. Among these three components, if any one of them is absent or unfavorable, this can hamper the population dynamics of the pests.

Nature of damage:
The characteristics of damaging symptoms of one pest differ from another pest. Based on these characteristic the pests are categorized as leaf/foliage and stem damaging and according to severity of pest, management practices is recommended.

Foliage loss:
Foliage loss caused by any pest depends upon the severity of that pest. If severity of the pest is low, it will cause minimum foliage loss whereas if the severity of pest is high will cause maximum foliage loss.

Table: Seasonal abundance, nature of damage and foliage loss in tasar food plants

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Biological Name</th>
<th>Common Name</th>
<th>Seasonal Abundance</th>
<th>Nature of damage</th>
<th>Foliage loss (pest infestation in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><em>Trioza fletcheri minor</em> Crawf</td>
<td>Gall Insect</td>
<td>Mar. – Nov. (Jul-Sep)</td>
<td>Leaf Damage</td>
<td>10 -20 80 – 90</td>
</tr>
<tr>
<td>2.</td>
<td>Megatrioza hirsuta</td>
<td>Jumping plant lice,</td>
<td>July. – Nov</td>
<td>Leaf Damage</td>
<td>- -</td>
</tr>
<tr>
<td>3.</td>
<td><em>Notolophus antiqua</em> Linn.</td>
<td>Vapourer Tussock Moth</td>
<td>April – Nov (Jul-Sep)</td>
<td>Defoliator</td>
<td>8 -10 70 – 90</td>
</tr>
</tbody>
</table>
### Table: Current Status of Major Insect Pests in Tasar Food Plants in Different Region

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Centre</th>
<th>Major pest</th>
<th>Minor pest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Gall, bark eater and termite</td>
<td>Stem borer, shoot borer and defoliators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall</td>
<td>Stem borer, bark eater, shoot borer, termite and defoliators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall and bark eater</td>
<td>Stem borer, shoot borer, termite and defoliators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall, stem borer, bark eater and</td>
<td>Shoot borer and termite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>defoliators</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall and bark eater</td>
<td>Stem borer, shoot borer, termite and defoliators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall fly</td>
<td>Stem borer, bark eater, shoot borer, termite and defoliators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall and stem borer</td>
<td>Bark eater, shoot borer, termite and defoliators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall, defoliators and termite</td>
<td>Gall, bark eater, stem borer, shoot borer and defoliators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall fly</td>
<td>Stem borer, bark eater, shoot borer, termite and defoliators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall and termite</td>
<td>Stem borer, bark eater, shoot borer, and defoliators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall, Bark eater and defoliators</td>
<td>Stem borer, shoot borer and termite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall, Bark eater and defoliators</td>
<td>Stem borer, shoot borer and termite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall and stem borer</td>
<td>Bark eater, shoot borer, termite and defoliators</td>
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<td></td>
<td>Gall, shoot borer, termite and</td>
<td>Stem borer, shoot borer and termite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>defoliators</td>
<td></td>
</tr>
</tbody>
</table>

### Table (cont.)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Centre</th>
<th>Major pest</th>
<th>Minor pest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Gall, shoot borer, termite and</td>
<td>Stem borer, shoot borer and termite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>defoliators</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gall, shoot borer, termite and</td>
<td>Stem borer, shoot borer and termite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>defoliators</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Gall, shoot borer, termite and</td>
<td>Stem borer, shoot borer and termite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>defoliators</td>
<td></td>
</tr>
</tbody>
</table>

### Notes

1. **(A) GALL FLY** *(Triozia fletcheri minor* Crawford)*
   - Gall forming insect on the leaves of primary tasar food plants (Singh and Thangavelu, 1994). Lot of work has been done on the seasonal...
abundance of Psyllids (Dhar et al., 1988) and control measures. It is a serious pest causing 40-50% crop loss during peak period (August) in T. arjuna and T. tomentosa, the primary food plants of tasar silkworm (Singh and Thangavelu, 1991). Almost all the tender and medium leaves are affected by this insect making the leaves unsuitable for tasar silkworm rearing. Severe infestation of gall in T. arjuna in Haryana nurseries and he has also emphasized its negative impact in tasar silk industry (Jagdish Chander, 2015). The insect activates perturbation and growth mechanisms alter the differentiation processes in the host plants, modifying the plant architecture to its advantage (Raman A., 2005). The psyllid appears during the month March on fresh leaves of T. arjuna and T. tomentosa. Their population remains till mid November mid-December or until the beginning of leaf fall, however, the peak infestation period is from July to September. A major part of the life cycle of gall insect is closely associated with the formation of gall build in which the insect completes its development. Various nymphal stages live in gall which gets larger in size with subsequent developing instars. Galls initially are greenish but later on get brownish in coloration. The present study was undertaken to study the morphology of Trioza fletcheri minor (adult and nymph) and gall infested leaves of T. arjuna and T. tomentosa.

Classification:
- Phylum: Arthropoda
- Class: Insecta
- Order: Hemiptera
- Family: Psyllidae
- Genus: Trioza
- Species: fletcheri minor

Pest Identification / Symptoms of pest infestation: Yellow gland like structure, looking like small pox on the surface of leaf

Life cycle: The female generally lays 400-500 eggs on tender newly sprouted shoots. The eggs are slightly yellowish in colour at the time of oviposition and within 12 hours it turns black. The eggs are very minute and slightly elongated which is very difficult to identify through naked eye. After 5-6 days of incubation the egg hatch out and the young nymph crawls on the surface of the leaf for a couple of hour and ultimately penetrate in the leaf tissue where it passes its entire nymphal stage.

**Period of occurrence:** March – November with peak infestation during July to September.

**Extent of damage:** 10-20% (low infestation) to 80-90% (severe infestation)

---

**Control measures:**

**Cultural method:**
- Two times deep ploughing after silkworm rearing during November - December and March – April. Application of neem cake @ 60kg per acre in two split doses before the onset of monsoon (15th May and 30th May)
- Pruning of tasar food plants at 4 to 6 feet height is to be postponed up to 30th April to minimize gall insect infestation (Sharma et al., 2002).

**Mechanical method:** Collection and destruction of gall infested leaves and pruning waste.

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**Source:** Sunita Mukherjee et al., 2016 & 2017

**Fig 1:** (A) Gall infested Arjun leaf, (B) Burst gall on adaxial surface of Arjun leaf, (C) Gall infested Asan leaf, (D) Burst gall on abaxial surface of Asan leaf, (E) Eggs of gall fly (inset), (F-H) Nymphal stages of T. fletcheri minor (I) Adult of T. fletcheri minor, (J) Head portion (K) Antennae (L) Fore wing venation of T. fletcheri minor (R1-R3: Radius, M1, M2: Media, Cu: Cubitus) (M) Male genitalia, (N) Female genitalia

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**Chemical method**: Three Consecutive foliar sprays of 0.09% Dimethoate (Rogor 30 % EC) at an interval of 15 days after sprouting of leaves (3 ml per litre of water).

Waiting period: **15 days**.

**Biopesticide**: Three Consecutive foliar sprays of 15 ppm Azadirachtin (Vanguard 1500ppm) at an interval of 15 days after sprouting of leaves (Sharma et al., 2005).

1 (B) Jumping plant lice, *Megatrioza hirsuta* (Crawford)

Symptoms of curling and crumpling on *T. arjuna* & *T. tomentosa* leaves observed in the form of small thickening of the terminal leaves which starts thickening almost after a fortnight due to the feeding action of the nymphs followed by the complete curling of the leaves (Fig. 1a,1b,1c). The nymphs feed on the dorsal side of the leaves and fold them outside in. The damage was noticed short as well as in long height plantations during October 2018 but insect remained undocumented. Close examination of the leaves showed the presence of woolly white sucking nymphs (Fig. 2c). They later became gallinaceous as they grew. Due to active sap sucking action of the nymphs, the leaves were rolled, thickened and get curled & crumpled. This provides a nearly stable surface for the nymphs to settle and feed comfortably. Such leaves catch the attention as they attain pinkish red colour (Fig. 1a). The curled leaves once exhausted became brown, hard and corky upon drying. Actively feeding nymphs urinate continuously. This fluid gets collected in the rolled portion of the leaf as milky fluid and honeydew globules (Fig. 2b). Besides milky fluid, the folded leaf contains powdery mass and exuviae of the moulted nymphs (Fig. 1c). Mature nymphs have white waxy skin (Fig. 2c). Similar observations and studies have also been documented by Dhiman and Sangeeta (2006).

![Curling and puckering of leaves](image1.png)

![Folding of the tender / mature leaves](image2.png)
c. **Thickening, curling and puckering of terminal leaves**

*Fig. 2. Thickening, curling and puckering of leaves in *Terminalia arjuna***

The emerged adult of the pest has a light shining yellowish body with white transparent wings that extended beyond pointed abdomen (Fig. 2d, 2e). The members of family Triozidae are commonly called jumping plant lice and form galls on plants by their feeding action. Mathur (1949) have also reported *Megatrioza hirsuta*, a major pest of *Terminalia* sps. *T. hirsuta* on *T. alata* and *T. tomentosa* has also been reported by Dhiman and Sangeeta (2006) in U.P. Chander (2018) has also reported the occurrence of leaf curl of leaves of *T. arjuna* and its causal insect pest in Chandigarh, Haryana, Punjab and Himachal Pradesh as the first report from these region. Gupta and Gupta (2013) observed the seasonal variation and reported that *T. hirsuta* infests plants during the last week of April. Dhiman and Sangeeta (2007) has reported that the eggs are laid on the ventral side of the leaves singly on either side of the leaf midrib and a female lays 48-180 eggs during her lifespan, with an average of 98.6 eggs. However, such observation on oviposition behaviour and fecundity of *M. hirsuta* needs to be studied from this region (Jharkhand).

Raman (2012) has reported in details the mechanism of leaf thickening which is similar to gall formation; the saliva of the insect contains hydrolyzing enzymes and soluble proteins, which induce many changes in the cellular contents. This acts as stimulus for the induction of galls. The stimulus weakens the defence mechanism of the plant. Actively feeding nymphs vigorously take oxygen from the site of the attack and bring the cells and tissues under stress. The hormonal balance changes and results in repeated cell division (hyperplasia) and enlargement of cell (hypertrophy). In response to this, the plant releases lot of phenolics which get deposited over the feeding nymphs. Dhiman and Sangeeta (2006) studied the moulting behaviour of nymphal instars of *Trioza hirsuta* and reported that only nymphal stages contribute in making the gall. Moulting of nymphs occurs inside the gall, but last instar nymphs come out of the gall. Before moulting, the instar powerfully clings the host surface with claws. After emergence, the exuvium is left attached with host surface leaf in case of last instar (Fig. 1c). The nymphs finally moult to become adult leaving its exuviae sticking to leaves. Similar observations on *Megatrioza hirsuta* has also observed in the present study which validates the report on infestation of *M. hirsuta* on Tasar host plants in Jharkhand (Mittal *et al.*, 2019)

Besides some parasitoids of *T. hirsuta* were also found and collected which were identified as *Psyllaephagus phylloplectae* (Hymenoptera: Chalcidoidea: Encyrtidae).

a. **Young nymphs feeding inside the folded leaves**
Conclusion

The feeding action of *Megatrioza hirsuta* harms tasar host plants by curling and crumpling of terminal leaves which later get dried and fall off. This also affects the photosynthetic activity of the plants and the terminal shoot becomes abandoned & dead. The infestation of leaf curls of leaves / leaf roll galls of *T. arjuna* & *T. tomentosa* and its causal insect pest in Jharkhand didn’t get much attention since long from this region as the insect remained faceless and it could not be documented. However, proper vigil required for this insect pest in future to avoid its further invasion to the tasar host plants.

Other sucking insect pests:

Besides gall insects, some more sucking insect pests like thrips, *Rhithiphorothrips cruentatus* Hood (Thysanoptera: Thripidae), spittlebug, *Clovia* sp. (Hemiptera: Aphrophoridae) and leaf hoppers (LH), *Hishimonus indicus* (Sohi) and *H. viraktamathi* Knight (Hemiptera: Cicadellidae) are also observed infested tasar host plants. The infestation of *R. cruentatus* is found severely during pre-monsoon season, which coincided with new leaves sprouting period. Delayed monsoon also augments *R. cruentatus* population on *T. arjuna*. But, during peak rainy season, its population reduces drastically and during winter and summer seasons. The *Clovia* sp. and leafhopper is found throughout the year. But, their damage is very severe from June to January which coincided with rainy and winter seasons. The aforementioned information are an indications that the *T. arjuna* is susceptible to sucking pests throughout the year (Chandrashekharaiah etal, 2018).

Fig. 3. Different stages of jumping plant lice, *Megatrioza hirsuta* (Crawford)
VAPOURER TUSSOCK MOTHS (more than seven species are observed)

Common Name: Vapourer Tussock Moths

Classification:
- Phylum: Arthropoda
- Class: Insecta
- Order: Lepidoptera
- Family: Lymantriidae

Pest Identification / Symptoms of pest infestation: Showing wavy nature of feeding pattern on leaf lamina.

Life cycle:
Adult female are pale green in colour. The mated female lays about 500 eggs on its puparium. Eggs are white in colour, round in shape and dorsoventrally flattened. There are five larval instars. Larvae are voracious feeders. The total larval period varies from 30-35 days. Fully grown larva measure 21-27 mm in length and 2.5-4.5
mm in diameter. The head of fully grown larvae is brilliant vermillion in colour and the body is yellow banded with white and black tipped tufts and bundles of black colour hairs. The pupal period ranges from 9-12 days. The total life cycle of *N. antiqua* varied from 40 to 48 days. Generally it starts appearance in the monsoon season, peak period is from June to September.

![Eggs of vapourer tussock moth](image)

**Fig: 4- Different types of Vapourer tussock moth**

**Period of occurrence:** April to November with peak period from July to September.

**Extent of damage:** 8 – 10 % (low infestation) to 70-80% (severe infestation)

**Control measures:**

**Mechanical:** Collection and destruction of egg masses, larvae, pupae and adults.

**Chemicals:** Spray of 0.09% Dimethoate. Spray of 0.1 % Nuvan in case of severe infestation.

2. **MAY-JUNE BEETLE** (*Anomala blanchardi* Blanch)

**Classification:**

<table>
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<tr>
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<td>Anomala</td>
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<tr>
<td>Species</td>
<td>blanchardi</td>
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</table>

**Pest Identification / Symptoms of pest infestation:** Showing smooth circular feeding pattern on surface of leaf lamina
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

May-June beetle infested leaf

Life cycle:
It is a dark brown to black insect with clubbed antennae, with six visible abdominal segments, 1.0 -1.2 cm in length. Nocturnal in habit, adults feed on foliages and grubs feed on roots during embryonic development. The pest is Nocturnal in habit. The female lays eggs in the soil. White larvae are general feeders, attacking the roots of the grasses, woody plants and many herbs. Larval body is large, 2.0 -2.2 cm, segmented, soft, whitish and the long axis sharply curved thereby appearing as c shaped. Pest completes larval duration in soil during winter. Pupation occurs in the spring in the soil. The adult starts appearing in May and June (hence commonly known as May-June beetle) and continued till August.

Period of occurrence: March to August

Peak period: May to June.
Extent of damage: 8 -10% (low infestation) to 35 – 40% (severe infestation)

RED BEETLE (Triclonia picea Jacoby & Triclonia variab

Classification:
Phylum : Arthropoda
Class : Insecta
Order : Coleoptera
Family : Chrysomelidae
Genus : Triclonia
Species : picea

Pest Identification / Symptoms of pest infestation: Nibbling of leaf surface (scraping of chlorophyll)

1Life cycle:
It is a small dark brown and shining beetle. Male is 4.0 mm and female is 5.1mm in length. They are diurnal feeders and scraping off the chlorophyll leaving net like appearance in the leaves. Eggs are white to creamish in colour, 0.24 mm in size and hatch in 6 to 7 days. Small grubs live in soil and pass whole winter in it. The adult beetles appear in the month of June and continue till winter commencement. The peak infestation period is July-August.

Period of occurrence: May to October with peak period from July to August.

Extent of damage: 5 - 7 % (low infestation) to 30 – 35% (severe infestation)

4. ASH WEEVILS (Myllocerus viridanus Fab., Myllocerus undecim-pustulatus Fast., Myllocerus transmarinus)

Classification:
Phylum: Arthropoda
Class : Insecta
Order : Coleoptera
Family : Curculionidae

Pest Identification / Symptoms of pest infestation: Showing irregular feeding habit giving palm shape appearance on the leaf
Weevil infested

Period of occurrence: June – Nov with peak period from July to August.

Extent of damage: 5 - 7% (low infestation) to 15 – 20% (severe infestation)

Recommended control measures for defoliators of tasar food plants

**Cultural:** Two times deep ploughing after silkworm rearing Nov.-Dec. and March-April is to be done.

**Mechanical:** Collection and destruction of different developmental stages of insect such as eggs, grubs/larvae, pupae and adults of coleopteran and lepidopteran pests during morning and evening hours twice a week from the month of May to July.

**Botanical:**

Soil application of neem cake (dried and fine meshed @ 60 kg per acre in two split doses at 15 days interval before the onset of monsoon (1st dose – 15th May & 2nd dose-30th May).

Foliar application of 15 ppm Azadirachtin once after 15 days of soil application of neem cake (15th June).

5. Leaf Rolling Weevil

**Classification**

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Attelabidae

**Identifying Characteristics of Insect Pest:** Eggs are spherical and yellowish; Females typically deposit a single egg into each roll. Occasionally, more than one egg may be laid, especially when tender leaves are in short supply. Larvae develop in and feed upon leaf rolls. Larvae are legless, C-shaped, and grub-like. Adults are strikingly-colored weevils. The body is red with black compound eyes and fore legs is well developed with robust femur. Fore wings (Elytra) are shiny porcelain-like finish with yellow spots (Fig 1).

**Damaging symptoms:** Adults feed by skeletonizing or chewing small holes in the leaves of arjuna plants. Portions of some leaves are damaged by construction of leaf rolls. Female weevil lays a single egg on young oak leaves at the terminal end, then scores the leaf and tightly rolls it up into a little incubator to protect it. Once a leaf roll has aged a couple days, the leaf tissue dries into a hard casing around the egg. These leaf rolls may be severed from their point of attachment to a leaf and fall to the ground; area under tree canopy may contain numerous detached leaf rolls. Some leaf rolls may remain attached. Incidence was only observed in arjun plants.

**Period of occurrence:** May to June

![Fig 1: a: Leaf rolls containing eggs/grubs b: Egg inside leaf roll c: Grub inside the rolls d: Adult](image)

6. Hairy caterpillar

**Classification:**

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Noctuidae

Genus: - Selepa

Species: - celtis

**Identifying Characteristics of Insect Pest:** Eggs are laid in masses and freshly laid eggs will be yellowish and translucent with round shape with reticulate markings on chorion. The larvae of this defoliator are highly active, hairy, and yellowish with black dots on the 2nd, 7th, 8th and 9th abdominal tergites. Moths are medium
size with pale brown colour (Fig 2).

**Damaging symptoms:** The larvae of *Seepa celtis* are voracious leaf defoliators of *T. arjuna*. Larvae cause damage by defoliating the leaves. Early instar larvae causes damage by feeding the epidermal layer of the leaves by scraping. However late instars larvae causes the defoliation/skeletisation of the leaves. Incidence was only observed in arjun plants.

**Period of occurrence:** June to August

**Control measures:** Collection and destruction of egg masses and larval from infested leaves.

![Fig 2: a: Egg mass b: Damage by early instar larvae c: Late instar larvae defoliating the leaves d: pre pupal stage e: Pupae f: Adult moth](image)

7. **Leaf webber**

Classification:
- Phylum: Arthropoda
- Class: Insecta
- Order: Lepidoptera
- Family: Noctuidae

**Identifying Characteristics of Insect Pest:** Eggs are laid in masses after incubation period larvae hatches from egg and they will feed gregariously on the epidermis of the leaves. Early instar larvae are with transparent body with brown head capsule. Late instar larvae are with white and dark stripes with black head capsule. Adults are medium in size with dark brownish forewings and white colored hind wings with slight brownish margin (Fig 3).

**Damaging symptoms:** larvae web the leaves together with a silken thread and feeds on the webbed leaves. Incidence was only observed in arjun plants.

**Period of occurrence:** Incidence was observed from the month May with a peak incidence during June -July

![Fig 3: a: Early instars feeding on epidermis b:Late instar instar larvae with silk gallery c: Webbed leaves d: Pupae e: Adult moth](image)

8. **Leaf miner**

Classification:
Phylum: Arthropoda  
Class: Insecta  
Order: Lepidoptera  

**Identifying Characteristics of Insect Pest:** Larvae are very small in size with creamy or pale yellow color body. After completion of the larval stage it pupates inside the leaf mines. Adults are very small in size with light brown color wings with white spots (Fig 4).

**Damaging symptoms:** larvae mines the leaf epidermis layer and feeds on the chlorophyll and eventually plant leaves will show drying and burning symptoms. Incidence was only observed in both asan and arjun plants.

**Period of occurrence:** incidence was observed from the month of May with peak incidence during Nov-Dec.

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**Stem Borer and Bark Eaters:**
The borer complex is very important pests, due to their persistence attacking behaviour, mainly on weak and young plants. The loss caused in terms of the death of plants or otherwise, borer damage, which in turn affect growth and vigor of the plants. Among the borer complex, the *Sphenoptera cupriventris* Kerr. (Coleoptera: Buprestidae) and *Indarbela quadrijnatais* (Walker) (Lepidoptera: Cossidae) are important pests on *T. arjuna* and cause severe damage to the plants and reduce lants vigor gradually. The round-headed stem borer, *Aeolesthes holosericea* Fabr. (Coleoptera: Cerambycidae) is also an economically important borer on *T. arjuna* and their damage led to death of side branches or the entire plant. (Prakash et al., 2010; Joshi, 2012). Both, adults and grubs of *S. cupriventris* are causing damage to *T. arjuna* plants. The adults lay eggs by excavating small pits on the bark and grubs feed on the barks as well as stem by boring into it. The exit hole made by the adults also causes damage to the plants. The gum exudation, bark splitting, rotting and fungus growth are common symptoms of this pest damage. Severe damage leads to the death of plants. Similarly, *I. quadrijnatais* construct larval galleries on the stem and feed within the galleries and bore into the stem and inflict severe damage to trees and reduce the vigor of the plant (Dhar et al., 1989; Kumawat and Swaminathan, 1990; George Mathew, 1997). The proper identification of susceptible stages and timely management practices enable the plants to recover from the pest damage and maintain the pest population below economic threshold level.
2. Monitoring and killing of stem borer larvae in stem borer infected plant with the help of knife and aluminum wire.
3. Use of light trap for adult stem borer control in tasar food plants
4. Application of Azadirachtin, Neem based pesticides and lime were effective treatments combination to prevent oviposition of stem borer in tasar food plants.
5. Clean hole with knife and aluminum wire and after that insert cotton wool soaked in emulsion of Neem based pesticides/Kerosene/Diesel/Petrol followed by mud plastering were effective treatments for stem borer in tasar food plants.
6. Painting of stem with methylparathion and lime mixture (1:4) to prevent oviposition.

**Waiting period:** 10 days.

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**Bark Eater**

Pest Identification / Symptoms of pest infestation:

- Early stages of damage by bark eaters are not easily recognized or highly visible.
- Its occurrence could be noticed by the presence of elongated zigzag ribbon-like messy web. If we remove the web, we can see a small bore hole in the angle of the thick branches and may find the larva inside.
- In case of normal attack the bark of tasar plant are not dies whereas in case of severe attack the tree dies as the sap movement blocked.

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**Fig-5, Different methods for stem borer management in tasar food plants**

**Fig-6, Bark eater infested plant, bark eater larva and adult**
**Period of occurrence:** Throughout the year

**Extent of damage:** 5-10% (low infestation) to 40-60% (severe infestation)

**Control:**
2. Monitoring and killing of bark eater larvae in infected plant with the help of knife and aluminum wire.
3. Use of light trap for adult bark eater control in tasar food plants.
4. Application of Azadirachtin, Neem based pesticides and lime were effective treatments combination to prevent oviposition of bark eater in tasar food plants.
5. Clean hole with knife and aluminum wire and after that insert cotton wool soaked in emulsion of Neem based pesticides/ Kerosene/Diesel /Petrol were effective treatments for bark eater in tasar food plants.
6. Painting of stem with methylparathion and lime mixture (1:4) to prevent oviposition.

**Formulation and Implementation of Neem Based Pesticides for Management of Bark Eater.**

**Salient features:**
1. Formulation and implementation of Neem based pesticide which is eco-friendly and cost effective.
2. It reduces the cost of protection for management of bark eater and enhances the quality and quantity of tasar food plant leaf.
3. Neem contains azadirachtin kill the pest whereas butter milk contains billions of beneficial bacteria which helps rejuvenate the infested part of bark.

**Usages:**
1. One kilogram neem leaf along with 2 litre of butter milk kept in earthen pot and stirred thoroughly to facilitate the leaf immersed in buttermilk. The earthen pot contained mixture is covered with lid and muslin cloth and stored in dark place for about 15 days.
2. After fifteen days, the solution is mixed by mixer and filtered through muslin cloth. This solution can be used as a base solution for preparation of active pesticides.
3. The base solution is diluted to 10 times with water (1:10 ratio) and sprayed on bark eater infested part of the plants.
4. For better results of pesticide, clean the bark eater infested part of the plant (remove web/litter with the help of knife, pupae & larvae kill in web or in hole with aluminum or iron wire) before spraying the solution.
5. Spray prepared neem solution on bark eater infested parts of the plants once in a week for three to four times.
6. Neem solution is effective for management of bark eater pest, rejuvenate the infested part of bark and enhance the quality and quantity of tasar food plants leaf. (Singh, et. al., 2018).

**Expenditure:** Rs: 300 for low and 500 for severe infestation per hectare.
Termites:

Termites, popularly known as the ‘white ants’ belong to the order ‘Isoptera’, are found abundantly in the terrestrial ecosystems and live in colony as a social animal in the soil by constructing earthen mound. Termite infestation is detrimental for many forest plant species including tasar host plant (Mandal et al., 2010). The stakeholders are not aware or concerned about its implications. Due to lack of information and negligence on the part of stakeholders, the situation is becoming a matter of concern in traditional tasar zones. Termite infests taproots of especially young host plants immediately below the soil, this intern results in damage to the central root system and creation of cavities, which then becomes filled with soil. The infested plant not only experience root damage but in extreme conditions, the infestation reaches up to the bark, resulting in secondary infection and ultimately leading to death of the plant. This results directly on economic loss and has a negative impact on income of marginal farmers due to reduced silkworm brushing capacity and cocoon yield. In Indian termite fauna has approximately 338 species, 37 genera and 07 families. About 35 species have been reported damaging crops and timber in buildings. Various termite species are known to attack on crop plant are belonging to family Termitopsidae, Hodontotermitidae, Kalotermitidae, Rhinotermitidae, Stylotermittidae, Indotermitidae and Termitidae. Major pestiferous species in Termitidae are Odontotermes boveni (Thakur), Odontotermes bruneus (Hagen), Odontotermes feae (Wasmann), Odontotermes guptai (Roonwal and Bose), Odontotermes indicus (Thakur), Odontotermes obsesus (Rambar), Odontotermes redemanni (Wasmann), Odontotermes wallonensis (Wasmann), Macrotermes convulsionaries (Konig), Microcerotermes beesoni (snyder) and Microtermes obesi (Wasmann), and in Rhinotermitidae are Coptotermes hemi (Wasmann), and Heterotermes indicola (Wasmann) (Roonwal and Chhotani, 1989; Mahapatro and Chatterjee, 2018; Paul etal.,2018; Rathore etal, 2018 and Baig etal, 2018,). The T. arjuna plantation, both block as well as natural plantation, utilizing for rearing of tasar silkworm are usually in the rainfed condition and such plantation is susceptible for termites.

Table: List of termite species identified from various tasar growing areas

<table>
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<tr>
<th>S.No</th>
<th>Termite species</th>
<th>Host plant</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td><em>Pseudocapritermesfletcheri</em> (Holmgren and Holmgren) (Termitidae)</td>
<td><em>Terminalia tomentosa,</em> <em>Shorea robusta</em></td>
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<tr>
<td>2.</td>
<td><em>OdontotermesadampurensisAkh tar</em> (Termitidae)</td>
<td><em>Terminalia tomentosa,</em> <em>Shorea robusta</em></td>
</tr>
</tbody>
</table>
### Table: Termite Species and Host Plants

<table>
<thead>
<tr>
<th>S.No</th>
<th>Termite species</th>
<th>Host plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td><em>Odontotermes ganpati</em> Bose (Termitidae)</td>
<td><em>Terminalia tomentosa</em></td>
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<tr>
<td>4.</td>
<td><em>Odontotermes obesus</em> (Rambur) (Termitidae)</td>
<td><em>Terminalia tomentosa, Shorearobusta, Ziziphus sp.</em></td>
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<tr>
<td>5.</td>
<td><em>Odontotermes latiguloides</em> Roon wal and Verma (Termitidae)</td>
<td><em>Terminalia tomentosa, Shorearobusta</em></td>
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<td>6.</td>
<td><em>Odontotermes redemanni</em> (Wasmann) (Termitidae)</td>
<td><em>Terminalia tomentosa</em></td>
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<td>7.</td>
<td><em>Odontotermes proformosanus</em> Ahmad (Termitidae)</td>
<td><em>Terminalia tomentosa, Shorearobusta</em></td>
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<td>8.</td>
<td><em>Odontotermes parvidens</em> Holmgren and Holmgren (Termitidae)</td>
<td><em>Terminalia tomentosa, Shorearobusta</em></td>
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</tbody>
</table>

**Month wise pest and parasite severity at CTR&TI, Ranchi during rearing period**

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**Fig: Termite and termite infested plants and their mound.**

**Region Wise Host Plant Pest Calendars:**

Although pest occurrences having a wide range, peak pest infestation occurs only for short period. Knowing a favorable and unfavorable period for pest emergence and outbreak, would be helpful for preparation of pest calendar at regional level. Pest calendar may be prepared, weekly, monthly and annually based on historical data of pest and weather. Central Tasar Research and Training Institute, Ranchi has developed pest calendar for Gall fly, V.T moth, May June, Red beetle, Ash weevil and stem borer for CTR&TI, Ranchi, REC, Hatgamaria, REC, Kathgora and REC, Bangriposi.
<table>
<thead>
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<th>Months</th>
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<th>Predators Parasites</th>
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<td>Jan</td>
<td>21</td>
<td>5</td>
</tr>
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</table>

Month wise pest and parasite severity at REC, Hatgamharia during rearing period

| April  | 40 | 20 | 64 | 40 | 2 | ++ | + | + | ++ | +++ | +++ |
| May    | 38 | 24 | 74 | 38 | 22 | +++ | ++ | +++ | ++ | ++ | ++ |
| June   | 36 | 24 | 86 | 36 | 24 | +++ | +++ | +++ | +++ | ++ | ++ |
| July   | 36 | 24 | 92 | 35 | 8 | +++ | +++ | +++ | +++ | ++ | ++ |
| Aug    | 32 | 20 | 92 | 32 | 38 | +++ | +++ | +++ | +++ | ++ | ++ |
| Sept   | 30 | 22 | 90 | 30 | 12 | ++ | +++ | ++ | +++ | ++ | ++ |
| Oct    | 32 | 21 | 88 | 31 | 22 | ++ | ++ | + | ++ | +++ | ++ |
| Nov    | 26 | 15 | 88 | 38 | 0 | +++ | ++ | + | +++ | ++ | +++ |
| Dec    | 25 | 12 | 88 | 26 | 4 | +++ | ++ | + | +++ | ++ | ++ |
| Jan    | 24 | 12 | 86 | 25 | 2 | ++ | ++ | + | +++ | ++ | ++ |

Month wise pest and parasite severity at REC, Katghora during rearing period

| April  | 44 | 21 | 53 | 35 | 2 | ++ | ++ | ++ | ++ | ++ | ++ |
| May    | 46 | 24 | 40 | 25 | 3 | +++ | ++ | +++ | +++ | ++ | +++ |
| June   | 44 | 24 | 70 | 45 | 15 | +++ | +++ | +++ | +++ | ++ | +++ |
| July   | 31 | 22 | 82 | 70 | 70 | +++ | +++ | +++ | +++ | ++ | +++ |
| Aug    | 32 | 24 | 90 | 74 | 60 | +++ | ++ | +++ | +++ | ++ | +++ |
| Sept   | 33 | 26 | 90 | 78 | 50 | ++ | + | + | ++ | +++ | ++ |
| Oct    | 34 | 20 | 72 | 66 | 5 | ++ | + | + | ++ | +++ | +++ |
| Nov    | 31 | 16 | 82 | 50 | 2 | ++ | ++ | + | +++ | +++ | +++ |
| Dec    | 30 | 12 | 85 | 49 | 2 | ++ | ++ | + | +++ | +++ | +++ |
| Jan    | 29 | 10 | 55 | 42 | 0 | ++ | ++ | + | +++ | +++ | +++ |

Month wise pest and parasite severity at REC, Bangriposi during rearing period

| April  | 40 | 24 | 64 | 30 | 2 | ++ | +++ | + | +++ | ++ | +++ |
| May    | 42 | 22 | 84 | 30 | 4 | ++ | +++ | +++ | +++ | ++ | +++ |
| June   | 41 | 25 | 62 | 34 | 38 | ++ | ++ | +++ | +++ | ++ | +++ |
| July   | 31 | 25 | 80 | 68 | 35 | ++ | ++ | + | +++ | +++ | +++ |
| Aug    | 32 | 26 | 84 | 70 | 78 | ++ | ++ | + | +++ | +++ | +++ |
Low Cost And Eco-Friendly Technology For Pest Management

Low cost and eco-friendly technologies are not only reduces the cost of protection but also it reduces the pollution load from tasar ecosystem. Tasar farmers easily adapt these technologies due to low cost investment for higher quality and quantity of leaf production. In tasar food plant, directional approach for pest management, formulation and implementation of Neem based pesticide, selection of suitable pruning, and assessment of congenial weather condition for outbreak of pest are not only reduce the cost of protection and increase the cocoon production but also effective for host plant protection.

1. Direction approach for stem borer infestation and management

A study was conducted at Central Tasar Research & Training Institute, Ranchi to assess the direction wise individual plant as well as plot level stem borer infestation in primary tasar food plants namely, Individual plant level, plant categorized into plant axis into two part (EW) & (NS) whereas plot wise, two part North-East-South (N-E-S) and North-West-South (N-W-S) for study the egg laying behavior (direction wise) of stem borer and planning for management of pest. Plant axis wise average stem borer infestation was recorded high in E-W axis (42) as compare to N-S (25). Similar trend was also observed in arjun plants. In case of plot, an average infestation of half part of the plots namely North – West - South (N-W-S) showed about two times more infestation in Asan and about three times more in Arjun plots as compare to half part of the plot North-East-South (N-E-S). The application of these finding could reduced the effective monitoring time and pesticide application for host plant management (Singh, et. al., 2016 and 2017).

Table 3- Direction wise stem borer infestation in Asan (Terminalia tomentosa) plants

<table>
<thead>
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<td>24</td>
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</tr>
<tr>
<td>Mean</td>
<td>15</td>
</tr>
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Table 4- Direction wise stem borer infestation in Arjun (Terminalia arjuna) plants

<table>
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<th>Plot level</th>
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<td>4</td>
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<tr>
<td>18</td>
<td>17</td>
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<td>Mean</td>
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</table>

Assessment of Congenial Weather for Emergence and Outbreak of Pest

The occurrence of pest in tasar food plants is mainly governed by three components (called triangle concept) viz., host, pest and environment. These three components are determining success of quality and quantity of leaf production. When all three components are present in favourable condition resulted in high pest severity which consider peak period caused maximum crop loss. Among three components, if any one of the components is absent or prevailing unfavourable condition resulted in minimum crop loss. There is less amenable to change host and pest during rearing period and modification of micro climate is possible through altering pruning and pollarding date, selection of optimum distance between plant to plant and row to row density of leaf canopy and suitable agronomical practices.

“Weather health” is one of the most crucial prerequisite for successful incidence of insect pests as their bionomics is intimately related with congenial weather parameters. For example (temperature), each pest has a threshold temperature (lower and upper) where development of pest is zero. Above lower and below higher a range which indicates maximum development of pest, this range of temperature is congenial temperature for that pest. Forewarning refers to prediction of forthcoming infestation of pest in numbers which would cause economic damage to the crop. On the basis of interactive approach between weather and pest data, congenial weather condition which is favorable for high infestation of pest is assessed. Weather based forewarning for pest can help growers to be in preparedness at times of anticipated economic damage by pest and to optimize the time of insecticidal application for increased production and profit. Finding of congenial weather is robust for use in tasar advisory for tasar farmers at regional level (Singh et al., 2017 & 2018).

References


Introduction: Tasar silkworm physiology is a very interesting and convoluted subject which deals the various organs in details. This book chapter deals the tasar silkworm physiology with an expanding horizon focusing on current status and recent advances on bodily processes (Fig.1-17). This chapter is also includes some morphological and hemocytic defense mechanisms against infections. Therefore, this chapter targets a wide audience tasar semi-culturist, biologists, and entomologists including both teachers and students in gaining a better appreciation of this rapidly growing field of tasar silkworm Physiology. The most significant change of outlook among tasar researcher today is the ever-increasing positive reception of the importance of the tasar silkworm physiological aspects. These aspects are also drawing an increasing number of modern sciences in their research to unravel various problems of tasar silk industry in future.

A variety of literature already exists on tasar insect physiology which some time shows disconcerting wide and variable. Therefore the aim is to keeping up to date with this literary growth has already transcended the possibilities of most researchers. CTR&TI has done the great service of coordinating and sifting out this great accumulation of data and facts and welding it as a whole into a really indispensable book chapter. At the same times, results of researches which are illustrous for their inventiveness and for the creativity of the technique that has been used. The general anatomy of *Antheraea mylitta* is also included in this chapter which is intimately linked up with the interpretation of the functions of organs and parts. It is coming to be recognized that physiological 'make-up' of the insect is very important. As knowledge of the physiological-ecology of tasar silkworm is necessary in order to achieve maximum outputs, therefore understanding of physiology is the key. Now tasar physiology and endocrinology is linked to the post-genomic era. The genome projects, functional genomics and genetics, including gene microarrays, mutations, RNAi, and sophisticated mass spectrometry techniques, which are helping to unravel complex regulatory processes of physiology. Now our institute researchers have a rich history and strong tradition of cutting-edge research in tasar biology with particular strengths in *A. mylitta* physiology. Hence it is focused that how these very modern omics technologies can be squeeze and applied to tasar silkworm physiology and endocrinology and the subsequent cold hardiness, and stress, food intake and digestion, endocrine control and depth understanding of post-genomic revolution. (Arora and Gupta; 1979; Barua, et al., 2000; Geist and Lambin 2002; Jolly et al., 1969; Jolly et al., 1976; Jolly et al., 1968; Jolly et al., 1979; Kakati and Chutia, 2009. Kar, et al.,2010; Kushwaha and Roy 2002; Reeta et al., 2016; Sahu 2005; Sinha et al., 2017; Singh, et al., 2005.; Singh & Chakravorty, 2006; Singh, et al., 2005. Singh and Maheswari, 2003; Suryanarayana and Srivastava 2005; Thangavelu 1991).

Diapause

Diapause may occur in any stage of the developmental cycle though within one species, it is mostly genetically defined to a single and well defined period but environment played crucial role on diapause period. *A. mylitta* is faces pupal diapause. Pupal diapauses are characterized by a reduced metabolic rate, reduction of body water content, and increased fat body reserves. The conditions which are unfavourable are generally passed by several insects either by reducing their body metabolic activities followed by quick recovery in normal conditions or through genetically programmed suppressed development the expression of which may be controlled by environmental factors. These two types of arrested development are referred to as a state of dormancy. The spectrum of dormancy depends upon the nature and extent of deviation of environmental factors from the optimum and dormancy may intervene at embryonic, larval, pupal or adult reproductive stages of the insect's life cycle. Dormancy depends upon the nature and complexity of physiological, biochemical and endocrinological adjustments in the dormant individuals and it may result into retardation of growth or its arrest. Most instances of dormancy in nature are the result of temperature variations associated with weather or climatic changes. These can be divided into two well known groups, “hibernation” and “aestivation” All other instances of dormancy which are induced by factors other than temperature should be grouped together and called “athermopause”. (Arora and Gupta; 1979; Barua, et al., 2000; Geist and Lambin 2002; Jolly et al., 1969; Jolly, et al., 1976; Jolly et al., 1968; Jolly, et al., 1979; Kakati and Chutia, 2009. Kar, et al.,2010; Kushwaha and Roy 2002; Reeta et al., 2016; Sahu 2005; Sinha et al., 2017; Singh, et al., 2005.; Singh & Chakravorty, 2006; Singh, et al., 2005. Singh and Maheswari, 2003; Suryanarayana and Srivastava 2005; Thangavelu 1991). The most important factor for diapause induction is the photoperiod, although, several other factors such as temperature, type of food, available moisture, the parental age, and intra-specific relations like crowding are known to modify the photoperiodic effects. Temperature interacts with photoperiod and in long-day insects the critical day length, below which diapause occurs, is often lower at lower temperatures. Ecoclines of *A. mylitta* show different voltinism at different locations and latitude. Their behaviour changes with changed agro-climatic conditions. Particular photoperiod and thermo-period have been found to determine diapause behaviour of *A. mylitta*. The intensity of light during the photoperiod is not important provided that it exceeds a very low threshold value. This varies with the species, but commonly is about 1.0 f. candle or less. Hence, daily fluctuations in...
light intensity due to clouds have no effect on photoperiod and the effective day length includes the period of twilight. As a result of this high sensitivity, insects in fruit and even the pupa of *Antheraea* inside its cocoons are affected by photoperiod. In general high temperature suppresses and low temperature enhances tendency to diapause. Effect of temperature and photoperiod interact. Short-day length is dominant and induces diapause irrespective of temperature unless the photoperiod is very high. With long photoperiod temperature is dominant, low temperature inducing diapause and high temperature preventing it. There is evidence that the amount or quality of food can influence diapause. Starvation or feeding on senescent leaves induce diapause in adults even in long days. In many cases diet is apparent, only when the day length is close to the critical photoperiod. In Lepidoptera great increase in haemocytes is responsible for the rise in oxygen consumption. Whatever the injury factor may be, it certainly evokes a generalized metabolic response; for injury to one member of a pair of pupal joined in parabiosis, will induce a high rate of injury metabolism in the other pupa.

**Circulatory system:**

The circulatory system of tasar silkworm *A. mylitta* is open and simple type consisting of a single closed dorsal vessel. The body cavity is of two-fold origin which is formed during the embryonic development by the fusion of the lumen of the coelom sacs and haemolymph remains in it. Majority of organs like epidermis, tracheal system, digestive system, reproductive system, excretory system and other tissues are in direct touch with circulatory system and other tissues are in direct touch with circulatory haemolymph (Fig.1-17). Circulatory system comprises dorsal blood vessel, heart chambers and coelom. In the larva of tasar silkworm *A. mylitta*, the dorsal blood vessel is more or less a straight tube which runs from cephalic region to posterior abdominal cavity. It is anteriorly differentiated into the form of aorta after the second thoracic segment and posteriorly in the form of heart. The dorsal blood vessel runs along the median dorsal line just beneath the integument and dorsal diaphragm protects it. The dorsal aorta opens into the cephalic extremity (Arora and Gupta; 1979; Barua, et al., 2000; Geist and Lambin 2002; Jolly et al., 1969; Jolly, et al., 1976; Jolly, et al., 1968; Jolly, et al., 1979; Kakati and Chutia, 2009. Kar, et al.,2010; Kushwaha and Roy 2002; Reeta et al., 2016; Sahu 2005; Sinha et al., 2017; Singh, et al., 2005; Singh & Chakravorty, 2006; Singh, et al., 2005; Singh and Maheswari, 2003; Suryanarayana and Srivastava 2005; Thangavelu 1991).

**Haemolymph (Blood) circulation mechanism:** In tasar silkworm *A. mylitta* the blood flows backwards through the body cavity. The blood or haemolymph enters into the heart to a least extent by the lateral ostia of the first abdominal segment. Major proportion of the blood enters into the heart by abdominal segments VII and VIII. When the heart is full of haemolymph received through lateral ostia through wavy motion which starts from posterior region towards anteriorly, the heart is contracted and, through aorta, the blood is discharged anteriorly in cephalic region of body cavity. This discharge process of haemolymph creates a differential pressure at the anterior region of haemocoel and thus the created pressure facilitates the flow of the blood in the haemocoel from anterior to posterior region. The activities of the heart and haemolymph flow take place into a cyclic order viz. contraction or systole; relaxation or diastole and rest or diastases. Sometimes, after diastases or diastolic rest, a sudden phase of dilation is noticed before a new systole which is said to be “pre-systolic notch”.

**Composition of haemolymph:** Blood or haemolymph has two major parts: plasma and haemocytes. Plasma is also known as haemolymph plasma and the haemocytes are also known as haemolymph cells. The colour of the haemolymph of *A. mylitta* is yellowish-green which varies slightly based on instar, life stages and food plants.

**Haemolymph Plasma and their function:** The major portion of the plasma is water (around 85%), slightly acidic (6.5 to 6.9) and it contains inorganic ions, amino acids, proteins, fats, organic acids, sugars, vitamins, enzymes, waste products, food materials, pigments, respiration proteins and other substances in varying quantity. The major and minor content of haemolymph varies vaguely based on instar, life stages and their food plants. Key functions of the plasma are following:

- Various nutritive materials are carried from the digestive system to the storage tissues or to the site of metabolism.
- Excretory products are transported from the site of their origin to the excretory organs.
- It transports the hormones from the site of secretion to the site of action.
- It acts as storage for some energy viz., trehalose, and storage protein etc.

**Haemolymph cells or haemocytes and their types:** The haemocytes or haemolymph cells are the blood cells of the insects which are suspended particles float along the flow of plasma. These haemocytes are mesodermal in origin. The rate of mitosis, total haemocyte count (THC) and differential haemocyte count (DHC) vary along with the stage, age and instars of tasar silkworm. (Fig.1-3). Different types of haemocytes have been reported in tasar silkworm, *A. mylitta*. These are Prohaemocytes, Plasmatocytes, Granulocytes, Spherulocytes and Oenocytoids (Sharan, 2005; Singh et al., 2012). The number of the haemocyte also varies under stress conditions like disease, temperature etc. It was the year 1758 when Schwammerdam for the first time described insect blood cells (hemocytes) as transport globules. Although, in last 250 years, lot of research work has been conducted on hemocytes but many of the aspects like categorization of plasmatocyte variants are explored very little. It is reported that cellular immunity of insect involves different types of hemocytes (Mishra et al., 2015; Kiuchi et al., 2008; Charroux and Royet 2009; Rathesh et al., 2015) and PLs is one of the main hemocyte type which is found in almost all insects with 20-70% of total cell population [Baishya et al., 2019; Pampigione and Gupta 1998; Pandey and Tiwari 2012]. These cells (PLs) participate in many functions during post-embryonic development (Kiuchi et al., 2008; Clark et al., 2005; Srikanth et al., 2011). Generally for
haemocyte count, the Neubauer ruling haemocytometer used for total hemocyte count (THC) experiment. In this procedure, the hemolymph collected from larvae into a thoma blood-cell pipette up to its 0.5 mark and diluted up to the 11th mark with Tauber-Yeager’s fluid (Tauber and Yeager 1935). The pipette used to then shaken for 5-8 minutes and the first three drops were discarded. A double line with improved Neubauer ruling haemocytometer filled with diluted hemolymph and the circulating hemocytes per cubic millimeter (mm3) can be calculated according to Jones (1962) with slight modification.

Almost all animal species interact with environment and microorganisms during their subsistence. Cellular and humoral immunity of insects are the main factors for their huge survival in all territories of the earth (Akai 1969; Beaulaton 1979; Sujatha and Dutta-Gupta 1991; Wago 1991; Neven2000; Figueiredo et al., 2006; Contreras and Bradley2010;Lalouette et al., 2011; Catalan et al., 2012; Baishya et al., 2015; Mishra et al., 2015). Cellular immunity of insect consists of different types of blood cells “hemocytes” (Mishra et al., 2015; Kiuchi et al. 2008 Charroux and Royet (2009) Ratheesh et al., 2015). The plasmatocyte is one of the main hemocyte type which is found in almost all insects with 20-70% of total cell population (Akai 1969; Beaulaton 1979; Sujatha and Dutta-Gupta 1991; Wago 1991; Pampiglione and Gupta 1998; Pandey and Tiwari 2012). These cells (PLs) participate in many functions during post-embryonic development (Charroux and Royet 2009; Clark et al., 2005; Srikanth et al., 2011). PLs are thought to work as a surveillance system detecting cuticle wounds and infections in the hemolymph. The plasmatocytes (PLs) are referred to as immunocytes (Pampiglione and Gupta 1998; Pandey and Tiwari 2012) as they are principally responsible for immunological functions (Charroux and Royet 2009; Clark et al., 2005; Srikanth et al., 2011) against foreign materials/invading organisms. Although, few variants of PLs i.e. vermicytes (VEs) and podocytes (POs) have been observed in the specific stages of insect but their association in cellular immune responses under various stress conditions has not been documented well. Most popular stain for the staining is Giemsa and Gention violet. Various types of the cells are reported in tasar silkworm: They are prohemocytes (PRs), plasmatocytes (PLs), granulocytes (GRs), spherulocytes (SPs), oenocytoids (OEs) and adipocytes (ADs). Besides, vermicytes (Ves) and podocytes (POs) were occasionally observed in smears of moulting phase of late fifth instar larvae (Pandey et al., 2017).

Prohaemocytes (PRs): Prohaemocytes are usually round in shape and relatively smaller than the other haemolymph cells. PRs are typically sphere-shaped with a large centrally located nucleus leaving only a small peripheral cytoplasmic area. These cells bear a distinct central nucleolus and are frequently seen in mitotic divisions. They are characterised by light purple staining of cytoplasm by stain and comparatively bigger spherical nucleus.

![Fig. 1 Pictorial categorization of various types of hemocytes found in hemolymph smear tropical tasar silkworm Antheraea mylitta](image1)

![Fig. 2 Showing different types of hemocytes found in tropical tasar silkworm Antheraea mylitta hemolymph smear](image2)
Plasmatocytes (PLs): PLs are polymorphic cells, fusiform, spindle shaped. Some times PLs are round to elliptical in shape. Seven PLs variants were observed by some investigator (Pandey et al., 2017). These cells are with a relatively smaller central or eccentric nucleus. They possessed one or two small cytoplasmic prolongations, the pseudopods. Interestingly, these cells exhibited mitotic figures occasionally.

Granulocytes: GRs are usually rounded with small central nucleus. Their cytoplasm is characteristically filled with sparsely scattered small sized dense granules. Granulocytes were recognised as spherical or oval shaped haemocytes, which varied considerably in size. The cytoplasm had numerous vacuolar bodies distributed around the nucleus. Densely dispersed cytoplasmic inclusions/granules clearly distinguish these haemocytes from other types.

Spherulocytes (SPs): SPs are filled with many spherules. Spherulocytes were round to oval in shape. The shape of the nucleus was irregular.

Adipohaemocytes (ADs): ADs are large, roughly rounded cells with a relatively small spherical or slightly elongated nucleus placed eccentrically. A number of fat globules in the form of vacuoles were observed in cytoplasm of these cells.

Oenocytoids (OEs): OEs are spherical or oval relatively large, widely variable sizes possessing small rounded peripheral nucleus. Their cytoplasm is found generally thick and homogeneous. Oenocytoid cells are characterised by their spherical or ellipsoidal shape, large amount of cytoplasm and small nuclei. The nucleus is comparatively smaller and spherical. Under phase contrast microscope, their spherical shape, relatively large amount of cytoplasm and small nuclei can be observed.

Functions of haemocytes: Haemocytes are having many functions like phagocytosis, encapsulation, secretion and metabolism, wound healing, injury repairing, connective tissue formation, transport of nutrient and hormones, storage of proteins etc. Some of the key functions are enlisted:

Phagocytosis: As a defence mechanism, foreign particles, microorganisms are engulfed through phagocytosis by the haemocytes up to some extent. Plasmatocytes and granulocytes play an important role in phagocytosis. Generally, phagocytosed material either digested in the cell or further encapsulated with aggregation of several haemocytes.

Encapsulation: In this process, foreign particles in the haemolymph capsulated with congregation of several haemocytes around the parasite. Gradually this formed capsule becomes two layered. The outer layer is of living haemocytes which return to the blood. The inner layer haemocytes fuse and form an opaque capsule with dead parasite and connected tissue. This inner capsule remains as such is dead tissue in the insect’s body till rest of the life of the pest.

Secretion and metabolism: Haemocytes are involved in formation of connective tissue. First they congregate beneath the epidermis and polysaccharides presenting them are secreted to form the
membrane. Similar cells also form sheath around muscle fibre. They also attached to prothoracic gland during critical period and activate it for release of ecdysone. They are also involved in formation of fat body and transfer of nutritional material in other parts of the body. At the time of need, haemocytes break themselves and provide nutrients as per need.

**Wound healing and coagulation:** At the time of injury damaged tissues are phagotysed by the haemocytes and Plasmatocytes attach with other tissues with their protoplasmic process and form a network of cells.

Respiratory system

Respiration in tasar silkworm is very complex process. It is documented that, the tasar silkworm, *A. mylitta* breathes by the tracheal tubes which usually open at the surface of the body through a number of spiracles, and convey air directly to the tissues. In general, respiration of *A. mylitta* includes diverse chemical and physical processes collectively (Mishra et al., 2008). The chemical process involves oxidation or metabolic processes in the body tissues resulting into formation of carbon dioxide and water. Interestingly, the physical process involves carrying out the oxygen to deferent body parts/cells and removal of carbon dioxide. Arora and Gupta; 1979; Barua, et al., 2000; Geist and Lambin 2002; Jolly et al., 1969; Jolly, et al., 1976; Jolly, et al., 1968; Jolly, et al., 1979; Kakati and Chutia, 2009. Kar, et al., 2010; Kushwaha and Roy 2002; Reeta et al., 2016; Sahu 2005; Sinha et al., 2017; Singh, et al., 2005; Singh & Chakravorty, 2006; Singh, et al., 2005. Singh and Maheswaran, 2003; Suryanarayana and Srivastava 2005; Thangavelu 1991; Mishra et al., 2008). Respiratory system is mainly formed by the tracheae, air sacs, tracheoles and exterior openings through spiracles. (Fig.1-17).

**Tracheae:** Tracheae is very crucial part of respiratory system. It is ectoderm-envaginations and lined by a cuticular intima which is continuous with the rest of the cuticle of insect. In this a spiral thickening of the cuticular intima runs along each tube and each ring of the spiral being called a taenidium. These taenidia stop collapsing of tracheae due to pressure. This is important to note that the intima is a cuticulin layer with wax on the surface living the lumens chitin layer and protein on the outside in which the chitin cells. Moreover the, luminar layer are axially oriented in the taenidia and they are parallel in between the taenidia and serve in prevention of over-extension of tracheae in lucid mode (Mishra et al., 2008).

**Air sacs:** The air sacs are also very crucial part of respiratory system. It is reported that trachea are over-expanded at several places to form air sacs. These air sacs are filled with air and are collapsible and help in ventilation of the trachea (Mishra et al., 2008). Taenidia are poorly developed or absent and irregularly arranged.

**Tracheoles:** Tracheoles play essential role in respiration. The tracheae give rise to finer tubes which are known as the tracheoles. When the trachea is reduced by repeated branching to a variable diameter, it enters a large stellate cell, the tracheal end cells or transition cell and these break up into a number of tracheal capillaries or tracheoles. These are less than 1 fm in thickness and are devoid of spiral folds as seen with light microscope (Mishra et al., 2008).

**Spiracles:** The tracheal system opens exteriorly through spiracles. In *A. mylitta* 9 spiracles reported: one meso-thoracic and eight abdominal and known as peripneustic. In *A. mylitta* pupae 7 pairs of abdominal spiracles are distinctly visible (Mishra et al., 2008). The spiracles of *A. mylitta* larva are of typical Lepidoptera type.

**Tracheal system:** The tracheal system of *A. mylitta* larvae consists of a pair of longitudinal trunks extending along the body wall from the first thoracic to the last abdominal segments. The principal abdominal branches are given off from the longitudinal trunks surrounding the areas of the spiracles. It is reported that the tracheal system in *A. mylitta* is devoid of dorsal tracheal trunk like that of the highly developed groups of insects. These lateral longitudinal trunks are connected with the spiracles of the respective segment by a short spiracular trachea. The adult tracheal system is very similar to that of larva except that it communicates with the exterior by means of two pairs of thoracic and seven pairs of abdominal spiracles. The two main tracheal trunks and transverse tracheal branches re-branch to form a fine tracheal network (Mishra et al., 2008). The tracheal system of the *A. mylitta* connectively works in connective style. By process of diffusion of the gasses with in trachea respiration takes place through tracheal, branching to all parts of body. General mechanism of tracheal respiration: There are two distinct phases in the transport of gases, one through the tracheal system, known as air tube diffusion and other through the tissues in solution in the cytoplasm called tissue diffusion. By the process of diffusion of gases within the tracheae, respiration takes place through tracheal branching to all parts of the body. In insects partial ventilation of tracheal system takes place through movement of the body wall. Through diffusion oxygen passes through the tracheal system to the tissues and ultimately reaches to mitochondria where it is utilized in oxidative process. Similarly, carbon dioxide passes the reverse path.

**Ventilation:** In *A. mylitta* diffusion alone does not bring sufficient oxygen to the tissues to meet their requirements. It is expected that the oxygen uptake is supplemented by the convection or pressure produced by changes in the volume of the tracheal system. The collapsing of trachea forces out air of the tracheal system and its subsequent expansion sucks air in again. Such collapsing and expansion of tracheal system facilitates better gaseous exchange. During course of flight activity of insects the process of ventilation is faster.

**Pneumatisation:** Soon after ecysis, and in the embryonic insect, the tracheal system is filled with liquid, which is gradually replaced by gas. This replacement of water by gas is called pneumatisation. During the period of high energy consumption, the liquid is withdrawn from the system and air is drawn further into the tracheae.
Fig. 4 Showing the various larval instars of the tasar silkworm *A. mylitta* (A to C) First instar, (D) Second Instar, (E) Third instar, (F) Fourth instar, (G) Fifth instar.

Fig. 5 (A to D): Showing the various organs of V tasar larvae of tasar silkworm *A. mylitta*
Fig. 6 Showing the various organs of V tasar larvae of tasar silkworm *A. mylitta* A: Fifth instar larvae B: Dissected larvae C: Dissected gut of larvae.

Fig. 7 Showing the various organs of V tasar larvae of tasar silkworm *A. mylitta* A: Fifth instar larvae B: Dissected larvae showing ventral nerve cord C: Dissected larvae showing silk gland

Fig. 8 Showing the various organs of V tasar larvae of tasar silkworm *A. mylitta* A: Fifth instar larvae B: Dissected larvae showing silk gland C: Dissected larvae showing complete silk gland in details
Fig. 9 Showing the various organs of V tasar larvae of tasar silkworm *A. mylitta* A: Fifth instar larvae showing complete ventral nerve cord (VNC) BC&D Dissected larvae showing VNC ganglions

Fig. 10 Showing the pictorial simulation of various physiological organs of V tasar larvae of tasar silkworm *A. mylitta* under infection of pebrine disease. A: Fifth instar larvae; B& C Pictorial simulation of gut physiology under infection of pebrine disease.

Fig. 11 Showing the impact of pebrine disease on fat body and gut-morphology. A& B: Fat body and gut-morphology of control/uninfected V instar larvae C& D Fat body and gut-morphology of pebrine infected V instar larvae.
Fig. 12: Showing the pictorial presentation of various major physio-morphological, reproductive measures during larva-pre-pupa- pupa-adult metamorphosis of tasar silkworm *A. mylitta* A.V instar larvae, B. Prepupa, C. Various stage of pupation D. Cocoons. E. Emergence F. Coupling G. Male larva H Female larvae

Fig. 13: Showing temporal changed inside the *A. mylitta* eggs during embryonic development: (A) Dissected eggs section, (B). Zero day old eggs, (C.). 1 day old eggs D. 2 day old eggs E. 3 day old eggs, F. 4 day old eggs G. 5 day old eggs (H). 6 day old eggs (I) 7 day old eggs.
REPRODUCTIVE SYSTEM

Tasar silkworm *A. mylitta* reproductive system is a composite organ which can be divided into three parts: internal organs of mesodermal in origin, evaginations of body wall known as ectodermal in origin and comprise exit apparatus and external appendicular structures. Morphological structure of male and female reproductive organs of *A. mylitta* has been reported by various researchers (Anonymous, 1975; Dubey et al., 1992; Jolly et al., 1974; Ravikumar et al., 1993) in details: Arora and Gupta; 1979; Barua, et al., 2000; Geist and Lambin 2002; Jolly et al., 1969; Jolly, et al., 1976; Jolly, et al., 1968; Jolly, et al.,1979; Kakati and Chutia, 2009. Kar, et al.,2010; Kushwaha and Roy 2002; Reeta et al., 2016; Sahu 2005; Sinha et al., 2017; Singh, et al., 2005; Singh & Chakravorty, 2006; Singh, et al., 2005. Singh and Maheswari, 2003; Suryanarayana and Srivastava 2005; Thangavelu 1991). (Fig.1-17).

Reproductive organs of female insect: It is reported that the development of reproductive organs starts during the late larval instars. Differentiation of ovariole starts in pre-pupal stage. Yolk deposition and chorion formation take place in later stages of pupal development. Cellular differentiation is not observed in day zero fifth instar larvae.Ovary has four small ovarioles and looks triangular in the late fifth instar larvae lying dorsally inside the 5th abdominal segment. Transparent larval primordial ovary is encapsulated in a peritoneal sheath. It encloses a few tightly packed germ cells. The size of ovary increases by 40 times during differentiation. Complete maturation of ovary takes place within 20-21 days in non-diapausing and 205-220 days diapausing generations. Temperature affects the maturation of eggs severely. On the ventral surface of the female larva two pairs of translucent spots are found, one pair of each on 8th and 9th segments. These spots are prominent in the fifth instar and reported as Ishiwatas glands. The female reproductive system in adult A. *mylitta* consists of a pair ovarioles which are poly...
trophic. Each ovariole contains a chain of developing ova. Each ovariole has four prominent parts: 1. Terminal filament: It is thread-like continuation of the connective tissue layer. Terminal filaments of all the ovarioles are united and connected to the body wall in the abdominal cavity. 2. Germarium: Just behind the terminal filament the germarium is present, which consists of the closely packed cells. From the germarium cells, the oogonia or primordial germ cells and nutritive nurse cells differentiate. 3. Vitellarium: It is the major part of the ovariole and it has a series of developing oocytes. Each oocyte is enclosed in an epithelial sac called follicle. Distally these oocytes become chorionated and are known as chorionated mature oocytes. 4. Ovariole stalks: A thin walled tube leading to the oviduct from each ovariole is known as stalk or peduncle.

**Male reproductive system:** It is important to note that the development of reproductive organs initiates during the late larval instars of tasar silkworm. In late V instar larvae of male *A. mylitta*, a pair of testes is lodged dorsally in the 5th abdominal segment and a blind tube terminating between the 8th and 9th abdominal segments where it connects with the ‘Herald’s gland’. The small sized rudimentary paired testes are visible in mature fifth instar larva, which is covered with fat body. Among male pupae, the testes consist of a pair of blind tubes, which is connected with the Herald’s gland located between 8th and 9th abdominal segments. A fine thread like band originates from the concave surface of the testes of larvae which is gradually transformed into vas deferens. Male reproductive system in adult remains embedded in fat body which can be observed in the dorso-lateral abdominal cavity in the 6th abdominal segment in its posterior region. The testes are paired, cream coloured and each testis has four follicular lobes fused at their bases. The four follices in *A. mylitta* are with this in a connective tissue sheath and follicle has different cones in succession where sex cells are in different stages of development. The different zones of a testicular follicle generally recorded in insects are: The germarium, zone of spermatocytes, Zone of maturation and reduction, Transformation zone. The spermatids, enclosed in their cyst, transform into spermatozoa which are flagellated. In *A. mylitta* during pharate adult development, sperms from testis along with secretion from accessory glands and seminal vesicles constitute the semen. The number of sperms in normally and erratically emerged moths has been recorded to be 6.80 and 5.77 millions, respectively. The pH of undiluted semen is 6.9 to 7.0. Both types of spermatozoa are non-motile in the seminal vesicles and become motile after 10-15 minutes. The loose spermatozoa of both the types move to spermatheca and are stored. In the spermatheca the movement of apyrene sperms recedes shortly, whereas the eupyrene sperms remain active in spermatheca till 7-8 days. With experimentation in *A. mylitta* it has been confirmed that both the spermatozoa are motionless in the male reproductive tract but they become motile when they pass through ejaculatory duct because of some secretion from the ejaculatory duct. Each testis is posteriorly connected with a paired tubular vas deferentia, previously designated as vesicular seminis ending in an enlarged sac like seminal vesicles. These seminal vesicles secrete seminal fluids. With each seminal vesicle one accessory gland is attached. The glands are tubular in structure and open into the distal end of seminal vesicle. These glands lie blindly in the haemocoel. Accessory glands produce secretion that is known to enhance the fecundity in insects. The proximal ends of seminal vesicles unite to form a common ejaculatory duct and it proceeds downwardly and ends in aedeagus, which is lined with cuticle. In most insects, matured spermatozoa have already left the testis at the time of emergence from the pupa.

**Fig. 15:** Male Reproductive system of *A. mylitta*  
*Courtesy: Mishra et al., (2008)*

**Fig. 16:** Female reproductive organ of *A. mylitta*  
*Courtesy: Mishra et al., (2008).*
Organ of copulation and oviposition: The organs of copulation and oviposition are present on the ventral surface of the posterior part of the abdomen. These organs surround the male and female genital opening. Organ of copulation or male genitalia is a complex structure and is made from the modified terga, pleura and sclerite of seventh to tenth abdominal segments. The 7th and 8th abdominal segments modified to form the base for copulatory organs. The 9th and 10th abdominal segments are greatly modified in A. mylitta and are known as gonosomites. Ninth gonosomite also known as tegumen is a narrow ring like and encircles the apex of body. On this ring or its periphery the peripheral genital processes are attached. The 9th sternum or vinculum is usually invaginated interiorly into 8th abdominal sternite and forms a median saccus. A pair of valves or claspers (harpens of pierce) is hinged to the 9th sternum and these claspers are the most prominent part of the genitalia. Medially, from both sides of harpens accessory harps are present, which project posteriorly. There is a median ventral sclerite or gnathus which is attached to the uncus on its base. Te uncus is hood like posterior projection from the 9th terga. Its gnathus and uncus are the modified sternum and tergum of the 10th abdominal segment. The gnathus lies vertically and its tips are serrated and rudimentary. Opening of the anus is present just beneath the uncus and between the sclerite and the gnathus. Thus formed encircled structure/cavity is also known as genital pouch. The actual copulatory organs or phallus or the penis is at the base of the genital pouch. The actual copulatory organs or phallus or the penis is at the base of the genital pouch. The phallobase is a mere reflection of the genital chamber forming a wall called phallocrypt. The phallocrypt contains the base of aedeagus. The phallobase is produced posteriorly as tubular plate called phallotheca. The opening of the phallobase is encircled by a sclerotic ring, called anellus. From this ring the aedeagus protrudes anteriorly. The aedeagus, behind the phallotheca, is slightly thickened tubule called cornua and more anteriorly it is known as apodem. Two pairs of muscular bands are attached with apodem and cornua. The cornua contains a middorsal aperture through which ejaculatory ducts joins the aedeagus.

Oogenesis or oviposition: In case of A. mylitta the female oviposition organs are made from the modified posterior 7th to 10th abdominal segments which can be protracted the form of a slender telescopic tube. The base of the external genitalia of the female is formed by the 7th abdominal segment. Eighth abdominal segment is transformed into a sclerotic ring. The opening of the ductus bursa is situated on the sternal part of the 8th abdominal segment. The tergum of the 8th abdominal segment is anteriorly projected up to 7th abdominal segment in the form of two sclerite rods called valvifers (1st pair). The 9th abdominal segment is transformed into protractile and retractile in nature. The 9th sternum is triangular which bears aedeagus. A pair of gonopophysis or ovipositor valves. Another triangular sclerite is present on the posterior region of both of the 9th pleurite which also bears a sclerotic rod (2nd pair of valvifers) which projects anteriorly up to 7th abdominal segment and form the protractor and retractor apparatus for oviposition. The 10th abdominal segment is represented by two terminal lobes. These lobes are attached at their bases with the 9th abdominal segments. They are present at the sides of egg exit and serve to grasp the issuing eggs. When they are spread they look like a disc and press the eggs against a surface where they are cemented with the secretion of colletenal glands. The egg laying opening is on the base of the 10th abdominal segment.

Chorion formation and discharge of the eggs: In any type of ovariole present in insects the mouth of the egg tube is generally
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formed in tasar silkworm nucleated (apyrene) and nucleated (eupyrene) spermatozoa are of nuclear material helps in motility of spermatozoa. The non-water and chromosomes are condensed. This reduction in weight spermiogenesis in Lepidoptera the nucleus gradually releases its

The spermatids are haploid cells containing nucleus, cytoplasm, and Srivastava 2005; Thangavelu 1991). Other than malpighian tubules, various organs or tissues also involved to eliminate excretory substances in insects are: integument, respiratory organ, gut-wall, nephrocytes etc. (Fig.1-17).

Mechanism of excretion by the Malpighian tubules: The mechanism of excretion by the Malpighian tubules is a complex process. The ampulae and the basal end of Malpighian tubules contain muscle fibers which are arranged in circular and longitudinal forms and they are continuous with the muscular sheath of intestine. Peristaltic movement, which takes place in the muscular part of Malpighian tubules, creates a wavy movement along the whole tract of Malpighian tubules. Such movement facilitates movement of absorbed excretory product in the lumen. It is reported that A. mylitta the muscular basal portion of Malpighian tubules may be responsible for its peristaltic movement. Such movement of Malpighian tubules may help in proper functioning of these tubules in the excretory processes. A crypto-nephridial arrangement of Malpighian tubules in A. mylitta is like that of a typical lepidopteran larvae and in this case Malpighian tubules come into intimate relationship with the hindgut. These tubules surround the segment of hind gut and play a crucial role in absorbing all the harmful substances before the fluid passes into body cavity as is evidenced in other insect. This also enhances the water absorbing capacity of gut wall from excreta. In the lumen of Malpighian tubules active movement of potassium is linked with the passing of uric acid in the Malpighian tubules, particularly, the distal part of tubules having honey comb border type of cells. In insects in more proximal part, water and salts are reabsorbed while uric acids or urates may precipitate out to some extent. The separation of uratic spheres is accompanied by a change in pH from weak alkaline to weak acidic. It has been reported that a continuous flow of water through the Malpighian tubules helps in carrying over the nitrogenous waste to rectum. This movement of water is dependent on the movement of active potassium chloride in tubules which creates active ingredient. This facilitates absorption of water and is directly linked with the concentration of potassium in haemolymph. The excretion process of A. mylitta is slightly different from other non-sericigenous insects.

EXCRETORY SYSTEM

In A. mylitta excretory system is mainly involved in maintenance of constant internal environment for body tissue. This system helps in elimination of waste nitrogenous materials accumulated after break down of protein molecules and also in controlling the ionic composition of haemolymph. In larvae, pupae and adults

enclosed/ plugged by follicular epithelial cells. The last oocyte is thus completely enclosed by follicular chamber and is not prematurely liberated to oviduct. When egg is fully formed the epithelial cells secrete a substance of nonchitinuous nature which adheres upon the egg surface and is of hard nature. The surface of eggs retains the mark of those cells, which released the substance. These marks are known as follicular imprints. A place is left on the upper end without these markings and it becomes the micropyle of the egg. At the time of egg laying the epithelial plug of the ovary is degenerated and egg slips into lumen of the pedicel of ovariole and through oviduct and before reaching to exterior near the mouth of spermathecal duct a small mass of spermatozoa is discharged upon the micropyle area of the egg and thereafter it leaves the oviduct.

Next oocyte is ready for deposition. At this time vacant chamber of first oocyte in ovariole degenerates and are absorbed. The mass of degenerating cells is called corpus luteum. With the gradual deposition of eggs ovariole shortens posteriorly and anteriorly new oocyte are gradually formed in their various stages of development.

Oogenesis and fertilization: In the lower portion of the ovariole oocyte is placed towards the lower and with the oocyte. The oocyte continues to grow and later becomes the egg. Ultimately nurse cells degenerate completely, the follicular cells envelope the developing egg and supply nutrients to it. When eggs are laid the reduction division m the eggs is not complete. Until 1 to 2 hours of oviposition the eggs are flooded with sperms in bursa copulatrix, particularly on their mycropyolyr region. When the sperm head penetrates the egg through it’s micropyke and stays in mycropyler region until maturation division of the oocyte is completed. The three nuclei thus formed are gradually released and one haploid nuclei remains in the ovum. The head of the sperm splits and the two gametes unite thus fertilization process is over. More than one spermatozoan may enter the ovum but only one takes part in the fertilization process, rest degenerate. After fusion of the two nuclei the zygote is formed.

Spermiogenesis: The process of transformation or differentiation of the spermatids into spermatozoa is called spermiogenesis. The spermatids are haploid cells containing nucleus, cytoplasm, mitochondria, centrioles and Golgi bodies. During course of spermiogenesis in Lepidoptera the nucleus gradually releases its water and chromosomes are condensed. This reduction in weight of nuclear material helps in motility of spermatozoo. The non-nucleated (apyrene) and nucleated (eupyrene) spermatozoa are formed in tasar silkworm A. mylitta. These apyrene spermatozoa are free swimming initially whereas eupyrene remain in bundle. A nucleated sperm consists of a long filamentous body with an acrosome followed by the chromatic head, axial filament, sheath substance and the tail. There is one nutritive cell near the head.
NERVOUS SYSTEM

The nervous system is composed of ramified neurological cells with supporting and nutritive functions and with numerous neurons which are specialized for rapid generation of electro-chemical process. (Arora and Gupta; 1979; Barua, et al., 2000; Geist and Lambin 2002; Jolly et al., 1969; Jolly, et al., 1976; Jolly, et al., 1968; Jolly, et al., 1979; Kakati and Chutia, 2009. Kar, et al.,2010; Kushwaha and Roy 2002; Reeta et al., 2016; Sahu 2005; Sinha et al., 2017; Singh, et al., 2005; Singh & Chakravorty, 2006; Singh, et al., 2005. Singh and Maheswari, 2003; Suryanarayana andSrivastava 2005; Thangavelu 1991). It is reported that the basic unit of nervous system is neuron. These neurons are ecto-dermal in origin. The neuron has a nucleated cell body and long cytoplasmic processes which make connection with other neurons. The nucleated cell body is commonly known as perikaryon or soma. Cytoplasmic processes or projections which are long filament types are called axons. These axons have a collateral branch near its origin. The axon and its collateral branches have several fine branching known as ‘terminal arborisation’. Numerous cytoplasmic filaments smaller in size arises from the main Perikaryon. The smaller protoplasmic filaments are called dendrites. These neurons and their bundles of axon filament when run freely through the body are called nerves (Wigglesworth, 1973). The set of neurons are generally unipolar with only one axon, while some are bipolar with a long axon and short distal dendrites (especially peripheral sense cells). Distal dendrites in bipolar neurons receive environmental signals and long axonal process sends the signal to the connected central ganglion. The neurons present in frontal ganglion and hypocerebral region are multipolar in nature and are associated with stretch receptors. (Mishra et al., 2008). Neurons are also of three types 1. Sensory neurons: The cell body of these neurons is bipolar and their perikaryon is situated near periphery of the body. The short axonal process receives the stimuli from the peripheral organ and sends it to the central region of nervous system. 2. Motor neurons: Motor neurons are the unit of central nervous system. They are made of a long pyriform cell body and are unipolar in nature. They do not have dendrites and are present in the periphery of ganglia and with the help of a stalk they attach with neuropile. Terminal arborisation is connected with the sensory neurons. 3. Association neurons: The association neurons are present in the outer parts of ganglia. They have massed nuclei full of chromatin. The massed nuclei form the globule of the outer layers of ganglia. (Fig.1-17).

The nervous system of tasar silkworm A. mylitta may be divided into three parts: central nervous system, visceral nervous system peripheral nervous system are connected together (Jolly et al., 1973; Mishra et al., 2008).

1. Central nervous system: This is very crucial part of nervous system. The central nervous system includes of the supra-oesophageal ganglion or brain, the sub-oesophageal ganglion and the ventral nerve cord. Generally the insect brain comprises of three parts which are fused into a single mass. The first part is called proto-cerebrum and it represents the optic segment and innervates the ocelli and compound eyes. Larval brain of A. mylitta it forms the prominent part of brain. The second part is deuto-cerebrum and it is connected with antennary segment. The third part is tri-tiocerebrum, which is composed mainly of fibres and synapses between the brain, sub-oesophageal ganglion and frontal ganglion connectives. Two connectives arise from the deuto-cerebrum in the larval stage of A. mylitta, which connects posteriorly with the sub-oesophageal ganglion. It is called as circum oesophageal connective and the labro-frontal nerves. Labro-frontal nerves have two bundles of fibres, one unites with frontal ganglion and the bundles innervate the labrum (Mishra et al., 2008). In the larval stage of A. mylitta sub-oesophageal ganglion is attached with brain with the help of circum oesophageal connective through which the oesophagus passes. In case of adults the brain and sub-oesophageal ganglion are fused together and is pierced by the oesophagus. In insects sub-oesophageal ganglion is made after fusion of the mandibular, maxillae and labial ganglia and is located ventrally. In case of larval A. mylitta, it supplies nerves to the mandibles, maxillae, hypopharynx, labium, silk glands etc. Ventral nerve cord of A. mylitta larva is made of three thoracic (pro, meso and meta) and eight abdominal ganglia. All the ganglia are placed anteriorly in their respective segments. The 8th abdominal ganglion is placed more anteriorly and lies very close to the 7th abdominal ganglion. The thoracic ganglia are inter-connected with each other by a pair of mere connective or bifurcated nerve cord. In between the two main bifurcation of ventral nerve connectives, median nerves originate. Each thoracic ganglion gives of two pairs of thoracic nerves which go to their respective appendages and other goes to general musculature of the segment. Similarly each abdominal ganglion sends a pair of principal nerves on each side and the last abdominal ganglion in the larva gives three pairs of nerves (Figure ). The shape of VNC ganglion are polygonal.

2. Visceral or sympathetic nervous system: The visceral or sympathetic nervous system is divided into oesophageal sympathetic, ventral sympathetic caudal sympathetic system.

3. Peripheral nervous system: The peripheral nervous system comprises those of the nerves which are radiating from the multi-polar and bi-polar neurons. In insects innervating neurons of different organs (alimentary canal, stretch receptors, integument with delicate plexus of nerve fibres and sensory neurons and plexus of nerve fibres on other organs) of body come under the peripheral nervous system of insect.

Physiology of nervous system: The physiology of nervous system in insects generally takes place in the form of electrical impulses, which are the transformed forms of any stimulus perceived by an insect. These electrical impulses travel along the axons to the central nervous system, cross synapses and through motor neurons guide the effector organ to action, which is usually a muscle. The stimulus may be mechanical, chemical or visual. The stimulus given at a receptor site causes depolarization of dendrites and a receptor potential envelops. Later, receptor potential leads to develop a generator potential. Generator potential is produced in perikaryon (Davis, 1961). In insects the production and conduction of a nerve impulse is similar to that of other animals. Nerve impulse involves...
following direct reactions: At the time of development of membrane potential the sodium ions are actively pumped out of the axon membrane and it leads to the entry of potassium ions from outside. Such outflux of sodium and influx of potassium creates a high concentration of chloride ion outside. As a result the inside of the axon wall becomes negatively charged and it results into production of a potential called membrane potential. Generally, membrane potential has a magnitude of 70 mV. The action or spike potential is of constant amplitude which is produced by the depolarization of the axon membrane with change in its permeability. At first instant sodium ions enter into the axon membrane increasing its concentration gradient and, due to rapid positive charge inside the axon membrane, 80-100 mV potential is produced. This is called rising phase of action potential. The spike potential has a resting phase, rising phase, a falling phase, a positive phase and a negative after-potential phase. Trough action potential, a wave of increased permeability or nerve impulse is propagated along the axonal fibre. Action potential produces a wave of nerve impulse, which, on reaching to the synapses of another neuron, facilitates transfer of nerve impulse from one axon to another with the help of chemical called neurotransmitters.

**Conclusions**

Present book chapter provided the much-pictorial information regarding the tasar silkworm, morphology, anatomy explain the physiology in simple approach. Morphology of various types of haemocytes and their defense mechanisms has been also mentioned in details. Understanding physiology of applied insect is very crucial, therefore, this chapter targets a wide viewers, tasar seri-culturist, biologists and entomologists including both teachers and students in gaining a better appreciation of this rapidly growing field of tasar silkworm physiology. This chapter is the compiled form of already exists literature (Mishra et al., 2008 (Fig.1-17),) and the recent advances on tasar insect physiology which some time shows dis-concertingly wide and variable. The general the established anatomy of *Antheraea mylitta* is also included in this chapter based on the similarity of earlier researchers reports which is intimately linked up with the interpretation of the functions of organs and parts. It is concluded that physiological ‘make-up’ of the tasar silkworm is very important and showed minor differences too. Now tasar physiology and endocrinology is linked to the post-genomic era. The genome projects, functional genomics and genetics which will be helping to unravel complex regulatory processes of physiology.

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Gynandromorphism in Tasar silkworm, 
Antheraea mylitta D

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Introduction

Tropical tasar silkworm, Antheraea mylitta Drury, is a polyphagous non-mulberry silkworm used for production of commercial silk and distributed in diversified ecological and geographical regions ranging from 12°N to 31°N lat. and 72°E to 96°E long. About 44 eco-races have been reported in tasar silkworm (Singh et al., 2014). Gynandromorphism is a rare phenomenon in both natural and laboratory environments (Scriber and Evans, 1988) and it has been reported from 69 families of insects, across 13 orders (Cui and Cui, 2003). Bilateral gynandromorphs are developmental aberrations in which an individual’s body is half male and half female, with cells on either side of the bilateral split containing alternate sex chromosome combinations (Narita et al., 2010). For example, in most bilateral gynandromorphic butterflies, one half of the body contains ZZ sex chromosomes (male) while the other half possesses ZW sex chromosomes (female). In addition, many individuals can develop as mosaic gynandromorphs, with only some portions of their bodies developing as the opposite sex. The study of both bilateral and mosaic individuals offers potential insights into the range of phenotypes that may be produced by developmental plasticity in genitalia development because individuals experience unusual genetic and hormonal environments (both male and female) at the genitalic midline compared with normal individuals. It is worth noting that hormones have only recently been thought to be important in insect sex-determination; however, gynandromorphs are considered as one of the best evidence for cell-autonomous (i.e., genetically predetermined) sex determination (Bear and Monteiro, 2013). The factors like temperature, ultraviolet light, viral infections, mutations, nuclear power plant disaster and interspecific hybrid crosses are associated with the development of such irregularities (Scriber et al., 2009; Obara and Tamazawa, 1982).

This chapter reports that a half- male, half female moth still express a female gynandromorph in semi-domesticated DABA trivoltine race. Male characters were observed both on dorsal and ventral surface of the body from the half of the abdomen towards right side along with wings bearing brown colour and half of the abdomen towards left side along with wings bearing grey colour (Figure 1a). The colour of the leg portion also indicated half-male and half-female with brown and grey colours respectively. The size of the legs was bigger in female part compared to male part (Figure 1b). The present type was similar to schizophrenic kind, in which male and female behaviors expressed concurrently in their respective body parts.

The bilateral gynandromorph moth possesses bipectinate antennae which are broad in male side and narrow in female side (Figure 2). The body length measures about 3.8 cm. The size of both forewing and hind wing, as well as the eyespots on the respective wings, are more prominent and broad in the female part than male part. The length and mid width expanse of forewing and hind wing of male side is 55.5 & 30.0 and 38.5 & 27.8 mm respectively. Similarly, the length and mid width expanse of forewing and hind wing of female side is 65.0 & 34.0 and 45.5 & 32.0 mm respectively.

Forewing is sub-triangular in both the male and female side. But, in female forewing, subcoastal region is not curved, apical margin not extended, apical angle is pointed and termen is almost straight. Whereas in male forewing, subcoastal region is curved, apical margin is extended forward and curved, apical angle is prominently curved and termen appears to be S-shaped (Rathore et al., 2018).

The copulation was seen between gynandromorph female with a normal male (Figure 3) and the fecundity pattern of gynandromorph female on different days was observed (Figure 4). Around 110 eggs was laid upto three days, 16 eggs on fourth day, 6 eggs on fifth day and 1 egg was laid on sixth day, out of which 88 eggs got hatched into larvae from the batch of 110 eggs. Interestingly, 14 eggs got hatched into larvae out of the 16 eggs laid on fourth day and 1 egg got hatched into larvae out of the 6 eggs laid on fifth day. The total hatching percentage was 77.44%. The hatched out larvae were reared in the field of CTR&T, Ranchi (Figure 5). The same moth was used for longevity studies showed survivability upto 10 days.

Dissection of gynandromorphic moth revealed that the genitalia was similar to the female reproductive system and female copulatory apparatus was present (Figure 6). Hence the normal male when mated with these gynandromorphic moths could able to reproduce and laid fertilized eggs. It was also observed that the fat content in the gynandromorph moth was more on male side compared to female side. Gynandromorphism being a rare phenomenon and gynandromorphic mutations help reveal the developmental processes that facilitate the evolution of new phenotypes in insects.
Figure 1: (a) Dorsal and (b) ventral view of gynandromorphous moth of *Antheraea mylitta*

Figure 2: Gynandromorphous moth of *Antheraea mylitta* showing male and female structure of antennae

Figure 3: Coupling between gynandromorphous moth and male moth of *Antheraea mylitta*

Figure 4: (a) Ovipositing gynandromorphous moth and (b) hatched larva from gynandromorphous moth laid eggs
Figure 5: Rearing of hatched out worms of gynandromorphous moth laid eggs under nylon net at CTR&TI, Ranchi

Figure 6: Genitalia of gynandromorphous moth of *Antheraea mylitta*

References:


INTRODUCTION

*Antheraea* is a moth genus belonging to the family Saturniidae. The genus was erected by Jacob Hübner in 1819. Several species of this genus produce wild silk of commercial importance. Commonly called "tussar silk", the moths are named tussar moths. Tropical tasar silkworm, *Antheraea mylitta* is one among *Antheraea* sp. exploited for commercial *vanya* silk production in the country and presently, about 3.5 lakh families are directly or indirectly associated with tasar culture. There is need for improved races/breeds in order to enhance tasar silk production and bring improvement in its quality. Therefore, genetic resources of tasar silkworm are dire need to be explored, catalogued, conserved and characterized for its commercial utilization by breeders and geneticists. Genetic variations in the natural population and diverse genes in the individuals of the populations of tasar silkworm are the prerequisites for evolving improved breeds/lines. Among the available ecoraces, only Daba and Sukinda are commercially exploited in seed sector as breeding material because they have been semi-domesticated. On the other hand, majority of ecoraces are wild in nature and least amenable to human interference. Among the ecoraces, Raily and Modal female moth lays eggs as high as 485 and silkworm can spin cocoons with very high silk content, sometimes even more than 1800 meter. This indicates that there is potentiality in tasar genetic resources to augment production and productivity, but to harness the potential appropriate scientific intervention is required. Tasar silkworm genetic resources need to be characterized and evaluated for crop improvement, enhancement of yield, quality, and breeding for specific traits like fecundity, fertility, hatchability, cocoon weight, shell weight etc.

A. BIO-DIVERSITY IN TASAR SILKWORM

Totally, 124 species belongs to *Antheraea* are distributed in various countries such as United States, Mexico, India, Bhutan, Cambodia, Russia, China, North Korea, Indonesia, Japan, Laos, Brunei, Timor, Taiwan, North Korea, Malaysia, Myanmar, Philippines, Sri Lanka, Thailand and Vietnam (Fig.1). Among 124 species, India comprised of thirteen species, *A. mylitta*, *A. frithi*, *A. assamensis*, *A. roylei*, *A. compta*, *A. helferi*, *A. rubicunda*, *A. paphia*, *A. andamana*, *A. insularis*, *A. cernyi*, *A. kryvettii* and *A. meisteri* (Table 1). Major production of tasar silk is from tropical tasar silkworm, *A. mylitta*. *A. mylitta* has a wide distribution within the country. In India the range of distribution of this species covers Assam,
Table 1: Distribution of *Antheraea* sp. in various countries

|---------|---------|-----------------|
| 1       | Indonesia | A. alorensis  
A. banggaiana  
A. billitonensis  
A. borneensis  
A. cadloui  
A. celebensis  
A. cihangiri  
A. cordifolia  
A. diehli  
A. expectata  
A. fickei  
A. frithi javanensis  
A. gschwandneri  
A. helferi  
A. hollowayi  
A. imperator  
A. jakli  
A. jana  
A. jana fusca  
A. jawabaratensis  
A. kageri  
A. kalabahiensis  
A. kalangensis  
A. kelimutuensis  
A. korintjiana  
A. lampei  
A. larissa  
A. loeffleri  
A. lugubris dempoensis  
A. mentawai  
A. acehensis  
A. minahassae  
A. moutoni  
A. pasteuri  
A. paukpelengensis  
A. paukstadtorum  
A. pelengensis  
A. pratti  
A. puncakensis  
A. raffrayi  
A. ranakaensis  
A. rolfei  
A. rosemariae  
A. rosieri  
A. rumphi  
A. rumphi buruensis  
A. rumphi celebensis  
A. rumphi ceramensis  
A. selayarensis |
| 2       | Brunei | A. alleni  
A. brunei |
| 3       | India | A. assamensis  
A. compta  
A. frithi  
A. helferi  
A. mylitta  
A. paphia  
A. rubicunda  
A. knyvetti  
A. roylei  
A. andamana  
A. cernyi  
A. insularis  
A. meisteri |
| 4       | Cambodia | A. angustomarginata |
| 5       | Malaysia | A. broschi  
A. pahangensis  
A. ulrichbroschi |
| 6       | Bhutan | A. castanea |
| 7       | Srilanka | A. cingalesa |
| 8       | China | A. crypta  
A. discata  
A. harnhti  
A. hart  
A. pernyi  
A. yamamai titan  
A. yunnanensis |
| 9       | Thailand | A. frithi pedunculata  
A. ranongensis  
A. semperi |
| 10      | Myanmar | A. myanmarensis paukstadt  
A. platessa  
A. steinkeorum |
| 11      | Japan | A. sergestus  
A. yamamai  
A. yamamai yoshimotoi |
| 12      | Taiwan | A. superba |
| 13      | North Korea | A. yamamai bergmanni |
Himachal Pradesh, Sikkim, Meghalaya, Manipur, Nagaland, West Bengal, Odisha, Bihar, Jharkhand, Chhattisgarh, Madhya Pradesh, Karnataka, Maharashtra, Rajasthan, Tamil Nadu, Pondicherry, Kerala, Uttar Pradesh, Jammu & Kashmir and Andhra Pradesh. It is represented in the continent by a great number of similar forms many of which were treated as distinct species though they are ecological populations of the same species (Singh and Srivastava, 1997). Since, *A. mylitta* is widely distributed over a wide range of Indian subcontinent of varied topography, climatic conditions, vegetation and soil conditions it exhibits diversity in the phenotypic, physio-genetic, behavioural and commercial characters (Sengupta and Sengupta 1982; Sengupta et al., 1993; Singh and Srivastava, 1997; Thangavelu et al., 2000; Srivastava et al., 2002 and 2003).

Due to deforestation and anthropogenic activities, there is a constant threat to tasar silkworm biodiversity. Besides, wild/natural populations are supposed to harbour many beneficial alleles developed through centuries by the process of natural adaptation. It should be our duty to conserve the available tasar silkworm genetic resources. Survey, collection, characterization and documentation of tasar silkworm genetic resources should be done in a systematic manner. Further, characterization of the available tasar silkworm genetic resources through molecular tools will not only support the conservation approach but also help in the sustainable utilization through breeding programme. The genetic structure, genetic relatedness, identity and gene flow are the important features of genetic resources need to be assessed.

Diversity in *A. mylitta* is the result of adaptation of a species to a variable eco factor and interaction of genetic constitution. So far, 44 ecoraces of tasar silkworm have been reported (Table 2). It can be seen from the table that maximum number of ecoraces are available in Jharkhand followed by Chhattisgarh. Odisha is also bestowed with six known ecoraces. The distribution of ecoraces in relation to forest types is given in Table-3. Diversity of *A. mylitta* in relation to primary and predominant food plants is presented in Table-4. Wide range of phenotypic variation is observed in nature grown cocoons (Fig. 2). It may be appropriate here to mention that since a long time proper survey and collection has not been done, so there is the chance that many of the ecoraces might have been extinct due to deforestation and habitat loss. On the other hand, tasar populations may also be available in new zones or ecopockets which need to be surveyed and documented because the natural populations are the treasure of genes and alleles developed through centuries through the process of natural evolution.

### Table 2. Distribution of tropical tasar silkworm ecoraces in India

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Accession No.</th>
<th>Ecoraces</th>
<th>State/Union Territory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>CTRTI-SAT-01</td>
<td>Daba</td>
<td>Jharkhand</td>
</tr>
<tr>
<td>2.</td>
<td>CTRTI-SAT-02</td>
<td>Sukinda</td>
<td>Odisha</td>
</tr>
<tr>
<td>3.</td>
<td>CTRTI-SAT-03</td>
<td>Raily</td>
<td>Chhattisgarh</td>
</tr>
<tr>
<td>4.</td>
<td>CTRTI-SAT-04</td>
<td>Moda</td>
<td>Odisha</td>
</tr>
<tr>
<td>5.</td>
<td>CTRTI-SAT-05</td>
<td>Laria</td>
<td>Jharkhand</td>
</tr>
<tr>
<td>6.</td>
<td>CTRTI-SAT-06</td>
<td>Sarhan</td>
<td>Jharkhand</td>
</tr>
<tr>
<td>7.</td>
<td>CTRTI-SAT-07</td>
<td>Andhra Local</td>
<td>Telangana</td>
</tr>
<tr>
<td>8.</td>
<td>CTRTI-SAT-08</td>
<td>Modia</td>
<td>Jharkhand</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Accession No.</th>
<th>Ecoraces</th>
<th>State/Union Territory</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.</td>
<td>CTRTI-SAT-09</td>
<td>Mandalla</td>
<td>Madhya Pradesh</td>
</tr>
<tr>
<td>10.</td>
<td>CTRTI-SAT-10</td>
<td>Japla</td>
<td>Jharkhand</td>
</tr>
<tr>
<td>11.</td>
<td>CTRTI-SAT-11</td>
<td>Munga</td>
<td>Jharkhand</td>
</tr>
<tr>
<td>12.</td>
<td>CTRTI-SAT-12</td>
<td>Bhandara</td>
<td>Maharashtra</td>
</tr>
<tr>
<td>13.</td>
<td>CTRTI-SAT-13</td>
<td>Lodhma</td>
<td>Jharkhand</td>
</tr>
<tr>
<td>14.</td>
<td>CTRTI-SAT-14</td>
<td>Palma</td>
<td>Jharkhand</td>
</tr>
<tr>
<td>15.</td>
<td>CTRTI-SAT-15</td>
<td>Kowa</td>
<td>Jharkhand</td>
</tr>
<tr>
<td>16.</td>
<td>CTRTI-SAT-16</td>
<td>Barharwa</td>
<td>Jharkhand</td>
</tr>
</tbody>
</table>
## Table 3 Distribution of *A. mylitta* ecoraces in relation to forest type

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Forest type</th>
<th>Ecoraces</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tropical moist deciduous</td>
<td>Daba, Sarihan, Munga, Modia, Laria, Barharwa, Lodhma, Palma, Kowa, Japla, Modal, Nalia, Sukinda, Boudh, Simlipal, Omarkote, Kurudh, Multai, Mandla, Jhabua</td>
</tr>
<tr>
<td>2.</td>
<td>Tropical dry deciduous</td>
<td>Sukly, Raily, Bhopalpatnam, Piprai, Seoni, Janghbhir, Korbi, Tira, Bankura, Dadra &amp; Nagar Haveli, Bhandara, Andhra, Monga, Mirzapur, Sultanpur, KE-02</td>
</tr>
<tr>
<td>3.</td>
<td>Tropical wet ever green</td>
<td>Nowgong, NE1-95, NE2-95, Jiribam, NG-94, Belgaum.</td>
</tr>
<tr>
<td>4.</td>
<td>Mountain subtropical</td>
<td>Sivalika</td>
</tr>
<tr>
<td>5.</td>
<td>Thorn Forest</td>
<td>Tesera</td>
</tr>
</tbody>
</table>

## Table 4 Diversity of *A. mylitta* in relation to primary and predominant food plants

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Predominant food plants</th>
<th>Ecoraces</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Terminalia tomentosa</td>
<td>Daba, Sukinda, Sarihan, Boudh, Kurudh, Multai, Bhandara, Andhra, Monga, Sultanpur,</td>
</tr>
<tr>
<td>2.</td>
<td>T. arjuna</td>
<td>Dadra &amp; Nagar Haveli</td>
</tr>
<tr>
<td>3.</td>
<td>Shorea robusta</td>
<td>Munga, Modia, Laria, Lodhma, Palma, Barharwa, Kowa, Modal, Nalia, Simlipal, Omarkote, Sukly, Raily, Mandalla, Jhabua, Bhopalpatnam, Piprai, Janghbhir, Korbi</td>
</tr>
<tr>
<td>4.</td>
<td>Lagerstroemia parviflora</td>
<td>Seoni, Tira, Bankura</td>
</tr>
<tr>
<td>5.</td>
<td>Zizyphus jujube</td>
<td>Japla, Sivalika, NE1-95, NE2-95, NG-94, Monga, Mirzapur, Tesera, Nowgong, Jiribam,</td>
</tr>
<tr>
<td>6.</td>
<td>Anogeissus latifolia</td>
<td>Bhandara</td>
</tr>
<tr>
<td>7.</td>
<td>Anacardium occidentale</td>
<td>KE-02</td>
</tr>
<tr>
<td>8.</td>
<td>Hardwickia binate</td>
<td>Belgaum</td>
</tr>
<tr>
<td>9.</td>
<td>Careya arborea</td>
<td>NE1-95, NE2-95</td>
</tr>
</tbody>
</table>
CHARACTERIZATION OF ECORACES

1. Analysis through phenotypic/ Quantitative traits

Biodiversity in A. mylitta is the result of adaptation of a species to a variable ecological factors and interaction of genetic constitution of the silkworm. The knowledge of genetic diversity in crop improvement is essential for higher yield and to gain hybrid vigour. For the purpose, studies with different plants and insects show the suitability of multivariate analysis in differentiating the populations for their genetic magnitude. Crossing of more divergent parents is believed to increase the chances of obtaining hybrid vigor's number of silkworm breeders have also adopted D^2 statistics in order to measure genetic divergence in various genotypes of silkworm (Subba Rao et al., 1989; Siddiqui et al., 992; Razdan et al 1994; Jolly et al., 1989; Chatterjee and Datta,1992 &Rajan et al 1997).

Considering the potentiality, economic aspects of tasar silkworm, its scope of improvement and limited information available regarding genetic diversity of A. mylitta, 22 ecoraces were subjected to cluster analysis with nine phenotypic traits viz., fecundity, number of worms hatched, larval weight, number of cocoons harvested, female cocoon weight, and shell weight, male cocoon weight and shell weight besides absolute silk yield.

The variation in nature grown cocoon is shown in Table 5 and the ranges of cocoon traits in females and males are presented in Table 6 and 7 respectively. It is observed that male cocoons were found to be always higher in silk ratio than the female cocoons. Apart from the mean values, range and co-efficient of variation of these attributes were computed for better understanding of the differences between the collected ecoraces (Table 6 and 7). From the observations, it is clear that among the Terminalia based ecoraces higher co-efficient of variation was recorded for female and male shell weights of Sukly and Andhra, whereas for both females and males cocoon weight, highest co-efficient of variation was registered for Belgaum.

These observations indicated high intra-population variability of the ecoraces.

Perusal of Table 8 reveals that, out of 22 ecoraces, five, viz. Nowgaon, Sarihan, Mirzapur, Moonga and Korbi fall in cluster I, six, viz. Laria-P, Andhra, Nalia, Tira, Modia, and Jiribaum fall in cluster II, seven, viz. Raily-G, Palma, Sukly, Raily-K, Daba, Sukinda and Raily-N fall in cluster III, whereas single ecoraces Bhandara, Belgaum, Modal and Barharwa fall in cluster IV, V, VI and VII, respectively. The pattern thus reveals that there is no clear-cut relationship between genetic diversity and the geographical origin of the ecoraces. However, the emerging pattern has clearly put the two commercially exploited ecoraces Daba and Sukinda in cluster III. Also, all the Raily populations come in one cluster.

Inter cluster distances are presented in Table 9 and cluster means in Table 10. Comparisons of Shorea based ecoraces and Terminalia based ecoraces for commercial attributes (cocoon weight, shell weight and silk ratio ) indicated that majority of the ecoraces collected from the S. robusta plants had more silk contents when compared with that of Terminalia based ecoraces. Coefficient of variation of economic attributes for almost all the ecoraces were higher when compared with those of Terminalia based.

From the foregoing observations, it could be said that substantial variation is present both within and among ecoraces of A. mylitta which has been reported by many authors (Jolly et al., 1968; Sengupta and Sengupta, 1982; Sengupta et al., 1993 and Singh and Srivastava, 1997). This can be attributed to strong directional selection over centuries for particular characters. Selection is the major force operating in this insect although it is difficult to address the exact mechanism of selection. Some potentially identifiable evolutionary forces might have been responsible for population divergence of A. mylitta in India. Such determinist possibilities might include historical and/or spatial pattern of distribution at
different locations, temperature gradient, altitude, precipitation rate, forest type, food plant and edaphically situations that might reduce or eliminate gene flow across the Eastern and Central India.

It is significant that the ability of *A. mylitta* to form graded pathway of adaptation matches very well with the pattern of environmental variation found in its distribution range or area. Wade (1983) has suggested that one of the most common causes of spatial structuring of insect populations is the discontinuous or patchy distribution of resources. Furthermore, individuals within the same patch are often more likely to interact and interbred with each other rather than with individuals in different patches. In *A. mylitta* also the spatial structuring has been observed in relation to food plant distribution and polyphagous nature of the species. It is thus also substantiated that disruptive selection is in operation in *A. mylitta* also to evolve the populations as per adaptation in different niches.

Table 5. Observed variations in nature grown cocoons of important tasar ecoraces

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Ecoraces</th>
<th>Predominant cocoon colour</th>
<th>Peduncle length (cm)</th>
<th>Cocoon size (cm)</th>
<th>Cocoons per litre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>length</td>
<td>width</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Daba</td>
<td>Grey</td>
<td>6.8</td>
<td>5.7</td>
<td>3.7</td>
</tr>
<tr>
<td>2.</td>
<td>Sukinda</td>
<td>Yellow</td>
<td>5.3</td>
<td>4.9</td>
<td>3.1</td>
</tr>
<tr>
<td>3.</td>
<td>Modal</td>
<td>Blackish grey</td>
<td>6.4</td>
<td>5.4</td>
<td>3.5</td>
</tr>
<tr>
<td>4.</td>
<td>Bhandara</td>
<td>Grey</td>
<td>4.5</td>
<td>4.1</td>
<td>2.4</td>
</tr>
<tr>
<td>5.</td>
<td>Laria-P</td>
<td>Blackish grey</td>
<td>5.2</td>
<td>5.0</td>
<td>3.1</td>
</tr>
<tr>
<td>6.</td>
<td>Raily-N</td>
<td>Blackish grey</td>
<td>3.5</td>
<td>5.3</td>
<td>3.4</td>
</tr>
<tr>
<td>7.</td>
<td>Raily-K</td>
<td>Blackish grey</td>
<td>2.5</td>
<td>5.3</td>
<td>3.4</td>
</tr>
<tr>
<td>8.</td>
<td>Raily-G</td>
<td>Blackish grey</td>
<td>3.6</td>
<td>5.3</td>
<td>3.4</td>
</tr>
<tr>
<td>9.</td>
<td>Tira</td>
<td>Whitish grey</td>
<td>4.6</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>10.</td>
<td>Sarihan</td>
<td>Grey</td>
<td>4.1</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>11.</td>
<td>Andhra</td>
<td>Whitish grey</td>
<td>3.6</td>
<td>3.0</td>
<td>2.5</td>
</tr>
<tr>
<td>12.</td>
<td>Palma</td>
<td>Grey</td>
<td>5.8</td>
<td>5.2</td>
<td>3.8</td>
</tr>
<tr>
<td>13.</td>
<td>Sukly</td>
<td>Whitish grey</td>
<td>3.4</td>
<td>3.7</td>
<td>2.8</td>
</tr>
<tr>
<td>14.</td>
<td>Barhanwa</td>
<td>Grey</td>
<td>5.8</td>
<td>4.8</td>
<td>3.4</td>
</tr>
<tr>
<td>15.</td>
<td>Nalia</td>
<td>Grey</td>
<td>7.2</td>
<td>4.1</td>
<td>2.4</td>
</tr>
<tr>
<td>16.</td>
<td>Modia</td>
<td>Grey</td>
<td>3.2</td>
<td>5.7</td>
<td>3.5</td>
</tr>
<tr>
<td>17.</td>
<td>Korbi</td>
<td>Whitish grey</td>
<td>6.4</td>
<td>4.3</td>
<td>3.8</td>
</tr>
<tr>
<td>18.</td>
<td>Moonga</td>
<td>Grey</td>
<td>5.8</td>
<td>4.5</td>
<td>3.7</td>
</tr>
<tr>
<td>19.</td>
<td>Nowgong</td>
<td>Grey</td>
<td>3.5</td>
<td>3.8</td>
<td>2.9</td>
</tr>
<tr>
<td>20.</td>
<td>Mirzapur</td>
<td>Whitish grey</td>
<td>3.4</td>
<td>3.6</td>
<td>2.4</td>
</tr>
<tr>
<td>21.</td>
<td>Jiribam</td>
<td>Whitish grey</td>
<td>3.4</td>
<td>2.9</td>
<td>2.2</td>
</tr>
<tr>
<td>22.</td>
<td>Belgaum</td>
<td>Whitish grey</td>
<td>6.7</td>
<td>4.6</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Table 6. Variability in commercial characters of female cocoons of tasar ecoraces

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Ecoraces</th>
<th>Cocoon weight (g)</th>
<th>Shell weight (g)</th>
<th>Silk ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean ± S.D.</td>
<td>Range</td>
<td>CV%</td>
</tr>
<tr>
<td>1.</td>
<td>Daba</td>
<td>13.70±1.45</td>
<td>09.86-16.89</td>
<td>11.01</td>
</tr>
<tr>
<td>2.</td>
<td>Sukinda</td>
<td>12.25±1.54</td>
<td>09.38-12.36</td>
<td>12.57</td>
</tr>
<tr>
<td>3.</td>
<td>Modal</td>
<td>15.21±2.15</td>
<td>11.59-20.10</td>
<td>14.06</td>
</tr>
<tr>
<td>4.</td>
<td>Bhandara</td>
<td>08.85±0.99</td>
<td>07.23-10.61</td>
<td>11.19</td>
</tr>
<tr>
<td>5.</td>
<td>Laria-P</td>
<td>07.83±1.10</td>
<td>06.06-10.09</td>
<td>14.05</td>
</tr>
<tr>
<td>6.</td>
<td>Raily-N</td>
<td>14.04±1.95</td>
<td>11.16-18.58</td>
<td>14.10</td>
</tr>
<tr>
<td>Sl. No.</td>
<td>Ecoraces</td>
<td>Cocoon weight (g)</td>
<td>Shell weight (g)</td>
<td>Silk ratio (%)</td>
</tr>
<tr>
<td>---------</td>
<td>--------------</td>
<td>-------------------</td>
<td>------------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean ± S.D.</td>
<td>Range</td>
<td>CV%</td>
</tr>
<tr>
<td>7</td>
<td>Raily-K</td>
<td>12.34±0.57</td>
<td>10.50-14.00</td>
<td>04.62</td>
</tr>
<tr>
<td>8</td>
<td>Raily-G</td>
<td>12.97±0.22</td>
<td>10.32-13.20</td>
<td>01.79</td>
</tr>
<tr>
<td>9</td>
<td>Tira</td>
<td>06.44±1.09</td>
<td>04.34-10.15</td>
<td>16.92</td>
</tr>
<tr>
<td>10</td>
<td>Sarihan</td>
<td>07.98±1.10</td>
<td>06.64-09.98</td>
<td>13.78</td>
</tr>
<tr>
<td>11</td>
<td>Andhra</td>
<td>09.49±1.91</td>
<td>08.45-13.90</td>
<td>20.13</td>
</tr>
<tr>
<td>12</td>
<td>Palma</td>
<td>11.84±1.29</td>
<td>09.07-14.90</td>
<td>10.89</td>
</tr>
<tr>
<td>13</td>
<td>Sukly</td>
<td>08.64±1.48</td>
<td>06.39-11.60</td>
<td>17.13</td>
</tr>
<tr>
<td>14</td>
<td>Barharwa</td>
<td>12.00±0.98</td>
<td>08.06-14.58</td>
<td>08.17</td>
</tr>
<tr>
<td>15</td>
<td>Nalia</td>
<td>13.93±2.01</td>
<td>09.50-17.17</td>
<td>14.42</td>
</tr>
<tr>
<td>16</td>
<td>Modia</td>
<td>15.29±2.13</td>
<td>12.39-18.75</td>
<td>13.93</td>
</tr>
<tr>
<td>17</td>
<td>Korbi</td>
<td>09.42±1.30</td>
<td>07.39-11.85</td>
<td>13.80</td>
</tr>
<tr>
<td>18</td>
<td>Moonga</td>
<td>07.73±1.02</td>
<td>06.20-11.31</td>
<td>13.19</td>
</tr>
<tr>
<td>19</td>
<td>Nowgong</td>
<td>10.06±0.92</td>
<td>08.78-11.13</td>
<td>09.14</td>
</tr>
<tr>
<td>20</td>
<td>Mirzapur</td>
<td>08.14±1.22</td>
<td>06.33-12.60</td>
<td>14.99</td>
</tr>
<tr>
<td>21</td>
<td>Jiribam</td>
<td>11.31±3.17</td>
<td>07.81-14.23</td>
<td>28.02</td>
</tr>
<tr>
<td>22</td>
<td>Belgaum</td>
<td>06.38±1.20</td>
<td>05.28-06.98</td>
<td>18.80</td>
</tr>
</tbody>
</table>

M = Male, F = Female, S.D. = Standard deviation, C. V. Coefficient of variation.

Table 7. Variability in commercial characters of male cocoons of tasar ecoraces
### Table 8. Cluster analysis of 22 ecoraces based on Mahalanobis D² values

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Number of ecoraces</th>
<th>Ecoraces included in each cluster</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>05</td>
<td>Nowgong</td>
<td>Nowgong (Assam)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sarihan</td>
<td>Santhal Pargana (Jharkhand)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mirzapur</td>
<td>Mirzapur (Uttar Pradesh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moonga</td>
<td>Deoria (Uttar Pradesh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Korbi</td>
<td>Korbi, Korba (Chhattisgarh)</td>
</tr>
<tr>
<td>II</td>
<td>06</td>
<td>Laria</td>
<td>Peterbar (Jharkhand)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Andhra</td>
<td>Adilabad (Andhra Pradesh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nalia</td>
<td>Sundergarh (Odisha)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tira</td>
<td>Purulia (West Bengal)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Modia</td>
<td>Dhanbad (Jharkhand)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jiribam</td>
<td>Jiribam (Manipur)</td>
</tr>
<tr>
<td>III</td>
<td>07</td>
<td>Raily-G</td>
<td>Geedam (Chhattisgarh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Palma</td>
<td>Ranchi (Jharkhand)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sukly</td>
<td>Khairpali (Odisha)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raily-K</td>
<td>Keshkal (Chhattisgarh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Daba</td>
<td>Singhbhum (Jharkhand)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sukinda</td>
<td>Sukindagarh (Odisha)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raily-N</td>
<td>Nangoor (Chhattisgarh)</td>
</tr>
<tr>
<td>IV</td>
<td>01</td>
<td>Bhandara</td>
<td>Bhandara (Maharashtra)</td>
</tr>
<tr>
<td>V</td>
<td>01</td>
<td>Belgaum</td>
<td>Belgaum (Karnataka)</td>
</tr>
<tr>
<td>VI</td>
<td>01</td>
<td>Modal</td>
<td>Simlipal (Odisha)</td>
</tr>
<tr>
<td>VII</td>
<td>01</td>
<td>Barharwa</td>
<td>Gola (Jharkhand)</td>
</tr>
</tbody>
</table>

### Table 9. Average inter cluster distances based on nine characters

<table>
<thead>
<tr>
<th>Cluster</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.00</td>
<td>6.59</td>
<td>9.57</td>
<td>6.68</td>
<td>5.89</td>
<td>8.83</td>
<td>7.05</td>
</tr>
<tr>
<td>II</td>
<td>0.00</td>
<td>7.31</td>
<td>4.93</td>
<td>9.51</td>
<td>5.16</td>
<td>5.73</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>0.00</td>
<td>4.95</td>
<td>12.70</td>
<td>5.75</td>
<td>5.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>0.00</td>
<td>9.40</td>
<td>5.24</td>
<td>4.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>0.00</td>
<td>10.73</td>
<td>11.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>0.00</td>
<td>7.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VII</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Genetic diversity analysis through molecular markers

The genetic variability in the living beings and their response to various environmental components constitute the total variability and may not be always possible to differentiate both genetic and environmental components. However, genetic diversity is the most important component for any genetic resource. The genetic diversity in tasar silkworm was assessed earlier by morphological, physio-genetic, behavioural and biochemical methods. In recent years attempts are being made for the use of molecular techniques, but these are sporadic. Comprehensive and systematic studies on molecular characterization are yet to be made. Some of the reports are given below.

Studies carried out by Rao (2000) on molecular characterization of Daba and Andhra ecoraces showed that there are certain bands which are common in both the ecoraces which is indicative of the fact that there is possible genetic proximity between two ecoraces. Chatterjee et al. (2004) using 41 samples from five populations of Raily ecorace showed considerable DNA polymorphism among these populations. Kar et al. (2005) studied the genetic diversity in the wild and semi-domesticated populations of Daba ecorace of *A. mylitta* in order to ascertain the distribution of variability within and among populations of semi-domesticated Daba-bivoltine, Daba–trivoltine and nature grown Daba-wild populations with Inter-Simple Sequence Repeat (ISSR) markers. Considerable intra- and inter- population variability is found in all three populations. Population structure analysis further suggests that the semi-domestic populations of Daba ecorace are at the threshold of differentiating themselves. The genetic variability present within wild Daba population is of much importance for conservation and utilization in systematic breeding programme. Using 12 ISSR and 10 RAPD primers, Vijayan et al. (2005) studied genetic diversity within and between Raily, Daba and Modal ecoraces collected from Chhattisgarh, Jharkhand and Odisha States, respectively. It was observed by them that the genetic diversity among the ecoraces is not significant enough to make drastic genetic drift among these ecoraces in the near future. Saha and Kundu (2006) worked on molecular identification of ten ecoraces of silkworm, *A. mylitta* with RAPD and SCAR markers. It was observed that seven RAPD selected bands can identify eight ecoraces out of ten. These identified RAPD fragments were sequenced and primers were designed for SCAR markers. Out of seven sets of primers, a single primer pair produced polymorphic SCAR bands that diagnose five of the ten ecoraces studied. Mahendran et al. (2006) studied genetic variation in nine ecoraces using RFLP technique and reported that the phylogenetic relationship of different ecoraces supported the phenotypic and geographical isolations. Mahendran et al. (2005) characterized a repetitive DNA in tropical tasar silkworm, *A. mylitta*. Ghosh et al., (2005) worked on molecular characterization of Pao like long terminal repeat retrotransposons, *Tamy* in tasar silkworm. Further Mahendran et al., (2005) worked on molecular phylogeny of silkworm based on 16s ribosomal RNA and cytochrome-oxidase genes. A DBT sponsored project was concluded in 2009 on phylogeography using ISSR and SSR markers in collaboration with SBRL, where 10 tasar ecoraces of Jharkhand were studied and population genetic analysis was done. The genetic distance ranged from 0.0554 to 0.3098. In some of the ecoraces like Modia vs. Laria, Sarihan vs. Laria etc. gene flow value was less than 1.00 showing their isolation. Genetic distance values and UPGMA clustering of ecoraces indicate that there can be heterotic gain if the distantly related ecoraces could be hybridized.

These observations reveal that the phylogenetic analysis of the ecoraces is not congruent with the morphological variations and their geographical distribution. However, higher level of heterozygosity was recorded in wild populations. Also, from the molecular studies it was also found that maximum variation was within the populations/ecoraces. It is also clear that the molecular study of tasar silkworm is still in preliminary stage and long way to go to harness the application of biotechnology tools in tasar culture particularly for conservation and breed improvement.

**B) CYTOTAXONOMY OF TASAR SILKWORM**

Chromosome numbers of eight species of *Antheraea* have been studied and depicted in the following table 11, Jolly et al. (1974) opined that the *Antheraea* species with the lowest number of chromosomes *A. assamensis* (*n* = 15) were endemic in North Eastern India and from this primary epicentre of origin they seem to have spread over other parts of the world.
Table 11: Chromosome number in different species of *Antheraea*.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Species</th>
<th>Distribution</th>
<th>Haploid No. of Chromosome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><em>A. mylitta</em></td>
<td>North and Central India</td>
<td>31</td>
</tr>
<tr>
<td>2.</td>
<td><em>A. frithi</em></td>
<td>Eastern India</td>
<td>31</td>
</tr>
<tr>
<td>3.</td>
<td><em>A. pernyi</em></td>
<td>China</td>
<td>49</td>
</tr>
<tr>
<td>4.</td>
<td><em>A. roylei</em></td>
<td>Sub-Himalyan belt of India</td>
<td>30</td>
</tr>
<tr>
<td>5.</td>
<td><em>A. assamensis</em></td>
<td>Eastern India</td>
<td>15</td>
</tr>
<tr>
<td>6.</td>
<td><em>A. polyphemus</em></td>
<td>North America</td>
<td>31</td>
</tr>
<tr>
<td>7.</td>
<td><em>A. yamamai</em></td>
<td>Japan</td>
<td>31</td>
</tr>
<tr>
<td>8.</td>
<td><em>A. proylei</em></td>
<td>Sub-Himalyan belt of India</td>
<td>32, 42, 44, 48</td>
</tr>
</tbody>
</table>

CHROMOSOMAL BEHAVIOUR IN HYBRIDS OF *A. PERNYI* AND *A. ROYLEI*

Hybrids between *A. pernyi* (*n* = 49) and *A. roylei*, and their reciprocals have resulted in fertile offsprings in spite of disparity in the chromosome number of the parental species. Cytological investigations of the inter-specific cross between *A. perny* and *A. roylei* (Jolly et al., 1973) have revealed haploid number of 30 chromosomes during metaphase I and 32, 44 and 48 chromosomes in F2 generations. In four individuals of the backcross (*A. roylei* x *A. pernyi*) 34, 42, 46 and 49 chromosomes were observed. The possibility of coming across in *A. proylei*, the chromosome number ranging from 30-49 cannot be ruled out as detailed below.

Presence of 30 chromosomes in F1 hybrids indicates that 49 chromosomes of *A. pernyi* got arranged on the metaphase I in such a way so as to pair with 30 chromosomes of *A. roylei*. If such is the case, F2 individuals would possess any number of chromosomes ranging from 30-49. Presence of 32, 42, 44 and 48 chromosomes in the BC1, partly corroborate this contention. Regular pairing between *A. roylei* and *A. pernyi* chromosomes suggests the possible origin of one species from the other by chromosomal fission or fusion.

CYTOLOGICAL STUDIES IN TASAR SILKWORM

Followings are important cytological aspects for characterization of different population of *A. mylitta*:

- Pachytene mapping in female germ cells to study the banding pattern in different ecoraces.
- Analysis of pachytene and diplo-diakinesis cells for ascertaining the frequency of translocation
- Inversion in acclimatized ecorace and their hybrids.
- Analysis of pachytene chromosomes for total chromatin length, means, absolute length of chromosome, etc. in different ecoraces.
- Analysis of metaphase I cells for occurrence of *B* chromosome in different ecoraces.
- Development of male and female germ cells (meiosis) in diapausing and non-diapausing pupae to ascertain the occurrence of pachytene, diplo-diakinesis and metaphase I cells in the corresponding age of the pupae.

Karyotypic studies on chromosome number in tropical tasar silkworm, *A. mylitta* was established (Sinha and Jolly, 1967). There is no variation in respect of chromosome number amongst different ecoraces. Ecoraces are mono-basic in chromosome number i.e., *n* = 31 (Sharma et al., 1995). Commercially exploited ecoraces have been studied for their chiasma frequency and type of chiasma. Significant variations with regard to chiasma frequency have been reported by Gaur and Malhotra (1986) and Sinha et al. (1993). Variations in respect of *B* chromosome have also been reported in some of the ecoraces (Gaur and Malhotra, 1986). It is on record that *B* chromosomes have role in adaptation of an individual to a particular environment. Different stages of cytological studies carried out at CTR&TI, Ranchi is depicted in Fig. 3.
Karyo-morphological study is one of the methods to establish the intra- and inter-population variation. Analysis of karyotypes employing pachytene stage is highly advantageous in this regard. Since pachytene stage apart from providing information on chromosomal length permits the analysis of linear differentiation of chromosomes such as chromomeric pattern and distribution of eu- and heterochromatic segments.

C] BREEDING & GENETICS IN TASAR SILKWORM

Breeding is a science concerned with predicting the consequences of forces such as selection, inbreeding, cross breeding and devising optimum breeding policies for improvement in productivity in domestic animal populations. Success in breeding means economic success as well as scientific success and can be achieved by improving the varieties through selection, hybridization and population breeding approach. Considering the potentiality and economic aspects of tropical tasar, there is enough scope of improvement. Nevertheless, there is limited information on the population structure and variability, genetic architecture and genetic parameters, selection of right parents and other genetic parameters. Genetic variability in tasar silkworm is highly essential to sustain the level of high productivity. Genetic uniformity with an insect is readily brought about by using the same gene or gene complexes in breeding and by large scale extension of genetically related strains. When uniformity becomes the cause of genetic vulnerability, genetic diversity is the only insurance against it. The effectiveness of selection depends upon the range of genetic diversity in respect of economic characters, which are already present in the population. Almost all traits of interest in tropical tasar silkworm are highly influenced by environmental conditions. The progress of breeding in such a heterogeneous population is primarily conditioned by the magnitude, nature, inter-relationship and genetic variation in the biological, commercial and technological characters (Srivastava, et al., 2000). Genetic parameters like genetic advance helps in partitioning the overall variability into its heritable and non-heritable components which is directly or indirectly associated with biological characters and yield, thus, assumes special importance with regard to breeding.

Objectives of the breeding

Improvement may be measured in terms of increased quantity of production, superior quality of product and greater efficiency in relation to inputs. Success of improvement depends upon the extent of genetic variability, breeding value of parents, population size, mating design and improvement through selection.

Pre-requisites of Breeding

For increased silk production- selective breeding to increase the inherent genetic potential of breeds, improvement in nutrition and management and effective disease control is required.

Step I: Collection of the best available strains.

Step II: Heterosis breeding approach to take advantage immediately for improvement for which either maximization of initial rates of improvement or maximization in the total improvement is required.

Step III: Selective breeding to maximize productivity, selection within population and selection within each of several populations is must.

From breeders viewpoint followings are the criteria for development of a breed and its further utilization:

- Selection of the appropriate breeds
- Choice of the correct breeding plan and system
- Estimation of selection parameters and economic value
- Designing of mating system for selected individuals
- Designing of evaluation system
- Development of selection criteria
- Designing a system for multiplication of evolved breed
Progress of tasar silkworm breeding

With the establishment of Central Tasar Research and Training Institute, Ranchi, collection of genetic resources of tasar silkworm was initiated in the year 1965 and efforts were made for maintenance, characterization and evaluation of genetic materials. The history of tasar silkworm breeding is relatively recent. Although Tasar culture is old by centuries it is still a virgin field that calls for breeding on systematic lines. The variability present in the species provides the understanding of the material and makes the breeding methodology meaningful in achieving gains. Sengupta and Sengupta (1982), Sengupta et al. (1993), Singh and Srivastava (1997) studied the nature of variability available in *A. mylitta* ecoraces at different levels. Various attempts were made to exploit the genetic architecture of *A. mylitta* (Jolly *et al.*, 1969; Jolly *et al.*, 1972; Bardaiyar *et al.*, 1976; Siddiqui *et al.*, 1988; Sengupta *et al.*, 1987; Sinha, 1991; Sengupta, 1991, and Sinha and Sinha, 1994). However, wild nature of insect and inadequate knowledge of genetics of tasar silkworm has puzzled the breeders with regard to the best type of breeding programme, which could be laid out to improve the existing material. In the light of the knowledge acquired in recent past, some head way has been made (Table 12).

Having the objective of purity of material a number of inbred lines were evolved at CTR&TI, Ranchi. Some of these are: GB2, GB3, GB4, GB5, GB6, GB7, GB8, GB9, GE1, GE2, GF2, GF3, GF5, GB913, GB914, GB915, GB916, GB511, GE212, R57, L8, RS, S17, RF1, RF4, RF35, Nagri1, Nagri2, Nagri3, etc (Table 13).

Diallel analysis with four mutant lines of Daba were carried out by Jolly *et al.* (1969) based on larval body color of Green, Yellow, Blue...
and Almond (Fig. 4). It was observed that all the hybrids were better in respect of hatching percentage than the respective better parents. Yellow and Almond hybrid combinations were found superior in shell weight. It was reported that the larval body colour is controlled by two pairs of independently segregating genes. Accordingly the green body colour is expressed due to the interaction of two dominant alleles \(i.e., YB\), whereas almond body colour is due to the interaction of their recessive alleles \(i.e., yB\). The yellow and blue body colours are expressed by single dominant gene \(i.e., Yb\) (yellow) and \(yb\) (blue). The segregation ratios obtained from the possible combinations between green, yellow, blue and almond could be expressed on the basis of this digenic hypothesis except the appearance of green larvae at F1 from the cross yellow × almond. This suggests that few more genes are involved for the expression of larval body colour. In the existing (or improved) hypothesis, it has been suggested that a third gene pair is involved and all the three are situated on separate chromosomes, which segregate independently of each other. Accordingly the green colour results due to the interaction of all the three dominant genes (YBS) and blue (yBS) comes from the interaction of BB/Bb and SS/Ss. Thus, green and blue larvae have only one homozygous genotype, whereas the yellow and almond larvae have three homozygous genotypes for the expression of their respective body colour \(i.e.,\) Yellow: YBs, YbS or Ybs; Almond: ybS, yBs or ybs. Hybridization studies were also made through single, double and three-way crosses involving four mutant lines and maximum heterosis was reported in double crosses in respect of fecundity, larval weight, cocoon weight, shell weight and silk ratio (Bardaiyar et al., 1976).

**Inheritance of Moth Colour**

The moths of *A. mylitta* (Daba ecorace) show three pre-dominant colours with varying degree of intensity. The males are usually brown, while the females are grey and yellow in colour. However, occurrence of brown females and grey and yellow males is also observed occasionally. The moth colour in *A. mylitta* appears to be a sex-limited sex controlled character exhibiting balanced polymorphism in the case of female for grey and yellow moth colour. The occurrence of grey and yellow males and brown females in negligible percentage is probably a result of rare genetic conditions allowing the genes to express in the respective sexes, which otherwise remain suppressed. Although sex-limited explanation has been given even then the issue remains open due to a variety of shades exhibited in the moths of either sex.

**Inheritance of Cocoon Colour**

The cocoons of *A. mylitta* (Daba ecorace) are predominantly grey and yellow in colour. The crosses of homozygous grey and yellow lines and their reciprocals have shown dominance in F1 and segregation of grey and yellow during F2 in 3 G : 1Y ratio suggesting that this trait is governed by a single pair of alleles.

\[
\begin{array}{c|c|c|c|c|c}
\text{Parents} & G G & x & (Grey) & & \\
\text{Gamete} & G & G g & x & (Grey) & \\
\text{Gametes} & G & g & & & \\
\end{array}
\]

Grey : Yellow = 3 : 1

**Gynandromorphism**

A gynandromorph is an organism that contains both male and female characteristics. Notable bilateral gynandromorphism observed in moth of *A. mylitta*, wherein both types of body part can
be distinguished physically due to sexual dimorphism (Fig. 5). The cause of this phenomenon is typically an event in mitosis during early development. While the organism contains only a few cells, one of the dividing cells does not split its sex chromosomes typically. This leads to one of the two cells having sex chromosomes that cause male development and the other cell having chromosomes that cause female development. For example, an XY cell undergoing mitosis duplicates its chromosomes, becoming XXY. Usually this cell would divide into two XY cells, but in rare occasions the cell may divide into an X cell and an XYY cell. If this happens early in development, then a large portion of the cells are X and a large portion are XYY. Since X and XYY dictate different sexes, the organism has tissue of both male and female.

Sengupta et al. (1987) reported the nature of heterosis from the performance of eight hybrids involving 8 selected lines viz., Daba, Sukinda, Laria, Bmg, Ymg, GE1, R57 and L8. Heterosis over better parent for absolute silk yield ranged from 58.14 to 172.64 per cent. Overall study of the hybrid vigour revealed that cross Bmg x Ymg is the best cross followed by Laria x Sukinda for most of the desirable characters. During 1984 six lines viz., Daba, RF1, RF4, RF35, RS and L8 were crossed in all possible combinations and RF1 was found excellent general combiner for almost all the characters except fecundity and larval weight followed by RF4 for absolute silk yield, larval weight, shell weight and shell ratio. Daba was good combiner for absolute silk yield, fecundity and ERR. For SCA four combinations Daba x L8 (high x high), Daba x RF1 (high x high), RF1 x L8 (high x high) and RF4 x RF35 (high x low) were best (Siddiqui et al., 1988).

Sinha (1991), Sinha and Sinha (1994) and Sinha et al. (1998) made inter-varietal non-reciprocal crosses of eight inbred lines of A. mylitta viz., R57, GE1, GE2, GE3, N1, N2, Ymg and L8 and it was observed that N1 was the best combiner for the larval weight, cocoon weight, shell weight and absolute silk yield; GE2 for fecundity and ERR, GE1 for hatching percentage and L8 for absolute silk yield. Maximum heterosis was observed in cross GE3 x N1 in respect of absolute silk yield.

### Table 12. Phenotypic variability of eight characters in parents and F₁

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Characters</th>
<th>Mean</th>
<th>Range</th>
<th>S.E.</th>
<th>C.D. at 5%</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Silk Yield</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents</td>
<td>148.96</td>
<td>31.32 – 310.81</td>
<td>38.485</td>
<td>80.279</td>
<td>217.71</td>
<td></td>
</tr>
<tr>
<td>Hybrids</td>
<td>202.97</td>
<td>32.60-489.44</td>
<td>38.485</td>
<td>76.585</td>
<td>407.28</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Fecundity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents</td>
<td>190.59</td>
<td>145.00-280.00</td>
<td>5.911</td>
<td>12.331</td>
<td>33.44</td>
<td></td>
</tr>
<tr>
<td>Hybrids</td>
<td>205.78</td>
<td>137.00-279.00</td>
<td>5.911</td>
<td>11.763</td>
<td>62.56</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Hatching</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents</td>
<td>61.97</td>
<td>33.95-87.37</td>
<td>10.311</td>
<td>21.508</td>
<td>58.32</td>
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</tr>
<tr>
<td>4.</td>
<td>Larval Weight</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Parents</td>
<td>34.08</td>
<td>29.30-45.60</td>
<td>1.116</td>
<td>2.432</td>
<td>6.59</td>
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<tr>
<td>Hybrids</td>
<td>39.31</td>
<td>29.40-49.50</td>
<td>1.116</td>
<td>2.320</td>
<td>12.34</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>E.R.R.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents</td>
<td>69.81</td>
<td>51.30-91.20</td>
<td>1.834</td>
<td>3.826</td>
<td>10.37</td>
<td></td>
</tr>
<tr>
<td>Hybrids</td>
<td>76.21</td>
<td>51.20-91.20</td>
<td>1.834</td>
<td>3.649</td>
<td>19.41</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Cocoon Weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents</td>
<td>13.41</td>
<td>12.90-13.98</td>
<td>0.116</td>
<td>0.241</td>
<td>0.656</td>
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<tr>
<td>Hybrids</td>
<td>14.04</td>
<td>12.96-15.23</td>
<td>0.116</td>
<td>0.230</td>
<td>1.23</td>
<td></td>
</tr>
</tbody>
</table>
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Characters</th>
<th>Mean</th>
<th>Range</th>
<th>S.E.</th>
<th>C.D. at 5%</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Shell Wt.</td>
<td>1.79</td>
<td>1.16-2.63</td>
<td>0.122</td>
<td>0.255</td>
<td>0.69</td>
</tr>
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<td>Parents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrids</td>
<td>2.09</td>
<td>1.48-3.11</td>
<td>0.122</td>
<td>0.243</td>
<td>1.29</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Silk Ratio</td>
<td>13.15</td>
<td>8.95-18.86</td>
<td>0.898</td>
<td>2.128</td>
<td>5.77</td>
</tr>
<tr>
<td>Parents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrids</td>
<td>14.87</td>
<td>10.37-21.76</td>
<td>0.898</td>
<td>2.030</td>
<td>10.80</td>
<td></td>
</tr>
</tbody>
</table>

### Table 13. Salient features of some of the important inbred lines of *A. mylitta.*

<table>
<thead>
<tr>
<th>Line</th>
<th>Derived from</th>
<th>Larval color</th>
<th>Cocoon color</th>
<th>Shell wt.</th>
<th>Silk yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>YPG</td>
<td>Daba</td>
<td>Yellow larval shining spot absent</td>
<td>Grey</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>YMg</td>
<td>Daba</td>
<td>Yellow larval Shining spot</td>
<td>Grey</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>GPg</td>
<td>Daba</td>
<td>Green without lateral shining spot</td>
<td>Grey</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>GMg</td>
<td>Daba</td>
<td>Green with lateral shining spot</td>
<td>Grey</td>
<td>Higher</td>
<td>Moderate</td>
</tr>
<tr>
<td>GM (6.6)g</td>
<td>Daba</td>
<td>Green with lateral shining spot</td>
<td>Grey</td>
<td>Higher</td>
<td>High</td>
</tr>
<tr>
<td>GMY</td>
<td>Daba</td>
<td>Green with lateral shining spot</td>
<td>Grey</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>BPg</td>
<td>Daba</td>
<td>Blue with lateral shining spot</td>
<td>Yellow</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>SMg</td>
<td>Daba</td>
<td>Blue with lateral shining spot</td>
<td>Yellow</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>GE1</td>
<td>Daba</td>
<td>Green</td>
<td>Grey and yellow</td>
<td>Higher</td>
<td>Moderate</td>
</tr>
<tr>
<td>GE2</td>
<td>Daba</td>
<td>Green</td>
<td>Grey and yellow</td>
<td>Higher</td>
<td>Moderate</td>
</tr>
<tr>
<td>GF3</td>
<td>Daba</td>
<td>Green</td>
<td>Grey and yellow</td>
<td>Higher</td>
<td>High</td>
</tr>
<tr>
<td>L8</td>
<td>Laria</td>
<td>Green</td>
<td>Grey and yellow</td>
<td>Higher</td>
<td>High</td>
</tr>
<tr>
<td>R57</td>
<td>Raily</td>
<td>Green</td>
<td>Grey</td>
<td>Higher</td>
<td>High</td>
</tr>
<tr>
<td>Nagri 1</td>
<td>Sukinda x Daba) (Laria x L8)</td>
<td>Green</td>
<td>Grey</td>
<td>Higher</td>
<td>Higher</td>
</tr>
<tr>
<td>Nagri 2</td>
<td>Sukinda x Daba) (Laria x Daba)</td>
<td>Green</td>
<td>Grey</td>
<td>Higher</td>
<td>Higher</td>
</tr>
</tbody>
</table>

### Inter-Racial hybridization and its outcome

Freshly collected nine ecoraces of tasar silkworm, namely Daba, Ampatia, Barharwa, Bhandara, Modal, Nalia, Mugia, Laria and Raily were taken up for inter-racial hybridization during II crop of 1965. It was observed that Ampatia x Barharwa and its reciprocal performed best and exhibited marked superiority over Daba (Annual Report, 1965-66). During 1966-67 seven races of previous year again crossed with Daba in II crop. The result could not confirm findings of the previous years and instead of Ampatia x Barharwa cross as best combination, Laria x Barharwa and Ampatia x Nalia emerged as better performer (Annual Report, 1966-67).

After a lapse of several years the hybridization between ecoraces were again taken up in the year 1974-75 with Sarihan, Mugia, Patjharia, Raily and Modal. From these ecoraces nine cross combinations were raised and Patjharia x Mugia, Sarihan x Raily and Sarihan x Patjharia showed marked gain over the two parents. However, none of the crosses were superior over commercially exploited variety Daba (Annual Report, 1974-75). In the very next year ecoraces Raily, Barharwa, Laria and Modal were crossed with Daba and it was observed that cross combination Daba x Raily and its reciprocal expressed considerable gain in shell weight over check variety Daba (Annual Report, 1975-76). The same crosses were tried to be repeated in next year for both the crops. The results confirmed that Daba x Raily crosses are maintaining the expression of heterosis (Annual Report, 1976-77). Again in the I crop of 1977-78, Laria, Barharwa, Raily and Daba were used for hybridization among themselves. Marked gain was not observed for any of the combination (Annual Report, 1977-78).
Hybridization studies involving ecoraces- Daba, Raily, Modal, Laria and Sukly and evolved lines- Ymg, R57, GE 1 and GF3 were taken up in the year 1989-90 after a lapse of over a decade. In Daba x Modal cross combination improvement over superior parent was observed with regard to absolute silk yield (Annual Report, 1989-90).

Selection indices in Tasar silkworm

Quantitative traits viz. fecundity, hatching, larval duration, effective rate of rearing, yield per dfl, cocoon weight, shell weight and shell ratio of nine ecoraces of tasar silkworm maintained in Germplasm Bank were evaluated in the commercial crop. Observations recorded for these characters were statistically evaluated using multiple randomized complete block design to quantify the genetic component namely genotypic and phenotypic variance, covariance, heritability and correlation between characters. Based on the evaluation it was recorded that the mean difference of each genotype for each character is highly significant (p<0.01) except for larval duration. The phenotypic correlations between characters were positive and significant which ranged between 0.632 to 0.809 except fecundity vs. yield/dfl. The highest index (17.65) was recorded for the ecorace Daba bivoltine followed by Daba trivoltine (17.07) and Sukinda (15.43). The lowest index (14.08) was recorded for Bhandara. The simultaneous selection analysis indicated that Daba is the best suited ecorace considering all the quantitative traits (Srivastava et al., 2005)

Diallel Cross Analysis among ecoraces of tasar silkworm in Ranchi condition

Five ecoraces viz. Daba, Modal, Raily, Sarihan and Laria were crossed in diallel fashion. Twenty and 16 F1 hybrids were generated during seed and commercial crop respectively. Genetic components of parents and hybrids of seed crop were estimated by Griffing Method-II. Based on mean and general combining estimates, three parents viz. Raily, Modal and Daba were identified as best performers for almost all the traits. Performance of biological and commercial traits based on specific combining ability and heterosis over better parent indicated that the F1 hybrid Sarihan x Laria and Sarihan x Daba excelled for hatching, larval duration, female and male shell weight and male SR%.

Based upon specific combining ability estimates and heterosis, short listing of best hybrid was done by combined trait index selection method. Subsequently, three promising hybrids Sarihan x Laria, Modal x Sarihan and Modal x Daba were identified. The hybrid SL recorded maximum survival of 77.09% (I crop) and 72.60% (II crop). In respect of cocoon and shell weight MS performed best (12.08g, 1.62g) in seed crop whereas during commercial crop highest cocoon weight (12.52g) and shell weight (1.90g) was recorded in the hybrid SL.

The phenotypic and genotypic variance was comparatively higher in seed crop than commercial crop for most of the traits. The estimate of phenotypic coefficient of variation for different parameters ranged from 0.531 to 28.885 and genotypic coefficient of variation from 0.51 to 20.251. The maximum heritability was recorded for fecundity (0.957, seed crop) and lowest heritability (-0.009, seed crop) for hatching percent. In seed crop lowest genetic advance observed was -0.080 for hatching per cent while highest genetic advance estimated was 101.25 for fecundity. The simultaneous selection indices based on total scores for all the eleven characters during commercial crops showed maximum values for the hybrid SL followed by MS and MD.

Rearing of three identified promising hybrids viz. Sarihan x Laria, Modal x Sarihan and Modal x Daba was conducted in Ranchi during seed and commercial crops. During seed crop yield per dfl was 79, 52 and 45 respectively, whereas in commercial crop it was 41, 38 and 33 cocoons for the hybrids. Trial rearing of the above mentioned hybrids was conducted at farmers’ level at Dumka. Maximum fecundity (302) was reported for the hybrid M x D whereas best hatching (81%) was recorded in M x D. The hybrid S x L recorded highest yield of 52 cocoons/dfl, followed by M x S (48 cocoons/dfl) and M x D (39 cocoons/dfl). Regarding cocoon weight, shell weight and silk ratio% the hybrids involving Sarihan as one of the parents performed better (Table 14). Hybrids of Sarihan x Laria, Modal x Sarihan and Modal x Daba were prepared at RTRS, Dumka and supplied to farmers for field trial. Farmers harvested 45 cocoons/dfl for Sarihan x Laria while for Modal x Sarihan it was 37 cocoons/dfl.

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**Table 14. Performance of hybrids during seed crop**

<table>
<thead>
<tr>
<th>Characters</th>
<th>Sarihan x Laria</th>
<th>Modal x Sarihan</th>
<th>Modal x Daba</th>
<th>Daba (Check)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rancho</td>
<td>Dumka</td>
<td>Rancho</td>
<td>Dumka</td>
<td>Rancho</td>
</tr>
<tr>
<td>Fecundity</td>
<td>242</td>
<td>235</td>
<td>223</td>
<td>238</td>
</tr>
<tr>
<td>Hatching</td>
<td>74.5</td>
<td>76.0</td>
<td>73.5</td>
<td>81.0</td>
</tr>
<tr>
<td>Yld/dfl</td>
<td>79</td>
<td>52</td>
<td>52</td>
<td>48</td>
</tr>
<tr>
<td>Coc. Wt.</td>
<td>11.26</td>
<td>11.70</td>
<td>10.83</td>
<td>12.00</td>
</tr>
<tr>
<td>Sh. Wt.</td>
<td>1.26</td>
<td>1.35</td>
<td>1.29</td>
<td>1.60</td>
</tr>
<tr>
<td>SR%</td>
<td>10.82</td>
<td>11.54</td>
<td>11.91</td>
<td>13.33</td>
</tr>
</tbody>
</table>

Isolation of high fecundity lines of commercially exploited Daba through recurrent selection

High fecundity line(s) are isolated from ruling Daba through introgression of beneficial genes available in wild Daba targeted for amalgamation of alleles followed by recurrent selection. The fecundity in the Wild Daba ecorace of *A. mylitta* varies from 86 to
400 and at commercial ruling Daba, it is considered about 200 to 220. Pooled population of Daba ruling was crossed with the wild Daba population in order to introgress beneficial genes and in subsequent generations, recurrent selection was followed. Initially, 10 breeding lines were isolated and selected based on the fecundity range (201-300) and further among these, three breeding groups BG1, BG2 & BG3 were selected for female pupal weight and male shell weight. Female pupal weight 11.00g, 11.85g and 12.27g was selected respectively. Concomitantly, male shell weight in these groups was 1.65g, 1.75g and 1.85g with fecundity range BG1 (241-260), BG2 (261-280) and BG3 (281-300). Developed high fecundity lines CTR14 are further rejuvenated through introgress with wild Daba for stabilization of characters and which will be supplied to P4 for further multiplication and utilization in the field (Lokesh et al., 2016).

Hybridization studies involving the Raily ecorace

Raily ecorace of Bastar region of Chhattisgarh is characterized by high cocoon and shell weight along with higher filament length. This race is not exploited for commercial production due to its racial/behavioral characters as it exhibit poor survivability and loose all the original characters under captivity. Hence, there was need for genetic improvement. Daba TV though is well established under semi-domestic conditions, the quality of cocoons is inferior in comparison to Raily. Hence, a breeding strategy has been formulated to achieve a balance between viability and productivity traits involving Raily and Daba. Reciprocal backcross breeding method was used for introgression of domesticated nature of Daba into Raily ecorace. During I crop, superior heterosis over mid parent value (MP) was recorded in respect of mating and fecundity in BC1 and F1A combinations, however it was negative in F1B combination. During II crop BC2 and BC1 and F1A combinations exhibited superior heterosis over mid parent value in respect of mating whereas it was negative in F1B (Daba x Raily) combination. Under popularization of Raily x Daba cross, five farmers were supplied with 50 dfls each during I and II crops. An average yield of 62 and 36 cocoons/dfl were recorded during I and II crops, respectively (Annual Report, 2009).

Under P4 stock maintenance, Daba and Jata Daba ecoraces were maintained and some hybridization studies were conducted. It was found that the F1s of Jata Daba x Daba performed better over the parents for a majority of quantitative traits.

Challenges of Breeding:

Causes for non-exploitation of hybrid vigor

For exploitation of hybrid vigor it is necessary to have luxuriant availability of pure stocks, a feature that is still lacking in A. mylitta. Many studies are yet to be done to understand wild nature of the insect and to help in commercial exploitation of tasar F1 hybrids. It is seen that, not many ecoraces are easily amenable to human handling. Many of the ecoraces if reared ex situ cannot survive after few generations. Based on the amenability, some important ecoraces are grouped in Table 15. Similarly, the merits and demerits of the wild ecoraces are enlisted in Table 16.

In tasar silkworm most of the traits are with high level of plasticity where, environmental interaction is more pronounced. There is remarkable deterioration in quantitative traits when the wild populations are reared ex situ (Table 17 and 18), which is a concern inviting the intervention of appropriate breeding plan. From the scanning of hybridization in course of all these years few promising hybrids were evolved but their exploitation could not be made in the field for its utilization. There must be some valid and strong reasons, which deterred the exploitation of F1 hybrids in tasar silkworm up till now. Unless these reasons are clearly examined, it is difficult to work out a feasible plan for its further execution.

### Table 15. Status of some of the races in relation to their adaptability

<table>
<thead>
<tr>
<th>Ecoraces</th>
<th>Status</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daba (bivoltine), Daba (trivoltine) and Sukinda</td>
<td>Easily amenable</td>
<td>Wide range of habitat preference and adaptation</td>
</tr>
<tr>
<td>Sarihan, Bhandara and Andhra, Mandla</td>
<td>Moderately amenable but poor adaptability</td>
<td>Poor commercial characters but lower denier</td>
</tr>
<tr>
<td>Raily, Modal and Laria</td>
<td>Least amenable</td>
<td>Silk richness maximum in situ and quality deteriorates ex situ</td>
</tr>
</tbody>
</table>

### Table 16. Merits and demerits of wild ecoraces

<table>
<thead>
<tr>
<th>Merits</th>
<th>Demerits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher shell weight</td>
<td>Least amenable to handling</td>
</tr>
<tr>
<td>Higher cocoon weight</td>
<td>Erratic moth emergence</td>
</tr>
<tr>
<td>Higher shell ratio</td>
<td>Poor coupling under captivity</td>
</tr>
<tr>
<td>Higher filament length</td>
<td>Poor survivability</td>
</tr>
<tr>
<td>Higher fecundity</td>
<td>Inconsistent voltinism</td>
</tr>
<tr>
<td>Tolerance to biotic and abiotic stress</td>
<td>High plasticity in traits</td>
</tr>
</tbody>
</table>
Table 17. Diversity in commercial characters of nature-grown cocoons

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the race</th>
<th>Cocoon Weight (g)</th>
<th>Shell weight (g)</th>
<th>Silk ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>1</td>
<td>Daba</td>
<td>10.20±1.29</td>
<td>13.17±1.45</td>
<td>1.71±0.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.69-12.94)</td>
<td>(9.86-16.39)</td>
<td>(1.15-2.47)</td>
</tr>
<tr>
<td>2</td>
<td>Sukinda</td>
<td>10.58±1.32</td>
<td>11.25±1.54</td>
<td>1.58±0.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(9.08-12.38)</td>
<td>(9.38-12.36)</td>
<td>(0.97-2.21)</td>
</tr>
<tr>
<td>3</td>
<td>Raily</td>
<td>11.68±1.68</td>
<td>14.04±1.98</td>
<td>1.97±0.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(7.00-12.89)</td>
<td>(11.16-18.58)</td>
<td>(1.18-2.96)</td>
</tr>
<tr>
<td>4</td>
<td>Modal</td>
<td>12.10±1.19</td>
<td>15.21±2.14</td>
<td>2.92±0.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(9.60-16.54)</td>
<td>(11.59-20.1)</td>
<td>(2.25-3.92)</td>
</tr>
<tr>
<td>5</td>
<td>Laria</td>
<td>7.72±1.05</td>
<td>7.38±1.10</td>
<td>1.63±0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.56-10.18)</td>
<td>(6.06-10.09)</td>
<td>(1.03-2.45)</td>
</tr>
<tr>
<td>6</td>
<td>Sarihan</td>
<td>6.62±1.02</td>
<td>7.89±1.10</td>
<td>0.96±0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.20-8.34)</td>
<td>(6.64-9.98)</td>
<td>(0.70-1.25)</td>
</tr>
<tr>
<td>7</td>
<td>Bhandara</td>
<td>5.75±0.9</td>
<td>8.85±0.99</td>
<td>1.27±0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.99-6.7)</td>
<td>(7.23-9.98)</td>
<td>(0.75-1.61)</td>
</tr>
<tr>
<td>8</td>
<td>Andhra</td>
<td>6.78±1.54</td>
<td>9.94±1.91</td>
<td>1.21±0.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.28-10.7)</td>
<td>(4.85-13.90)</td>
<td>(0.55-2.15)</td>
</tr>
<tr>
<td>9</td>
<td>Tira</td>
<td>5.20±0.9</td>
<td>6.44±1.09</td>
<td>0.85±0.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.40-8.84)</td>
<td>(4.34-10.15)</td>
<td>(0.39-1.47)</td>
</tr>
</tbody>
</table>

N.B. Figures in parentheses indicate range

Table 18. Diversity in commercial characters in ex situ (Ranchi) condition

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the race</th>
<th>Cocoon Weight (g)</th>
<th>Shell weight (g)</th>
<th>Silk ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>1</td>
<td>Daba</td>
<td>8.92±1.05</td>
<td>11.26±2.07</td>
<td>1.15±0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(7.04-10.67)</td>
<td>(8.49-14.44)</td>
<td>(0.61-1.46)</td>
</tr>
<tr>
<td>2</td>
<td>Sukinda</td>
<td>7.92±1.10</td>
<td>10.62±1.17</td>
<td>1.00±0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6.87-9.58)</td>
<td>(8.16-12.13)</td>
<td>(0.71-1.23)</td>
</tr>
<tr>
<td>3</td>
<td>Raily</td>
<td>7.80±1.33</td>
<td>11.01±1.70</td>
<td>0.89±0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6.18-10.31)</td>
<td>(8.41-13.75)</td>
<td>(0.66-1.47)</td>
</tr>
<tr>
<td>4</td>
<td>Modal</td>
<td>7.76±1.26</td>
<td>10.79±0.83</td>
<td>0.91±0.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.90-10.64)</td>
<td>(9.51-12.23)</td>
<td>(0.65-1.47)</td>
</tr>
<tr>
<td>5</td>
<td>Laria</td>
<td>5.80±0.66</td>
<td>8.11±1.52</td>
<td>0.70±0.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.90-6.86)</td>
<td>(6.14-11.39)</td>
<td>(0.40-1.03)</td>
</tr>
<tr>
<td>6</td>
<td>Sarihan</td>
<td>5.77±0.57</td>
<td>8.48±0.71</td>
<td>0.68±0.07</td>
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<tr>
<td></td>
<td></td>
<td>(4.76-6.47)</td>
<td>(7.66-9.95)</td>
<td>(0.53-0.78)</td>
</tr>
<tr>
<td>7</td>
<td>Bhandara</td>
<td>5.79±0.61</td>
<td>9.12±1.62</td>
<td>0.64±0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.21-6.97)</td>
<td>(6.41-11.01)</td>
<td>(0.44-0.72)</td>
</tr>
<tr>
<td>8</td>
<td>Andhra</td>
<td>6.50±0.34</td>
<td>8.48±0.58</td>
<td>0.87±0.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.90-8.09)</td>
<td>(7.74-9.44)</td>
<td>(0.65-1.05)</td>
</tr>
<tr>
<td>9</td>
<td>Tira</td>
<td>4.66±0.92</td>
<td>6.64±1.20</td>
<td>0.83±0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.96-6.09)</td>
<td>(3.15-8.75)</td>
<td>(0.71-0.98)</td>
</tr>
</tbody>
</table>

N.B. Figures in parentheses indicate range
Some of the probable hurdles in hybrid preparation and exploitation are grouped under two heads:

A. Plausible causes restricting the expression of hybrid vigour

i) Inter-crossing of races in nature keep them at hybrid level hence, further heterosis is not discernible.

ii) Inbreeding of ecoraces result in steep decline of commercial characters; when we utilize these for hybridization we do get heterosis over the deteriorated parents, but on comparison with the natural population such effect gets nullified particularly for cocoon weight and shell weight.

iii) Available ecoraces are prone to intermixing due to migration and this disturbs the stability of ecoraces, which is most required for hybridization programme.

iv) Polyphagous nature of the tasar silkworm is very frequently changing the phenotypic expressions of commercial characters thus making the comparisons loose. In other words the phenotypic plasticity is high.

v) Seasonal and environmental interaction has great influence on the expression of commercial character.

B. Causes restricting the adoption of evolved hybrids at commercial level:

i) Studies made earlier remained sporadic and restricted to particular environment.

ii) Lack of consistency in high yielding hybrid and parental stock.

iii) Continuity of parents and large scale production of parents remained a problem due to following reasons:

a) Uncertainty of crop due to environmental rigors and attack of pests, parasites and predators as rearing of silkworm is conducted on trees in open habitat.

b) High incidence of mortality due to diseases in the introduced habitat.

c) Low multiplication rate of genetic materials.

d) Inadequate knowledge of diapause physiology of tasar silkworm.

e) Non-synchronization of moth’s emergence in different races, so obtaining the F1’s become difficult.

f) Wild races are not amenable to handling and they lose their original characters consequent upon the change of habitat.

g) Lack of proper identification of genetic markers with phenotypic expression.

D. CONSERVATION OF TROPICAL TASAR SILKWORM ECORACE

Conservation

Conservation biology is tied closely to ecology in researching the dispersal, migration, demographics, effective population size, inbreeding depression, and minimum population viability of rare or endangered species. To better understand the restoration ecology of native plant and animal communities, the conservation biologist closely studies both their polytypic and monotypic habitats that are affected by a wide range of benign and hostile factors. Conservation biology is concerned with phenomena that affect the maintenance, loss, and restoration of biodiversity and the science of sustaining evolutionary processes that engender genetic, population, species, and ecosystem diversity.

I. Need of Ecorace Conservation

1. Rampant collection of Cocoons.
2. Threat of complete genetic erosion.
3. Environmental stress changes the climate/environment/forest ecosystem
4. Irrational collection & marketing of nature grown cocoon.
5. Deforestation for fuel, livelihood earning by tribals.
6. Increase in anthropogenic activities.
7. Unawareness among the tribal on restriction of collection.
8. Extensive losses due to parasite and predators.
9. Climatic attacks of heavy rains, storms, drought etc.
10. Human interference for industrial and housing areas with increasing human population.
11. Untested/diseased seeds to the core buffer area homeland.
12. To protect and maintain essential tasar host plants in the forest ecosystem.
13. To preserve the existing wild ecoraces and their population in natural habitat.
14. To ensure sustainable utilization of the ecoraces and ecosystem.
15. Large scale collection of cocoons from their ecological niches without giving any heed towards natural breeding process for self-perpetuation

II. Need of Wild Daba Conservation

1. High value of commercial characters & zero pebrine status.
2. Highly amenable can transform into cultivated ruling Daba unlike other in situ bred eco-race
3. Thus the high trait values & pebrine zero can be utilized for tasar seed system.
4. In situ conservation strategies will multiply the wild Daba in its native eco-niches.
SURVEY, GEOTAGGING ECO-ZONATION & TRANSECTION OF FOREST SECTOR/CORRIDORS CORE:

I. Survey and Geotagging

Surveys are very important for the assessment of the status of any genetic resources. Since the wild populations are dynamic in nature, regular and systematic surveys are required in order to ascertain the current status of wild silkworm species/ecoraces/populations. Due to deforestation and other anthropogenic activities, the invaluable populations/ecoraces are under the threat of extinction. Out of 44 ecoraces of tropical tasar silkworm known so far the current status of many are not known. Many of the ecoraces and populations are under the threat of extinction.

The ecosystems in the tropics, both humid and semi-humid are fragile because development of human civilization and exploitation of natural resources. In order to protect the environment, conservation of biodiversity is a must. Due to various reasons, the wild population of sericogenous flora and fauna are declining very fast. Since biodiversity conservation has drawn the attention of mankind for their survival, it is imperative to conserve the seric-biodiversity in the country and particularly commercially exploited and threatened tasar silkworm germplasm and its host plants. Besides, wild/natural populations are supposed to harbour many beneficial alleles developed through centuries by the process of adaptation.

At present, application of Geographical Information System (GIS) and Remote Sensing (RS) data have tremendously helped in survey and data banking of genetic resources. Central Silk Board has also been pursuing the application of satellite remote sensing for sericulture development ever since the launch of the first operational remote sensing satellite, IRS-1A in 1988. CSB and ISRO in collaboration with the concerned States Sericulture/Textiles Departments applied the technology of Remote Sensing (RS) and Geographical Information System (GIS) for mulberry acreage estimation, garden condition assessment and for finding suitable areas for introducing sericulture in the non-traditional States. Considering availability of improved resolving power of IRS satellites and information detail required for planning purposes. Similarly, appropriate ecozones in the forest for various ecoraces is being explored for the conservation of invaluable ecoraces. Consequent to geotagging there is need to identify and demarcate the valuable eco-zones of conservation namely Core, Buffer and Peripheral zones.

To carry out the complementary activities of biodiversity conservation and sustainable use of natural resources, biosphere reserves are traditionally organized into three interrelated zones, known as the core area, the buffer zone, and a transition zone or ‘area of cooperation.’

The zone concept is designed to be flexible and may be used in a variety of ways in order to address local needs and conditions. Ownership arrangements in a biosphere reserve vary as well.

II. The Zonation System

- **Core area:** includes protected areas, as they act as reference points on the natural state of the ecosystems represented by the biosphere reserves. Information from these core areas may be used to assess the sustainability of activities, or the maintenance of environmental quality, in surrounding areas. Managers of the core areas may contribute resources to projects developed with residents, businesses and other partners of the biosphere reserve (Fig. 6).

- **Buffer zone:** surrounds or is contiguous to the core area. Activities are organized so they do not hinder the conservation objectives of the core area, but rather help to protect it. The buffer zone might be an area for experimental research, or may involve ways to manage natural vegetation, agricultural land, forests, fisheries or ranchland to enhance overall
quality of production while conserving natural processes and biodiversity. This zone may also accommodate education, training, tourism, and recreation facilities. In many biosphere reserves the buffer zone is regarded as an area in which human use is less intensive than what might be found in the transition zone.

- **Transition Zone, or Area of Cooperation**: the large outer area of a reserve where people live and work, using the natural resources of the area in a sustainable manner. The term ‘area of cooperation’ underscores the role of cooperation as the main tool to achieve the objectives of the biosphere reserve. It is here that the local communities, conservation agencies, scientists, civil associations, cultural groups, businesses and other stakeholders agree to work together to manage and use the area in a sustainable way that will benefit the people who live there.

**Figure 6. Zonation System Of The Forest**

**CONSERVATION PROCESSES INVOLVED FOR NATURAL TO CAPTIVE ECORACE AND RECYCLING**

I. **Wild to Wild means Cocoon to Cocoon perpetuation on Shorea only under Shuttle Perpetuation Site (SPS) Plan**

1) The Cocoons of Natural wild Daba after hanging on Sal tree permitted to propagate all along the adjoining trees in suomotto manner which further proliferate with respect to the encountering of the most suitable eco-climate.

2) Shuttle Breeding means identifying the most suitable alternate site with congenial a biotic and biotic components in the forest econiche

3) Accordingly it will form the base of Shuttle Perpetuation Plan (SPS) in which based on geo-tag indicator the most congenial econiche on alternate basis will be searched and exploited.

4) The techniques of various types for Cocoon to Cocoon propagation/perpetuation should be adopted

5) Only Cocoon stage should be used for perpetuation and no other stage on shorea. In this the ratio remains 1:10

6) It takes long period for natural multiplication but the commercial characters are very high without any diseases. This stage of perpetuation is conducted in the Buffer part of the conservation sector

7) This operation to be perfumed in shuttle perpetuation mode.

II. **Wild to Semi-wild i.e. Cocoon to Grainage operation on Terminalia tomentosa**

1) This is the second level in which the cocoon is used for grainage whereas the rearing are done in situ and ex situ both.

2) The success rate of in situ and ex situ is almost identical and hence it is found that the harvest rate of cocoon in ex situ is more than ex situ.

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[Diagram of zonation system of the forest]
3) Accordingly due the fact that rate of amenability from in situ to ex situ is higher in Singhbhum Shorea based wild Daba in Jharkhand.

4) Grainage Success in Econiche:- The grainage success occurs in in situ area where there are availability of external natural males which comes towards the hanging female in and around the host tree.

5) The male are attracted towards the female hanging on host tree due to the 2 reasons 1. Synomone secretion from the host plant 2. Sex pheromone attraction between male and female. Since these moths are long flier and male flies from kms to kms.

6) The success of mating percentage are higher near econiche area of host-plant location due to the signal of synomone received by female moth triggering that here around host plant their offspring egg will be able to survive.

7) Thus organizing the male and female moth to achieve maximum mating is essentially required since the population of wild silk from the collected cocoon from nature consist of irregular and overlapping crop cycle.

8) Thus grainage gives 70 % success on acclimatization, it indicate that Wild Daba /shorea fed Daba shows better amenability than other.

9) These practices of conducting grainage of wild Daba for obtaining the stocks with zero pebrine and high productive trait being practiced by the CSB centres and DOS PPC centers and also by farmers in forest villages.

10) Such high productive trait and zero pebrine stock can be successively harvested from Asan host plant and in this way the Asan reared progenies are developed.

11) These progenies after being reared on Asan become adapted to captive status. Subsequently passing through successive generation.

III. Semi-wild to Captive reared means Grainage to Rearing

1) This is the third level in which the outcome of grainage the Dfls are subjected to rearing only on Asan (Fig. 7).

2) These Dfls are able to survive on Asan perhaps due to the availability of Asan in and around the Sal forest.

3) Out of the Dfls prepared from captive grainage in in-situ area partial Dfls in various ways and forms are transferred on Shorea for suo motto perpetuation and partial reared on Asan.

4) It is reported that those on Asan survive more than that of Sal, but the built up of those on Sal are very high from Asan.

Figure 7. Wild Daba Cocoon Reared Partially In Asan

IV. Exploration on Re-cycling of Captive to Perpetuating & Vice versa.

1) This an additional fourth level in which there is required to undertake the most important aspects of recycling of the Asan fed Daba back to Sal tree for taking the observation that what percentage of population are maintained while.

2) This is conducted to test the success 1. The Asan fed Cocoons are garlanded on the Sal.

3) The suo-motto multiplication of this Asan fed Daba occurs in uniform manner.

4) The rate of multiplication of thus transformed Asan based stock on Sal tree for feeding.

5) The Sal feeding in this continues to be adapted to the Sal acclimatization.

A. General model on methods/technologies of conservation

1. Core Zone Fortification: The interior forest patch (core-zone) in the tasar insect native habitat has to be selected and allowed the insect to reproduce suo moto and fortify its population. The restriction must be that nobody be allowed collecting any of tasar.
insects life form (egg, larva, cocoon and adult moth) from the demarcated core-zone, except for research purposes. This zone serves as a gene pool for defined tasar wild ecorace which is allowed to multiply amidst utter silence and serenity. The insect population of this zone, on proliferation, however, will move to adjacent buffer and peripheral zones on its own helping local tribal farmers for its utilization.

2. Host Plant Demarcation: A patch of tasar insect host trees in the forest has to be selected, pollard at 5-6 height, clear from pests and predators and optimum aseptic conditions to be maintained in and around areas. The garlands of cocoons relate to native tasar wild insect to be hanged on to the trees adopting free spacing in between the garlands. The host tree areas to be covered with net of the desired size based on selected and maintained canopy. The temporary shade of paddy straw or wild grass has to be fixed around the trees to avoid pupal mortality. The moths emerged from the cocoons will mate; lay eggs on the host plants and helps insect population to multiply rapidly under offered protection from diseases, pests and predators (Fig. 8).

3. Cocoon Preservation in Pagoda Device: The cocoons collected from wild to be preserved in hanging position inside the umbrella shaped pagoda device erected under host trees. The device made of indigenous wooden poles, paddy straw and the sides to be covered with net to provide protection to the cocoons from pests and predators (Fig. 9). The cocoons preserved in the device will have better environment and protection for better coupling and egg yielding. The gravid female moths and eggs are to be safely transferred to their habitats for better proliferation of insect. The cocoons so preserved in pagoda device can also be hanged on host trees of forests, just prior to their emergence.

4. Moth Egg and Larva Release: The male and female moths emerged from the preserved cocoons to be released in the selected core forest area. The male and female moths on mating inside net, the gravid female moths are to be released every day in the evening on to the host plants of the forest (Fig. 10).
5. Process of Increasing Conservation Sites: After the release of cocoons, moths, eggs and larvae, the interference of insect core zone to be cordoned off and a time bound ban on collection of cocoons in the peripheral area also to be imposed to improve insect population and subsequent sustainable utilization. The management activities at times also contribute to habitat loss, which needs to be corrected in time to enhance the protection process (Wilhere, 2002). The conservation status to be assessed at regular intervals using suitable sampling methods, to provide follow up in containing diseases, pests and predators and to check the conservation impact. The survey to explore fresh zones should be conducted with time schedule to benefit the involved tribal farmers, whose livelihood is linked with income from the collection and sale of nature grown tasar cocoons.

6. Conservation of Insect along with Related Flora: Basically, the conservation plan should encompass whole spectrum of biota and activities ranging from eco systems at macro level (in situ conservation) (Fig. 12) and at micro level ex situ conservation). The conservation (breeding) of endangered wild tasar silk insect species in India is a must activity.
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

Different Field Releasing Methods for Wild Ecorace Conservation

The intervention is needed from sericulture and forest departments along with native tribal rearers from the habitats of tasar silk insect for ex situ conservation, as those areas are under their vicinity and control. The conduction of regular census on flora and fauna in collaboration with scientific institutions and non-government organizations helps assessing the field conditions and silk insect species which need conservation. The in situ management study helps to address the cause of decline/extinction of wild insect population in its natural habitat, apart recommending inputs for improvement. The extensive cocoon collections, disease outbreaks, predators attack, besides the species suitability are to be enlightened to the native rearers for their effective participation in insect conservation.

7. Conservation through Eco-Park Creation: In traditional practice, the tasar larvae feed on irregularly distributed food plants leading to management problems and loss due to pests, diseases and natural hazards. The newly developed economic plantation method with close spacing can enhance foliage quality even under rain-fed and sub-marginal soils (Sinha and Sinha, 1994; Thangavelu, 2002; Rao et al., 2004). Till now the research has been stopped on exploration of species diversity as an individual population, but never talks about what its role in the total ecosystems. This agri-silvicultural and tasar culture potential can create sustainable returns, employment and rise in the living standards of forest-dwelling peoples, besides conserving the endangered tasar silk insect. The critically endangered species can be conserved through ex situ strategy by establishing eco-parks, a simulated ecological niche as like their native habitat. To bring in a holistic development of eco-parks and to achieve the main objective, we need to infuse more technical and scientific standards in operation of eco-parks and change the general perception of said parks from being mere picnic spots to more of a scientific institution. When natural enemies are missing, late to arrive at new plantings or too scarce to provide control, their numbers may be increased through releases. Such an approach is known as augmentation. Augmentation is the manipulation of natural enemies in order to make them more efficient regulators of pests. The principal limitations are the cost, quality and field effectiveness of the released organisms. Inoculative release and inundative release are two common augmentation approaches.

There are two approaches to the conservation of insects. Either humans set aside large portions of land using “wilderness preservation” as the motive, or confronting the particular processes that affect the charismatic vertebrates in order to achieve indirect conservation of insects. With biodiversity loss being a global problem, conserving habitat simply for species of insects is of low priority in the current environmental culture. Single-species conservation is said to preserve many other species indirectly, this preservation by default is referred to as the umbrella effect. “Charismatic species”, such as butterflies or large, colourful beetles, called flagship species, can expand public awareness and financial contributions for conservation efforts. Migratory species, such as the well-known monarch butterfly (Danaus plexippus), are in need of special conservation methods. One species may require several

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Figure 12: Various Methods Of In-Situ Conservation

Cocoon management study helps to address the cause of decline/extinction of wild insect population in its natural habitat, apart recommending inputs for improvement.
Insect conservation has been labeled in the past as a concern only for the affluent. The developing country of Papua New Guinea has a “happily ever after” ending in their attempts to preserve the world’s largest butterfly, *Queen Alexandra's Birdwing* (*Ornithoptera alexandrae*). This species is restricted to a very small range of habitat due to specificity in their diet. In the international market of insect collecting, the butterfly can retrieve up to US$2000. In 1978, the government of Papua New Guinea set up the Insect Farming and Trading Agency (IFTA) to regulate the exploitation and conservation of Queen Alexandra’s Birdwing and other valuable butterflies.

**ECORACE CONSERVATION MODELS**

For natural proliferation and conservation of some of the economically important tasar silkworm eco-races, the technology models have been developed by the CTR&TI, Ranchi & its Regional Research Stations. These conservation models are given hereunder.

**A. Conservation of Raily Ecorace**

Raily eco-race of tropical tasar silkworm, *A. mylitta* is an endemic eco-race of Bastar region of Chhattisgarh. It is a unique sericigenous wild ecorace found in nature in dense tropical moist deciduous forests abundantly on *S. robusta* (Sal) in forest ranges of Bastar in Chhattisgarh. It also feeds on *T. tomentosa* (Asan), *T. arjuna* (Arjun) and *Anogeissus latifolia* (Axle wood or Dhawra). The following package of practices has been developed to conserve the ecorace Raily utilizing vast Sal flora available in Bastar region of Chhattisgarh.

a. Identification of potential eco-niches
b. Augmentation of seed through Pagoda Device
c. Methods of Natural Regeneration
d. Ideal release period for different seasons
e. Module for different field releasing methods
f. Calendar (work plan) for rearing of Raily

1. Identification of potential eco-niches:
Through bio-prospecting, suitable eco-niches (forest ranges) for ecorace Raily have been identified in its core areas. These include Antagarh, Narayanpur, Dhaulai, Chotey Donger, Dantewada, Tongpal, Farasgaon, Makdi, Kondagaon, Mardapal, Bhanpuri, Bakawand, Tokapal, Barsur, Geedam, Darbha, Kanger, Nangoor and Keshkal. The same has been suggested to the State Govt. of Chhattisgarh to have a plan for restoration of deteriorated/disturbed ecological niches.

2. Augmentation of seed through Pagoda Device:
The innovation of a Pagoda device for *in situ* seed cocoon preservation and grainage operation has ensured a viable, efficient and effective seed production of wild Raily ecorace for conservation (Fig 13).

![Pagoda built in Sal forest](image1)
![Pagoda built in Sal forest with cocoons](image2)

**Figure 13. Preservation Of Raily Cocoons In Pagoda**

3. Methods of Natural Regeneration:
Five methods are suggested for natural regeneration (field releasing) of ecorace Raily.

a. Release of seed cocoons
b. Release of moths
c. Release of gravid moths
d. Release of eggs in Sal leaf cups
e. Release of Chawki worms in the place of conservation.

It was established that all the five methods contributed in enhancing the natural population of Raily with variable rates of productivity. The cocoons produced by these release methods exhibited similar commercial characters as of nature grown cocoons. As regard to cost-benefit ratio, conservation methods are operationally and technically more feasible but economically unfeasible; however, methods 3 & 4 are feasible on all counts.

4. Ideal release period for different seasons:
In order to derive ideal releasing period, phase rearing of Raily ecorace was conducted at an interval of 10 days over a period of five years involving ten crops. Based on the survival probability and economic traits, it was identified that second fortnight of June for 1
crop season and first fortnight of October for 2 crop season were
ideal release periods to relish maximum Raily cocoons production
in the eco-niches.

5. Module for different field releasing methods
B. Conservation of Modal Ecorace

The Similipal forest (Map-I) in Mayurbhanj district of Orissa state,
representing the totality of plants, animals (including humans),
and microorganisms, as an interconnected, interrelated, and
interdependent system, is notified as a Biosphere Reserve in
1994. It is rich in biodiversity, such as the vast expanse of stately
Sal (S. robusta) forest which serve as the principal food plant of
tropical silkworm A. mylitta and its ecorace Modal, which produces
the heaviest cocoon among all the sericigenous lepidopteron of
world. It is a hill studded ecosystem with varied topography, soil &
climate; innumerable crests & valleys, cascading waterfalls,
bewildering panorama of mammoth canopy bloomed in green veils
and compact block of virgin, moist-dry deciduous & semi-evergreen
forests with myriads of flora. and fauna of diverse genetic resources
(Dey, D, et al., 2010). Modal is reported as univoltine in its natural
habitat, but study is required to know the facts of this wild insect, as
evidences are there that Modal race is multiplying in nature round
the year. It behaves bi- or tri-voltine out of its natural habitat with
higher temperature and longer photoperiod. In plains of Mayurbhanj
district, Modal is commercially cultivated such cultivated generation
of Mayurbhanj district of Orissa up to 1965. Afterwards, with the
introduction of ecoceses like Daba and Sukinda, production of wild
cocoons showed a sharp decline from 10.81 millions in 1980 to
0.5 million in 2003. So, it is the high time to conserve and maintain
the biodiversity of Modal and to enrich its population in its natural
habitat. As such, Govt. of Orissa in collaboration with the Central
Silk Board, Govt. of India has launched a five-year project (2000-
2005) on Modal Ecorace Conservation in Similipal Biosphere
Reserve.

1. Natural Habitat of Modal Ecorace

The ecorace Modal is endemic to tropical forest of Similipal
Biosphere of Mayurbhanj and Keonjhar over a forest of 2750 sq.
kms of which core forest area is 845.70 sq. km and buffer area
is 904.30 sq. kms (Fig. 14). It is also reported in some pockets of
Dhenkanal Distt. of Orissa. The total forest in Orissa is 5.48 million h
of which 0.89 million h is in the Tasar belt. The total forest area under
S. robusta (SAL) is 0.77 million h and under Terminalia tomentosa
is 0.12 million h. The area under Sal (S. robusta) is commercially
exploited for Tasar cocoon production and only Modal, the wild
corace, is maintained in nature on this forest. The highest point
of Similipal Biosphere is Khairiburu and is above 1165.6 MASL. The
maximum temperature touches around 42°C during summer and
–3°C in winter. Average temperature fluctuates between 20.5°C
and 28.3°C. Average rainfall is around 2000 mm. Modal ecorace
is situated in between 21.32°N to 22.91°N Latitude and 86.35°E to
86.50°E longitude in Mayurbhanj Dist. of North Orissa with compact
block of virgin, moist-dry deciduous and semi-evergreen forests in
an altitude ranging up to 1182 meters above MSL.

Similipal Biosphere has a rich variety of plants. In addition to
many tree species, climbers and Orchids of attractive shapes and
sizes are seen. A total of 1076 sps. of plants including 87 orchids
have been identified. Similipal has a rich variety of animals. A list
of 42 species of mammals, 231 species of birds and 29 species
of reptiles have been prepared (Tripathy and Patro, 1997). In the
middle buffer zone and peripheral zone, tribes are leaving. After
becoming the forest reserve, Govt. of Orissa tried to shift the tribes
and prepared rehabilitation centre but some of the NGO has lodged
a case in Supreme Court in favour of Tribes against the Government
of Orissa.
1. Demarcation of simlipal biosphere

Entire Simlipal, genetic diversity as one of the factor, has been gazetted as a Biosphere Reserve in 1994. The Similipal Biosphere Reserve is the conglomeration of a National Park, a Project Tiger and a Sanctuary and divided into three zones viz., i) Central Core zone (with 845.70 sq km area where no human activity is permitted and gazetted as a National Park under the provisions of wild life protection act), ii) Middle Buffer zone (with 1904.30 sq km of area is gazette as a Sanctuary and restricted for conservation, research, environmental education & training, tourism and recreation) and iii) Peripheral zone (with 77.07 sq km of area is restricted to research and can be utilised as sustainable resource (Nayak et al, 1998).

- Copulation: Copulation takes place when emerged female moths are tossed into the net. Female moths after copulation lay eggs on bushes or leaf carpet. Such eggs are gently scraped and collected and disinfected. After disinfection, the eggs are kept in bamboo tray for incubation.

- Just before one day of hatching, eggs are clipped into food plants through leaf cups (Fig. 15). The trees selected for clipping should be at a good distance (200mtrs) from pagoda or base camp. Each big trees should not carry more than 3 leaf cups@ 20-30 eggs per cup.

2. Conservation Strategies Of Modal Ecorace

Seed

1. Time Of Collection : February – March From Sal Trees In Natural Forest After Leaf Fall; Long Distance Transportation To Be Avoided

2. Area Of Collection : Transitional To Buffer Zones Of Similipal Biosphere

Figure 15. Release of Modal eggs in Sal forest

- A distance of 2 m May be maintained between the two leaf cups. Distance between the 2 clipped trees may be around 20 m depending upon the availability of food plants. The larvae are left undisturbed to live on their own. The larvae comfortably complete their life cycle; spin cocoons, boosting up wild tasar population.

- At least 6 base came/pagoda is required to run closer to the core area of Similipal Biosphere.

Tourism And Recreation And i) Peripheral Zone (With 77.07 Sq Km Of Area Is Restricted To Research And Can Be Utilised As Sustainable Resource (Nayak et al, 1998).

- Copulation: Copulation Takes Place When Emerged Female Moths Are Tossed Into The Net. Female Moths After Copulation Lay Eggs On Bushes Or Leaf Carpet. Such Eggs Are Gently Scraped And Collected And Disinfected. After Disinfection, The Eggs Are Kept In Bamboo Tray For Incubation.

- Just Before One Day Of Hatching, Eggs Are Clipped Into Food Plants Through Leaf Cups (Fig. 15). The Trees Selected For Clipping Should Be At A Good Distance (200Mtrs) From Pagoda Or Base Camp. Each Big Trees Should Not Carry More Than 3 Leaf Cups@ 20-30 Eggs Per Cup.
3. Cocoon Characters
   Cocoon Colour – Blackish Grey
   Cocoon Stiffness – Hard And Tuff Uniform Cocoons
   Cocoon Size (Minimum) – Length: 5.0 Cm; Breadth: 3.0 Cm
   Peduncle Length: 4.3-6.5 Cm
   Peduncle Ring – Clear, Round And Thick Ring: Diameter: 1.08-1.44 Cm
   Cocoon Wt. (Min.) – Female: 13.0 G; Male: 9.0 G
   Sr % (Min.) – Female: 18.0 %; Male: 21.0 %

Cocoon Preservation-Cum-Grainage
1. Place Of Preservation : In Transitional To Buffer Zones Of The Biosphere
2. Grainage : Can Also Be Done Inside A Grainage House, If Available
3. Preservation : Hanging Garland In Nylon Net/Pagoda
4. Time Of Grainage : March - May
5. Oviposition : In Earthen Cups/Nylon Bags/Bamboo Baskets
6. Fecundity : Normally Above 250 Eggs Per Dfl (3 Days Oviposition)
7. Egg Disinfection : No Disinfection Or Surface Sterilisation Required. However To Avoid Fungal Infection And Remove Muconium, Light Soap May Be Used

Rearing
1. Season Of Rearing : Preferably May – June; If Climatic Conditions Are Congenial, Rearing Can Also Be Done In April, Rearing During August – September Is Not Advisable Due To Pests, Predators And Diseases
2. Place Of Rearing : In Situ Rearing, Preferably In Transitional Areas
3. Food Plant : Sal (S. Robusta)
4. Method Of Brushing : Worm Brushing On Sal Trees Of Medium Height In Compact Patched
5. Time Of Brushing : Early In Morning And Late In After Noon
6. Method Of Rearing : Natural Rearing With Minimal Of Interference

C. Conservation of Laria Ecorace
Laria is one of the important ecoraces of tropical tasar silkworm, A. mylitta distributed in various parts of Jharkhand State. The ecorace is notable for its small sized and robust cocoons with low denier (8-9) compared to Daba (10-12). The characteristic voltinism of Laria is uni, bi and tri but major population behaves as bivoltine. The farmers utilize Laria mostly for second crop as third crop is unstable and breeding behaviour during first crop in nature is not studied. In order to make Laria crop successful and remunerative, a suitable rearing schedule and package of practices has been developed for conservation of Laria ecorace utilizing vast Sal flora available in Jharkhand State.

1. Description of conservation site
Sal forest in Bhusur, Ormanjhi block of Ranchi district was identified as conservation site. The conservation site is situated in the Ormanjhi block of Ranchi district near Getalsud dam with longitude of 85.528°E and latitude of 23.458°N. S. robusta (Sal) is the dominant food plant with distribution of about 95%. Among other tree species Schleichera oleosa (Kusum), Emblica officinalis (Amla), Adina cordifolia (Karam), Anogeissus latifolia (Dhautha), Butea frondosa (Palas), Diospyros melanoxylon (Tendu), Semecarpus anacardium (Bhelwa), Terminalia beleica (Bahera), Terminalia tomentosa (Asan) are also found. This natural forest is on the small hillocks and undulating plains. The soil type was red loamy. The range of the forest has continuity with forests of Gola and Peterbar of Bokaro district identified as ecological niche for Laria ecorace.

2. Conservation net
Conservation rearing net utilized was made up of nylon polyamide (Code210D/213/25 mm) provided with interlocking polypropylene rope on all sides. The free fall size was 50'x50'x25' and this net covered 25 to 30 Sal plants of 15 to 20 feet height. Eight number of such nets were erected at the identified conservation site (Fig. 16).
3. Laria breeding material
Laria cocoons as breeding material were collected and sorting was carried out for dead pupa and flimsy cocoons. Cocoons were garlanded and hanged inside the net cover. In natural conditions the hanged and infused materials were observed to be attacked by rats, squirrels etc. To overcome this menace, inside the net cover at conservation site open cellars in the shade were erected with the help of iron mesh and bamboos during II year of conservation programme (2011-12). This cellar device checked rat menace and seed cocoons were protected from predator attack. Apart from the seed cocoons as breeding materials, eggs in leaf cups and gravid female moths in chullus (egg laying and transferring device made of local wild Kans grass (*Saccharum spontaneum*)) were also hanged inside and outside the net cover (Fig. 17).

4. Diversity in Laria breeding material
The ecorace Laria is notable for its small size and robust cocoons with blackish grey, grey and whitish grey colour and long peduncle with one or more rings. For infusion of breeding material, the cocoons of Laria collected from forest area were sorted out based on the sex and colour. Predominant colours of cocoons were recorded as whitish grey followed by yellowish cocoons. Samples for biochemical parameters viz. total proteins and reducing sugar contents were estimated in both haemolymph and testis in whitish grey and yellow cocoons.

5. Grainage behaviour
Laria ecorace shows facultative pupal diapause and is reported to behave as uni- bi- or tri-voltine. The seed cocoons (pupae in their shells) are preserved in the grainages for seed production. It was estimated that there is great loss during preservation due to unseasonal moth emergence and pupal mortality. In order to prevent loss of biomass experiment was designed and seed cocoons of the race were preserved in pucca grainage house (T1), mud wall grainage house (T2), outdoor under iron mesh net at CTR&TI, Ranchi (T3), outdoor preservation under nylon net cover at Virajpur, Kairo block, Lohardaga (T4) (Fig. 18) and farmers’ house, Rud village, Chandwa block of Latehar district (T5). Preservation of Laria seed cocoons was made from November through July. Pupal mortality in the cocoons preserved inside the room of pucca grainage house was observed to the tune of 24.4% whereas erratic emergence was 22.51%. Peak period of emergence was recorded 14.01 days. In T2, mud wall grainage house pupal mortality, unseasonal emergence and peak period of emergence was 20.13%, 12.29% and 20.02 days respectively. Minimum pupal mortality and peak period of emergence was observed in T4 at Virajpur. From the observations it is inferred that Laria seed production can be resorted by the preservation of seed cocoons in outdoor condition wherein pairing is also increased in comparison to pucca grainage house.

After having preliminary observations on the effect of different modes of preservation of Laria seed cocoons on the grainage performance during the year 2010-11, seed cocoons were hanged under sal trees which were covered with conservation net. The cocoons were consigned on 10th of May, 2010 and data were recorded for pupal mortality, moth emergence pattern, female and male moth emergence, pairing and peak period of emergence. The observations on grainage performance of the Laria seed cocoons infused in the Sal forest of Bhusur, Ormanjhi.

- Emergence in Laria seed cocoons was observed throughout the year. However, the peak emergence was recorded from last
week of June to first week of July. During this period the average emergence of male was 59.25 to 62.31% and female was 37.68 to 40.75%. During last week of August to second week of September, the peak period was observed in the II grainage. The male emergence percentage was 54.53 and that of female was 45.47% during this period. During the month of December about 42% of Laria silk moths emerged out indicating the weak voltinism with very low rate of coupling (20%). In the natural conditions, pairing was 80 to 85% in June-July and 88 to 91% in August-September. Univoltine cocoons were recorded to the tune of 2.723 to 9.36%. The egg laying behaviour was studied thoroughly and it was noticed that the female silk moths laid eggs in patches not only on bark, leaf and stem of Sal trees but also on different non-food plants (Fig. 19). The egg laying was in a scattered way, with clutch size of 9 to 16 eggs. Life cycle was allowed to continue in natural condition without human interference from June – July onwards.

**Figure 19. Coupled Moths Over Non-Food Plant**

6. Breeding behaviour and crop cycle

Laria silkworm may be categorised under diapausing and non-diapausing generation. The main difference between the two is the span of emergence and breeding period. In non-diapausing generations emergence starts after 20-25 days of spinning. The span of emergence in diapausing generations vary so much that it requires in depth study in its natural habitat with more emphasis on core areas. Observations revealed that voltinism pattern in Laria can be grouped in three categories namely uni-, bi- and trivoltine. Univoltine cocoons were observed to the extent of maximum 10%. About 60% of populations behave as bivoltine and about 30% behaves as trivoltine. Continuity of generations was observed throughout the year however main breeding season was noticed during June-July and August-September. Diapausing cocoons preserved in the Sal forest conditions show tendency to breed in winter although with low coupling percentage (20%) but the survival of the larvae was negligible. Further, observations revealed that the part of the larvae survived up to V stage of its life cycle but did not pupate.

First life cycle of Laria silkworm completed in 32 to 37 days (June – July rearing season) under temperature regimen of 24 to 32°C with relative humidity of 75 to 95%. Larval duration of second life cycle completed in 42 to 55 days (August – October rearing season) under temperature regimen of 20 to 30°C with relative humidity of 60 to 80%. Diapause occurred in pupal stage and continued for more than four months and regular moth emergence occurred in next June – July to start new cycle. It was interesting to note that emergence in Laria seed cocoons was observed to some extent throughout the year but not in an irregular manner. Therefore, all the life cycle stages starting from egg to final instar larvae were found available spread over larger area of conservation site. So, there was overlapping of generations. Results are indicative of the fact that there is tendency of multiple life cycles of this ecorace in core areas of its natural habitat. Some of the eggs were washed out of the net area by rain water. The silkworms hatched and fed on the Sal plants outside the net cover thus spreading to nearby area. A sizeable number of cocoons could be seen on tall trees outside the net which were left as such for natural proliferation of the race. These cocoons could not be collected as they were on the tall trees in a scattered way but not more than 4-5 cocoons on a single tree. The life cycle pattern observed in Laria ecorace in situ is indicative of the fact that this tendency of ecorace is the part for survival strategy in nature encountered with various pests and predators besides different environmental conditions and survival for the fittest completes its life cycle.

7. Overall impact of conservation programme and future strategies

In view of production of Laria cocoons, there are two sources for its commercial exploitation:

i. Collection of nature grown cocoons

ii. Harvesting of cocoons raised through rearing of Laria silkworm

In the former, there is no human handling and all the life cycle activities like moth emergence, coupling, decoupling, egg laying, hatching and growth of larvae, cocoon formation are fully dependent on natural environmental conditions without human interference, whereas in case of later, feed and growth of larvae and cocoon formation are out-doors and remaining activities are indoor wherein large scale pupal mortality, erratic emergence, unsynchronised emergence and pairing were noticed in the model grainage house. Observations revealed that Laria seed cocoons preserved under Sal forest of Bhusur, regular moth emergence was significantly delayed, emergence period was reduced and emerged male and female moths were more synchronised for coupling. The present study may lead to change in preservation methodology of seed cocoons of Laria. This concept came to solve the problem of large scale preservation of seed cocoons of Laria in outdoor conditions under shade, in or nearer to Sal forest.

Thus, it can be concluded that information generated from the above study may pave the way for future planning of preservation of seed cocoons and preparation of Laria seed to suit the requirement of the farmers. Cultivation of Laria is an important co-discipline of applied forest biology that needs special attention to promote conservation and sustainable utilization of its host plant, S. robusta.
(Sal) and Laria ecorace of A. mylitta as both are abundantly available as natural resources in Jharkhand which is the strength of the state and they contribute to rural tribal socio-economic and cultural heritage. The forest conservation needs basic information on ecology, environmental factors, climatology, Flora and fauna and their inter-relationship in the present observations while life cycle, reproductive biology, voltinism and population dynamics of Laria silkworm of eco-niche reveal their critical requirement. The commercial attributes of the viability and survival of the silkworm in the offered eco-climatic condition (Bhusur sal forest, Ormanjhi) suggests the effect of biotic and abiotic factors. Tropical silk insects have highly organised sensory and neuro-motor system with higher sensitivity than the higher organisms like vertebrates and the interaction of Laria silkworm and host plant-Sal is co-adaptation and co-evolutionary process. Thus the behaviour heterogeneity or plasticity within the population of wild silkworm Laria allows persistence or efficiently face the environmental changes. Thus, exploitation of host plant (Sal) and silkworm within the species is critical to attain optimal wild silkworm conservation due to umbrella effect.

<table>
<thead>
<tr>
<th>Character</th>
<th>Present Status</th>
<th>Potential</th>
<th>Standards</th>
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<tr>
<td>1. Survival %</td>
<td>30-40</td>
<td>60-80</td>
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<tr>
<td>2. Fecundity</td>
<td>175-200</td>
<td>250-300</td>
<td>&gt;300</td>
</tr>
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<td>3. Hatching (%)</td>
<td>65-70</td>
<td>80-90</td>
<td>&gt;80</td>
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<td>4. Larval duration</td>
<td>75</td>
<td>90</td>
<td>&lt;60</td>
</tr>
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<td>5. Shell ratio</td>
<td>10-12</td>
<td>12-16</td>
<td>&gt;12</td>
</tr>
<tr>
<td>6. No. of cocoons/kg raw silk</td>
<td>800-4000</td>
<td>800-2000</td>
<td>&lt;1280</td>
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<td>7. Denier/count</td>
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<td>7-8</td>
<td>8-10</td>
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<td>8. Filament length</td>
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<td>800-1000</td>
</tr>
<tr>
<td>9. Silk recovery</td>
<td>50-55</td>
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Salient points of breeding strategy to achieve these objectives are discussed below:

1. The first important question is for what we intend to go for hybridization. Firstly for more yield and secondly for quality yield. We have to enlist the contributing components of yield and workout the effect of hybridization on the yield components so that we may be very clear about the most affected components and degree of gains for a particular component in a particular cross. This will give us plenty of information on the response of a hybrid for a particular character. Examination of considerable number of such crosses will provide the requisite insight in the matter.

2. At this place another question comes to mind. Is hybridization the only way to achieve more yield and quality yield? A close watch on the scenario reveals that without the adoption of breeding methods we have great variations in most of the yield components. Obviously, causes for these variations are required to be worked out so that simulation of conditions to achieve desired variations may be possible.

3. The next riddle is to answer the questions – What we call better yield with what it has to be compared? Versatility in Daba BV, Daba TV and Sukinda has been proved. Naturally the comparisons are required to be made not only with parents but also with these check varieties. Unless the hybrids are better than check variety it has little significance in raising the production level. Due to semi-domestication of tasar, entire process of rearing and grainage is being practiced with the free mating system. Due to restricted mating system and human interference the quality of stocks gets deteriorated in comparison to natural ones. At this place we require to enforce methods for strengthening our stock to avoid deterioration and to invite further improvement.

4. Now comes the choice of material. What materials we are going to take for hybridization programme? Ecoraces (wild), ecoraces (acclimatized), endangered ecoraces, Semi-domesticated ecoraces, isolated lines from the ecoraces and so on. Whatsoever may be the choice of material it is clear that acclimatized ecoraces, semi-domesticated races and lines drawn from them are only in a position to be utilized for hybridization programme owing to consistency in its preservation, grainage and rearing behaviour.

5. Development of stable inbred lines. Tasar silkworm encounters high inbreeding depression upon inbreeding and hence inbreds are poor. Hybrids derived from them are heterotic, but not superior to prevailing material. This necessitates development of superior inbred lines. To achieve this, initially population has to be improved through recurrent selection and then inbreds may be developed with little inbreeding depression.

6. Sample size to maintain genotype is unknown. Breeders are constantly finding difficulty in maintaining breeding lines for longer time with their unique characters. Probable reason could be maintaining of these lines with small sample size. According to Hardy-Weinberg equilibrium genetic variation in population remain constant from one generation to next in the absence of disturbing factors like small sample, migration,
mutation and genetic drift. Therefore identification of minimum sample size at which breeding material show stable characters without any deterioration. This may be studied in priority.

7. For future utilization necessity of acclimatization and semi-domestication of isolated wild ecoraces is felt. Successful semi-domestication and isolation of lines from these non-exploited ecoraces will not only enrich the reservoir of parents but also keep the hybridization option open for the future.

8. Next step is the method to be employed:
Integrated approach to arrive at the actually differing ecoraces/lines derived from ecoraces based on suitable statistical methods taking parameters variations in different eco-climatic condition. Extensive survey to show the transition in cocoon character and behaviour of voltinism. Molecular characterization is required to be explored so that differences can sharply be detected.

9. Since our breeding stocks are being derived from nature and we are also pumping directly or indirectly genotypes from different stocks to the ecopockets through our seed system without having any restriction, the identity of races may get mutilated. To avoid this, ecopockets require to be delineated, introduction of seed to be prohibited and existing population be conserved to facilitate its proliferation.

10. Our study on hybridization remains restricted under Ranchi condition. Whatever, heterosis observed from different crosses were pronounced in Ranchi Field Laboratory conditions. Before arriving any conclusion in this aspect, the expression of hybridized genome for phenotypic traits must be verified in different geo-climatic conditions/locations. The change in morphological traits in A. mylitta ecoraces over a changed location is quite evident: because the domestication and influence of environmental factors seems much higher and intriguing than expected.

11. Our material is one time yielder in its life time (cannot preserve). There is hardly any way to keep the genotype for further use, if we encounter some mutant, isolate of breeding value, artificial insemination may solve the problem partly and work in this direction is most required.

12. All above efforts will not be fruitful unless standardization of race preservation and grainage methods were made so that comparisons are strictly on material difference and not on method/ condition differences.

13. As an immediate step, it is suggested that bivoltine x trivoltine cross may be made for large scale exploitation after working modalities like comparison of several of possible combinations, synchronization of emergence, raising of parents in sufficient quantity and arrangements for preventing the hybrids from use as seed.

14. It is found that there are more than a dozen of Sal based ecoraces, and also there exists vast sal flora in the country. So, necessary in situ breeding plans are to be implemented to achieve both horizontal and vertical growth in productivity.

15. Nutrigenomics research is more essential to study the interaction between the nutrient content of food crop and regulation of gene expression related to voltinism, fecundity, disease susceptibility, cocoon quality and quantity in A. mylitta to improve these traits in both food crop and silkworm using systematic breeding.

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Tasar Silkworm Rearing and Seed Technology: Its Recent Development

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Introduction:
Sericulture is one of the important sources of income for the rural populace, in India. It being the agro-based labour intensive industry a large number of farming families are involved in sericulture. Tasar silkworm (A. mylitta D.) is polyphagous in nature. The practice of tasar culture comprises of two major activities namely raising of plantations/maintenance of plantations for raising the leaf crop to feed the silkworm and rearing of silkworms to produce the cocoons which is the raw material for the silk reeling industry. Besides, management of silkworm rearing is also important for successful production of cocoon and thereby quality silk production. Several factors influence the rearing of silkworm and its management practices need proper care. Among various factors, quality silkworm layings, incubation of silkworm eggs, disinfection, selection of plantation area, maintenance of hygiene and rearing environments, quality of host plant leaf, disease and pest management etc. are important for silkworm rearing and its success. In this context Central Tasar Research and Training Institute (CTR&TI), Ranchi has developed various rearing and grainage technology to make tasar culture more profitable avocation for the farmers. Although, new technique has been fairly understood and practised by a good number of sericulturists today, still needs to educate them further and also others who are yet to take to it, so that the crop yields could be further improved.

Rearing of tasar silkworm:
The rearing method/process of tasar silkworm differs differently as per adoption of the developed technology. In this context, rearing methods are three different types:
- Experimental rearing
  - Outdoor condition
  - Indoor condition
- Seed rearers rearing
- Farmers rearing on forest plantation

1. Experimental Rearing:
Particularly, experimental rearing conducted at CTR&TI, field laboratory with all recommended package and practices. The rearing practices are:

1.1. Preparation of experimental blocks and plantation managements:
In order to conduct experimental rearing, demarked (with bonds) a portion of economic plantation of Arjun or Asan planted in a spacing of 4' x 4', comprising 70 plants (for taking up chawki rearing of 200-225 dfls). Prune the plants at 3 feet (for chawki rearing) and 5ft (for late age rearing) height during 1st fortnight of March and April respectively. Apply manure @ 3 kg FYM or 2 kg vermin-compost per plant by deep placement (9" deep around the plant). Apply fertilizers @ 100:50:50 NPK kg/ha/year

(Fig-1: Demarcation of experimental plots, Pruning, application of Bordeaux mixture & FYM, and spraying of bio-insecticides)
1.2. Cleaning and disinfection of rearing field
Before rearing, clean the rearing site by removing weeds, etc. from around the tasar plantation/bushes. In order to maintain hygiene, dust a mixture of bleaching powder and lime (1: 9) on the ground in and around the bushes. Dust the bleaching powder and lime mixture @ 10-15 gram per bush, once before rearing and then regularly at an interval of 4 to 5 days during rearing. Near the bushes, always keep a solution of 2% bleaching powder in 0.5% slaked lime (add 20 gram bleaching powder and 5 gram slaked lime in 1 litre of water) and water in two plastic tubs for cleaning of hands before and after handling the worms. Before using for rearing, wash all the rearing appliances by spraying with 5% bleaching solution and then keep them for sun drying. To disinfect the nylon net, dip it in a tank filled with bleaching solution (5%).

1.3. Incubation of tasar silkworm eggs
Each dfils should be kept separately (hatching box) for cellular rearing. Incubate the eggs at 28±2°C temperature and 70-80% relative humidity for a period of 8-10 days (Environmental chamber). Just before transfer, place the leaves inside the egg box and allow hatched larvae to crawl over the leaves and transfer on the marked food plant.

1.4.1 Rearing of chawki silkworm in outdoor condition
Fig-2:- Rearing under nylon net
Cover the chawki garden by firmly erecting a nylon net of 40’x 30’x 10’ size. One such net can cover 70 bushes which are sufficient up to sustain 200 dfils upto 2nd instar. Maintain cleaning and hygiene in the chawki garden, and use properly disinfected rearing appliances. If there is rainfall, shake off the water droplets/water on the nylon net to allow free circulation of air. Also, pull out the nylon net partially for better circulation of air and removal of excess humidity 5-7 times a day.

1.4.2 Rearing of chawki silkworm in indoor condition
CTR&TI, Ranchi (India), has developed several methods of indoor rearing of tropical tasar silkworm *Antheraea mylitta*, such as bottle rearing, pot rearing, box rearing, tray rearing and poly house rearing in order to reduce the loss of larvae and improve cocoon quality. The bottle rearing technique brushed the newly hatched larvae in a bottle containing water, covered with a polythene, and it does not require elaborate supervision as larvae is protected from pest through polythene, also the larvae need one to two feeding in first instar. The pitcher rearing use an earthen pot filled with water and twigs for food plants, but it does not facilitate the large-scale transfer of silkworms. The tray rearing method is found to be the most appropriate, where neonate larvae of tasar silkworm are reared in specially designed wooden trays, also helps to protect tiny worms from pest in most conductive macro and micro environment thereby improving the quantity and quality of rearing (Singh et al.,2009). However, recently CTR&TI, Ranchi has developed effective and successful method for chawki rearing on artificial diet (details in given below).

1.5. Rearing of late age silkworm
Transfer the young age worms from Chawki garden to late age plantation one day after 2nd moult. During transfer, distribute the worms on the plants uniformly to avoid overcrowding and handling of worms for frequent transfers. To prevent the worms from crawling down from the plants, wrap the plant trunk with 3”wide polythene strip coated with smell less grease on its outer face. To check the ant attack, smear the mixture of simple grease and Methyl Parathion (in a ratio of 100:15) on the plant trunk. When few worms
start spinning, transfer all the worms to plants having sufficient eating and hammock formation. To protect the worms from pests and predators, down to dusk watch and ward of rearing is essential.

1.6. **Disease and pest management during rearing period**

- To check the virosis and bacteriosis diseases spraying of Sodium hypochloride (NaOCl) (0.01%) solution on the bushes once in each instar from II to IV and twice in V instar after a gap of 5-7 days practices are adopted.
- Leaf Surface Microbe (LSM) is used for biological control of tasar silkworm diseases. It has strong antagonistic action against bacterial pathogens of tasar silkworm. Spray prepared LSM suspension on the leaves of food plants being used for rearing of 2nd instar larvae, preferably 24 hours after moult out.
- ‘Jeevan Sudha’ is a botanical formulation developed from medicinal plants for containment of virosis in tasar silkworm. Spray filtered solution on the foliage of bushes used for feeding the silkworm larvae, once each in 1st, 2nd and 3rd instar during feeding stage.
- Use sticky trap (Lassa-adhesive) for collecting and killing of various pests such as adult uzi wasp, Canthecona, Ichneumon fly etc.
- Spray 2% bleaching powder solution on silkworm body to kill uzi fly eggs, 3 to 4 times during 4 and 5th instars.

1.7. **Harvesting of cocoons**

Harvest the cocoons 6 to 8 days after spinning when they become stiff. For cocoon harvesting, cut the twigs holding cocoons and remove them from twigs carefully by pulling out or cutting their rings with a sharp knife.

1.8. **Selection of cocoons**

After harvest clean the cocoons by removing the leaves attached to them, and then sort out them in groups of good, dead, cut, pierced, flimsy and pest infested cocoons. Properly garland the good cocoons to use them in silkworm seed preparation and stifled other cocoons to be used for reeling and spinning purposes.

2. **Seed Rearkers/ Private grainuer Rearing:**

For seed crop rearing, rearing area must be fixed and maintained as per standard package of practices. The area shouldn’t be interchange with commercial crop rearing. The rearing practices are:

- Seed rearing area must have 1.5-2 km radius away from other crops to avoid chances of disease contamination. Rearing shouldn’t be practiced in water logging area. Selected plant height should be 5-7ft height.
- The rearing plot and plantations were disinfected properly through physico-chemically i.e. flame gunning or burning of plant residues, lime, bleaching and etc in each year.
- Dfs should be selected from Seed Act certified grainage by following three tier mother moth examinations. Dfs should be incubate at 28-30ºC temperature and 70-80% RH for ideal hatching.
- Application of lime: bleaching (9:1) mixture (10gm/bush) once before rearing and regularly during rearing at 5-6 days interval is required to maintain field disease free condition.
- Before commencement of rearing ant mounts must have destroyed and used Folidol as a repellant (during rearing period Folidol should avoid). In addition to this, after vigorous shaking the host plant application of brown tap with smellless grease around the trunk to avoid movement of ants from ground to the plant foliage.
- Days wise brushing should be conducted for uniformity of rearing. In addition to this, overcrowding of brushing should also be avoided for intra food consumption.
- Shifting of young age larvae must be carried out only by cutting twigs. Regular removal of dead and diseased larvae is highly essential to prevent further contamination of rearing plot. The collected larvae should be dipped in 5% bleaching solution and later on burned or cremated on ground.
- Regular watch and ward from down to dusk as well as management of pests and predators. Application of botanicals (Jeevan Sudha), LSM and chemicals (NaOCl) for management of diseases.
- For crop history larval testing should be conducted from 4th instar onwards to assess the disease occurrence (pebrine).
- Before spinning, larvae should transfer on the plant having sufficient leaf (if possible separate spinning plot may be selected).
- Harvest the cocoons after hardening (7-8 days after cocooning).

(Fig-4: Different rearing activities at ASR field)
3. **Farmers rearing on forest plantation**

In the wild condition farmers used leaf cups as brushing apparatus. The leaf cups are prepared with Siali leaves (*Bauhinia vahili*). Leaf cups containing eggs are clipped onto tall Sal trees. Number of cups per plant depends on the size of the tree. On an average each tree are clipped with 2-3 cups (Fig 5). Similarly, there must be some gap from tree to tree. A distance of 2 m is maintained between the two leaf cups. Cups are clipped towards the upper middle part of the tree. The larvae hatch and migrate towards the top of the tree to feed on the tender leaves. Gradually they grow in size and move downwards. The larvae are left undisturbed. The larvae comfortably complete their life cycle and spin the precious cocoons, thus boosting up wild tasar population. On an average not more than 5 to 6 cocoons are found on a Sal tree as the silkworm has to complete its life cycle in a natural ecosystem where it has to encounter pests and predators.

(Fig-5: Counting and keeping the eggs in leaf cups and Hanging of leaf cups on tall Sal trees)

4. **Preservation of cocoons for tasar silkworm seed production at commercial seed production centre:**

Preservation of seed cocoons in model grainage house minimizes loss of preserved cocoons during summer by reducing inside temperature by 5-7°C. It reduces unseasonal moth emergence and pupal mortality, and facilitates high seasonal moth emergence and mating, thus ensures the production of maximum quantity of seeds.

Country tiles grainage house

Pucca grainage house

Tubular grainage house

(Fig-6 Different tasar grainage house models)

4.1. **Model grainage house and its various activities**

- The cocoons are preserved in model grainage house (cemented house, country tile and tubular grainage houses).
- Model grainage house has a central preservation hall to accommodate seed cocoons and a verandah all around the hall to prevent direct sunlight. Windows fitted with wire mesh are provided in the hall for cross ventilation and only one door is provided to restrict the movement.
- **Disinfection:** Disinfect the grainage house by cleaning with 5% bleaching powder solution followed by fumigation with Formalin and Potassium Permanganate (Cemented house).
- Keep the surroundings clean and sprinkle 2% bleaching powder around the grainage house in order to maintain proper hygiene.
- **Garland preparation:** To prepare cocoon garlands, tie both male and female cocoons (60:40) at their peduncle ends with jute thread in a bunch of 5 cocoons each and form a garland of 20 such bunches (total 100 cocoons) providing space of 2-3" between two bunches. Hang cocoon garlands in the preservation hall by tying them to bamboo frames or wire strings leaving a space of about 6 to 8" between two garlands in a row and 1.5 to 2.0 feet between two garland rows to provide proper air circulation and operational movements. Hang cocoon garlands 2 feet above the ground level to facilitate cleaning of the floor.
- **Precautions during extreme weather conditions:** During hot summer, hang *Khus* mats or gunny cloth on the windows and door, and wet them by sprinkling water during day time
Maintenance of temperature and relative humidity: During grainage operations, maintain temperature of 25-30°C and relative humidity of 70-80% in grainage house by hanging wet Khus mats or gunny cloth on the windows and door.

Moth emergence: Usually moth emergence starts late in the afternoon and reaching its peak during 7.00 pm to 9.00 pm.

Coupling: Mating of moths takes place 2-3 hours after emergence, preferably in dark, cool and humid conditions. About 70 to 80% of female moths undergo natural mating inside the grainage house itself on the day of emergence. To obtain higher oviposition and hatching, allow moths to mate for 8 hours. In order to increase efficiency of grainage, the moth mating percentage can be enhanced up to 95% by releasing unmated moths inside the nylon net erected under cool and shady place which provides natural environment for mating. Release 1 virgin female moth surrounded by 3 males, maintaining moth density of 0.25 sq. ft per moth. In case of crisis, female and male moths are induced to undergo mating by hand coupling i.e., by rubbing the genitalia of both sexes with each other.

Decoupling: After required duration of mating (7-8 hrs), decoupling of moths done by moving the male and female moths in opposite direction so as to gently separate the mating moths without damaging to their genitalia. Even, decoupled males can be reused for second mating with virgin females.

Oviposition: To obtain higher egg recovery, healthy coupled female moths were kept for oviposition (in sweet box/ plastic egg laying devices) in a separate room with dark and hygienic conditions, maintaining temperature of 25-30°C and humidity of 70-80%. Allowed them for 72 hours to lay eggs.

Mother moth examination and surface disinfection: After oviposition for 72 hours, conduct individual mother moth examination for detection of Pebrine disease through pebrine visualising technology (details given in below). Disease free eggs were disinfection with Depuratex disinfectant.

Egg drying: After disinfection eggs were dryed with drying table. By using this machine 2000 dfls can be dried in 30 minutes.

Packing of eggs: The disinfected and dried eggs packed loosely in perforated plastic boxes or in muslin cloth bags.

### 4.2. Grainage operation at BSMTC

<table>
<thead>
<tr>
<th>Grainage operation</th>
<th>Period</th>
<th>Chemicals/disinfectant used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance of hygiene &amp; Disinfection</td>
<td>10 days before grainage</td>
<td>Grainage house and appliances are washed with 5 % bleaching powder followed by 3 % formalin solution.</td>
</tr>
<tr>
<td></td>
<td>8 days before grainage</td>
<td>Flame gunning of grainage house and appliances.</td>
</tr>
<tr>
<td></td>
<td>6 days before grainage</td>
<td>Spray 5 % bleaching powder solution in grainage houses.</td>
</tr>
<tr>
<td></td>
<td>4 days before grainage</td>
<td>Fumigation of grainage house by formalin and potassium permanganate</td>
</tr>
<tr>
<td></td>
<td>2 days before grainage</td>
<td>Open the doors and windows to remove fumes of formalin and potassium permanganate</td>
</tr>
<tr>
<td></td>
<td>1 days before grainage</td>
<td>Sprinkling of lime and bleaching powder 9:1 and in all round grainage houses.</td>
</tr>
<tr>
<td>During preservation</td>
<td></td>
<td>Cleaning of grainage floor with 5 % bleaching powder solution</td>
</tr>
<tr>
<td>During grainage operation</td>
<td>After completion of each day grainage operation floors are washed with 5% bleaching powder solution</td>
<td>Sprinkling of lime and bleaching solution at 9:1 ratio around the grainage house.</td>
</tr>
<tr>
<td>After each day grainage operation</td>
<td></td>
<td>Proper disposal of mother moth examination waste far away from grainage house.</td>
</tr>
</tbody>
</table>

Seed cocoon selection

| Physical selection: |
| Shell weight- 1.55 & above |
| Biological selection: Pupal examination |
| Pebrine (%)- below 5 % |
### Grainage operation

<table>
<thead>
<tr>
<th>Grainage operation</th>
<th>Period</th>
<th>Chemicals/disinfectant used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoon garland preparation &amp; hanging</td>
<td>Sealing to bamboo/ iron rod: 2-5 feet</td>
<td>Ground to garland: 2-3 feet</td>
</tr>
<tr>
<td></td>
<td>Bunch to bunch distance: 15-20 cm for easy eclosion of moth</td>
<td></td>
</tr>
<tr>
<td>Maintenance of abiotic condition</td>
<td>Diapause grainage:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temperature range: 30-34°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Humidity: below 70 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Devices used: wet gunny bags, wet sand in plastic container, Khas mats in door and windows</td>
<td></td>
</tr>
<tr>
<td>Selection of female moths</td>
<td>Moth selection based on dorsal vein observation. Clear blood vesseled moths are selected, and spotted, blackish moths are rejected.</td>
<td></td>
</tr>
<tr>
<td>Oviposition</td>
<td>Healthy moths are kept for egg laying in earthen cups and plastic egg laying boxes for 3 days.</td>
<td></td>
</tr>
<tr>
<td>Mother moth examination</td>
<td>Fuziwara method</td>
<td></td>
</tr>
<tr>
<td>Egg washing</td>
<td>5 % Depuratex @ 1 lit for 4000 dfls.</td>
<td></td>
</tr>
<tr>
<td>Drying</td>
<td>Eggs are dried in wooden dryers fitted with blowers.</td>
<td></td>
</tr>
<tr>
<td>Incubation</td>
<td>Incubated at 28±2°C at 75-80 % RH</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>Egg carrying boxes with Khas mat. To maintain proper condition eggs are transported to distance places by train by AC coaches.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All pierced cocoon are transferred to isolated grainages and kept until selling. All plastic egg laying boxes are disinfected with 9:1 ratio lime bleaching solution. Earthen cups are properly disinfected with flame gunning. Whole graining houses are disinfected with 5 % bleaching powder solution.</td>
<td></td>
</tr>
</tbody>
</table>

#### 5. Seed rearer’s grainage operation:

Most of the places seed rearers prepared grainage house by using low cost materials available in local area. One of ideal seed rearers grainage house is low cost green shade net grainage house.

![Low cost green shade net grainage house](Fig-7 Low cost green shade net grainage house)

#### 5.1. Advantages of low cost grainage house (Rathod et al., 2018):

- It is eco-friendly.

- The preservation loss is less in comparison to conventional grainage.
- Synchronization in emergence of the moth and pairing is better than conventional method.
- The prevailing condition in this grainage does not require any additional maintenance of temperature and humidity.
- In green shade net house inside temperature is lower by 2-3°C and humidity is higher by 5-10%.
- The shade net can be washed and disinfected easily with formalin and bleaching after completion of grainage operation.

#### 6. Farmers grainage operation in wild condition

Hill area studded with innumerable crests & valleys varied in topography, soil type, climatic and microclimatic conditions. With rivers, rivulets and waterfalls, the canopy is elegant and conducive. So, the forest type varies from moist-dry deciduous to semi-evergreen in nature. Thus it is bestowed with myriad of flora and fauna representing diverse valuable genetic resources. The forest area identified as core, buffer and peripheral zone. Core and buffer zones are restricted for sericulture activities; however, conservation...
and other programmes are permitted in peripheral zone. Peripheral Zone is the stretch of forest encircling middle buffer zone until it turns into a plain land.

6.1. Selection of Seed Cocoons
The traditional farmers collect wild cocoons from forests. They select it on the basis of size, bigger ones (female) are kept for egg production purpose. Sometimes the farmers buy them from nearby weekly markets where they are sold by cocoon collectors or middleman. Each farmer usually keeps 2 to 4 pons (160 to 320 cocoons) in their houses by garlanding them. Recently, efforts were made to preserve more number of cocoons in a selected house by formation of Rearer’s Group so as to maximize the recovery (Fig-8). Based upon the visual selection method the seed cocoons are selected. The area of base of the cocoon is broader and flattened. Thus, the chance of inclusion of females is more than 90%.

6.2. Egg production method
Moth emergence starts from the 3rd week of August and continues for about 20 to 25 days. The mating does not occur inside the house even if there is male moths emerged out from the preserved lot. So in the evening time, farmer takes the female moth to the nearby forest. For this purpose farmer prepare a small devise with cut branches of tree where each branch end is mounted with maize stalk. Female moths are allowed to sit on the maize stalk which supports the grip of moth. The female moth generally does not fly away. The farmers also go to the forests by group (Fig-9). They stay there for 2 to 3 hours and leave the females moth at a distance from them. Being attracted by the pheromone released by females male moths come flying from the forest and mate with the female. By this process about 95% females got the chance of mating. The farmers take back home the mated females on the branches, while unmated females moths are left there on another maize stalk branch overnight to allow mating. Normally, the mating continues till next day afternoon till female moths are kept inside bamboo baskets. Moths mated on a single day are kept in one basket, maximum up to ten. They cover the face of basket with plastic sheets with small holes. After that these baskets are hanged from bamboo structure or on walls inside the house for next three days to allow egg laying (Fig-9). Some farmers used Gangu leaf as oviposition devices (Fig-9). On an average a female would lay more than 300 eggs. The eggs are scrapped out, put on a bamboo tray. The eggs are rubbed with a pinch of homemade turmeric powder mixed with ranoo (also called as bakhar and mulika) (Fig-9). Ranoo/bakhar/mulika is the home made yeast used for fermentation of rice to prepare country drink called hadia/handia.
Egg washing solution

A. **Young age rearing on semi-synthetic diet (Tasar Amrit)**

Tropical tasar silkworm, *Antheraea mylitta* D. (Lepidoptera: Saturniidae) is a commercially important wild polyphagous sericigenous insect. It is an important component of Asian non-mulberry sericulture industry. The rearing of tasar silkworm is carried out in outdoor conditions where a major proportion (20-25%) of tasar silkworms die due to vagaries of nature, pest and predators etc (Sahay et al., 2000). during course of young age rearing. The one solution to this major bottleneck of the silkworm rearing lies in evolving a suitable semi-synthetic diet for tasar silkworm. The young age silkworms can be reared indoor on semi-synthetic diet and later transferred outdoor for carrying out late age rearing till spinning. This will save precious population of tasar silkworms and also help in increased production of tasar silkworm.

In tropical climatic conditions, tasar host plant leaf does not contain sufficient moisture and balanced nutrients, which ultimately affects the growth, development and surivibility of young age tasar silkworm. In order to cope of with situation, the present invented product called Tasar semi-synthetic diet (Tasar Amrit) developed at CTR&TI has been proved to be a foolproof alternative feed for young age tasar silkworm. Since it provides the requisite moisture (>75%) and optimum nutrients to the young silkworm as well as avoids pathogen contamination. Further, farmer need to feed Tasar Amrit only twice to thrice during rearing period which reduces labour in maintaining chawki garden, plucking chawki leaf and feeding the larvae every day in chawki rearing indoor condition.

**Methodology:** Methodology and process for tasar silkworm rearing on semi-synthetic diet is very simple which requires following key steps:

- Diet rearing tray (Length 2.5 feet x width 2 feet and height 4 inches) using 20 mm plywood. Bind the down portion of tray with 1-2 mm nylon-net-lon-jally (Fig-10).
- Rearing strands (bamboo or iron angel 11 feet (L) x 2 feet (B) x 5 feet (H)) for rearing trays make six racks.
- One day before egg hatching use the brown tape and paste the inner portion of tray using 2 inch length brown tape followed by pasting the thin layer of smell less brown colour grease on the tape.
- Inside the trays put small pieces of tasar amrit and brushed the newly hatched larvae, covered the trays with news papers (for darkening) and keep on rearing strands. *(This step can adopt before hatching also)*
- During the rearing process remove the litter regularly which pass through nylon-net-lon-jally.
- After completion of 5-6 days from hatching, keep the arjun leaves (with twig) in rearing tray and cover with another tray for 12 hrs followed by transfer of larvae to outdoor on food plants.
Benefits & usefulness of semi-synthetic diet:
- Larval survival % is about 87-92 for initial five days.
- As feed available while egg hatching, no starvation takes place.
- Uniformity in larval molting and growth.
- Diet fed larvae showed comparatively more body weight.
- Requires less human-handling of larvae.
- Rearing process is easy and man power requirement is less.
- Useful to curtail the initial loss 20-30% from egg hatching to 5-6 days.
- Improvement in ERR%, shell weight and silk ratio.
- It will helpful to maintenance of various stocks during adverse condition.
- Valuable to minimise the deleterious impact of impact global warming, useful for crop scheduling and multiplication of elite stock of tasar silkworm.
- Interestingly, diet is also functional to save the stock of tasar silkworm which emerges unseasonal / erratic or during dry spell of rain when outdoor rearing is not possible.

B. Novel Technology for pebrine identification in tasar silkworm

The pebrine disease in tasar silkworm caused by *Nosema mylilensis*, a microsporidia, is primarily spread by transovarial transmission from mother moth to next generation through eggs. To perpetuate Pebrine free generation of silkworm, disease free layings are produced through mother moth examination. Presently abdominal portion of female mother moth is crushed with Potassium bi carbonate (K₂CO₃) or Potassium hydroxide (KOH) and examined under microscope at 600X (15 X 40) magnification. The presence of fat globules, debris of body cells and other non pebrine artifacts in tissue sample, and improper liberation of spores from infected tissues make difficulty to identify the infective stage i.e. spore during microscopic examination. Examination of large number of samples at grainages and lack of trained personnel are other bottle necks. Hence, in the present technology, a successful attempt was made to develop a chemical reagent i.e. Pebrine Visualization Solution (PVS) for easy and quick identification of pebrine spores during microscopic examination of mother moth, and upgradation of existing microscopes with external light source and image capturing and transmitting device to increase the examination efficiency and the complete package of technology is termed as Pebrine Visualization Technology (PVT).

Salient features of PVT

1. Pebrine Visualization Solution (PVS) is developed for easy and quick identification of *Nosema mylilensis* spores causing Pebrine disease in silkworm.
2. PVS increases visibility by removing/dissolving tissue debris, fat globules and other non Pebrine artefacts in the smear.
3. External light source and image capturing and transmitting device reduce the stress and increase the examination efficiency.

Advantages of PVT

1. More sample can be examined with high precision even by a semi-trained person.
2. Helps to reduce the human error while examination because a live image on big screen of laptop/desktop is available.
3. Sample image (picture or video) can be captured and documented for future reference.
4. External continuous uniform light supply helps to examine the samples even inside the room.
5. The software of the image capturing and transmitting device is very small that works even in basic laptops or desktops.
6. Price of the technology will be decided by the competent authority.

How to use PVT?

1. Remove the eye piece of the compound monocular microscope and fit the image transmitter. Plug the one end of the cord image transmitter and other to the laptop/ desktop pendrive slot.
2. Replace the mirror for the external light with the battery-operated light source as shown in the figure 2.
3. Take a drop of the tissue homogenate on the clean slide and place a drop of Pebrine Visualization Solution (PVS) and mix for 10 seconds and place the clean cover slip.
4. Install the FUTURE WINJOE software in the laptop/ desktop and open the software. Now click on the webcam icon to receive the live image of the sample at 600x magnification.
5. Fine adjust the slide for better view.
C. Identification of live and dead spores

Recently a simple fluorescent dye technique has been standardized for identification of live and dead spores in tasar silkworm for various experimental purposes. The glass slides were daubed with spores, dried in the shade, stained with 0.02% of AO and 0.013% of PI (3:1) for 10 min. Fluorescence microscopy was used to observe the spores at excitation of 490 nm and the Grating filter at 510 nm (Jena et al., 2017).

![Live spores](image1)

![Dead spores](image2)

D. New oviposition devices

At present earthen pot or paper box (small sweet box) are used for tasar silkworm egg laying in which the eggs adhered to the bottom or sides tightly due the gummy substance muconium, which is very cumbersome, include much drudgery and involving more number of man days. To address these issues, CTR&TI, Ranchi has developed a newly oviposition devices for tasar silkworm. This is a round box made up of leaf green color plastic. The box size is 7.0cm diameter, 3.5cm depth, perforated with holes of 1.0 mm size all round and bottom, having roughness inner surface and bottom for the grip of tasar silk moth during egg laying. The size of the box is decided taking in to consideration of silk moth for its sitting and comfortable movement during egg laying. The lid is easily removable and the bottom of the box is easily fit in the lid. Further, round shape of the box provides more aeration for the moth due to gap between two rows during pile up.

![Fig-15 Newly developed oviposition box for tasar silk moth](image3)
the grip of tasar silk moth during egg laying.
- The size of the box is decided taking into consideration of silk moth for its sitting and comfortable movement during egg laying.
- The egg does not stick tightly with plastic material and takes less time in collection of eggs. The eggs can be collected easily and quickly by dipping the boxes along with eggs in a bouquet of water for a minutes and collect by filtering in nylon net
- Reduces drudgery, saves (50%) i.e. 100 man days as well in one lakh dfls processing without affecting the fecundity.
- This device is durable (6-7 years).
- Easily disinfect
- Require less storage space

E. Egg washing solution (Depuratex)
Depuratex is an ideal disinfectant, used for the surface cleaning and sterilization of tasar silkworm eggs. Depuratex improved hatching, sterilization and also reduced man days in washing of 10,000 layings. It is need based, very effective in cleaning and sterilization of tasar silkworm eggs, cost effective, user-friendly and easily adoptable to achieve qualitative and quantitative progress in tasar culture.

Advantages of Depuratex
- The process is very easy, simple, single step and takes only 10 minutes to complete egg washing and sterilization.
- Tasar silkworm eggs washing and sterilization process can be conducted in the same 5% aqueous solution of Depuratex.
- Chemicals which are involved in Depuratex are user friendly, emits leaving behind fragrance of roses.
- Depuratex cost is less and one litre is sufficient for washing and sterilization of 3000-4000 tasar silkworm layings.
- This technology needs only demonstration and no need trained personals to perform.
- Shelf life of Depuratex disinfectant is 3 years

Future strategies of CTR&TI, Ranchi
- Enhancement of fecundity in tasar silkworm, Antheraea mylitta through nutritional, physiological and mechanical approaches.

The quality tasar silkworm seed plays a vital role in productivity, sustainability and profitability of sericulture industry. Reproduction in insects is very closely related to nutritional factor, the qualitative and quantitative aspects of that have an impact on fecundity, rate of growth and development. A number of factors including hormonal, chemical, environmental, physical, behavioural aspects etc. have been attributed to be significant in successful egg deposition by female silk moth. Also the reproductive physiology, as mating, vitellogenesis, ovulation, oviposition, weight of pupae and pharate adult, surface texture and inclination also are important factors for viable egg deposition by adult female moth. Hence the upliftment of tasar seed sector to minimise the production demand gap through improving the reproductive performance of the silkworm can be achieved by multiple plausible angles of approaches like nutritional, physiological and mechanical ways.
- Cryopreservation of tasar silkworm, Antheraea mylitta semen and its artificial insemination

Conservation of the invaluable silicigenous genetic resources is of prime importance with respect to their utilization and improvement for wider exploitation. Conservation of wild silkworms and its applicability in hybridization have limitations due to incompatibility, less amenability, change of behaviour under ex situ conditions, non-synchronization of moth eclosion and difficulties in mating between variables. In view of this, the newer technologies such as cryopreservation and artificial insemination are offering better strategies for preservation of biologically active samples like semen at sub-zero temperature (-196°C) conditions for longer duration. Developed technique may have immense utilization in breeding programme, tasar gene banking and maintenance of semen copy as genetic resource of A. mylitta ecoraces in future.

Adoption of the improved technique in rearing as well seed sector recommended by the Institute is an essential step in tasar culture practice which would ensure sustained production of bumper crops.

Acknowledgments:
Our Special thanks to Dr. M.S. Rathod, Scientist-C, BTSSO Bilashpur for providing gainage photographs.
References:


Introduction
The rearing of Tasar silkworm, *Antheraea mylitta* D., is conducted in outdoor condition by the tribal peoples on the forest grown Asan and Arjun trees. Tasar farmers are losing their crop in forest based or economic plantation based rearing is mainly due to several pest of tasar silkworm like Endo-parasitoids (Ichneumon fly & Uzi fly) and predators (stink bug, reduvid bug, wasp, Praying mantis etc.,) which are natural enemies in abundance in the rearing field resulting in low yield of cocoons (Shiva Kumar and Shamitha, 2013). It’s accounts 80-90% crop loss due to pests, predators, natural calamities and diseases. Out of which in tasar silkworm pests, 10- 40% cocoon losses are caused by Uzifly and Ichneumon fly (Aruna et al., 2014). In general the seasonal occurrence of pest, range of crop loss (low to high) due to pest and susceptible stage of silkworm are given in table number 1.

Table -1 Major Parasites and Predators of tasar silkworm, *A. mylitta*

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Biological Name</th>
<th>Common Name</th>
<th>Seasonal Abundance</th>
<th>Economic Loss (%)</th>
<th>Susceptible Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Endo-parasitoids:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td><em>Dermestes ater</em></td>
<td>Dermestid beetle</td>
<td>June – Jan ** Aug- Nov</td>
<td>5-10</td>
<td>Spinning stage larvae</td>
</tr>
<tr>
<td>4.</td>
<td><em>Agamermis mylittensisantheraea</em></td>
<td>Nematode</td>
<td>July to Dec ** July to Sept</td>
<td>5-10</td>
<td>5th instar larvae</td>
</tr>
<tr>
<td></td>
<td>Insect Predators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td><em>Hierodula bipapilla.</em></td>
<td>Praying Mantis</td>
<td>Throughout year **Aug. – Oct.</td>
<td>5 – 7</td>
<td>1st, 2nd &amp; 3rd instar larvae</td>
</tr>
<tr>
<td>5.</td>
<td><em>Oecophylla smaragdina</em></td>
<td>Red Ants</td>
<td>Throughout year ** July – Feb.</td>
<td>5 – 7</td>
<td>1st, 2nd &amp; 3rd instar larvae</td>
</tr>
<tr>
<td></td>
<td>Non-insect predators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Birds</td>
<td>Throughout year</td>
<td>10-40</td>
<td>3rd – spinning</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Lizards</td>
<td>Throughout year</td>
<td>5-20</td>
<td>1st, 2nd &amp; 3rd instar larvae</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Squirrels</td>
<td>Throughout year</td>
<td>5-20</td>
<td>Cocoon</td>
<td></td>
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<tr>
<td>4.</td>
<td>Rats</td>
<td>Throughout year</td>
<td>2-20</td>
<td>Cocoon</td>
<td></td>
</tr>
</tbody>
</table>

** Indicate peak period

Sources: CTR&TI, Ranchi and different centre of RSRS and REC
Seasonal occurrence of pest

The occurrence of pest (parasite & predator) is mainly governed by three components (called triangle concept) viz., host, pest and environment. During the period of silkworm rearing, silkworm acting as host, endo-parasitoids & predator acting as pest and weather during rearing period as environment. These three components are determining success of tasar cocoon production. When all three components are presence in favorable condition resulted in high pest severity which consider peak period caused maximum crop loss. Among three components, if any one of the components is absent or prevailing unfavorable condition resulted in minimum crop loss. There is less amenable to change host and pest during rearing period and modification of micro climate is possible through altering brushing date, brushing direction, density of leaf canopy and suitable agronomical practices.

Economic loss is a term of art which refers to financial loss and damage suffered by a pest. Range of economic loss in tasar culture (low to high) caused by endo-parasitoids are Uzi fli (10-40), Yellow fly (10-48), Dermistid beetle (5-10) and predators viz, stink bug (10-15), reduviid bug (10-30), wasp (10-15), praying mantis (5-7), red ants (5-7) and black ants (5-15) respectively.

Susceptible stage

Silkworm larval phenological stage can directly affect pest infestation, which may increase or decrease as the silkworm develops, depending on the pest. Information regarding the susceptibility of silkworm to pest can help in identifying the best times to spray and can contribute to developing efficient approaches for pest control management. It is most important factor for occurrence and outbreak of pest during tasar silkworm rearing period. When tasar silkworm larva goes in susceptible stage for pest, probability of particular pest severity is high. On basis of historical records we identified the silkworm stage which is susceptible for various pests viz, III, IV, V stage susceptible to uzi fly, spinning stage susceptible to yellow fly, dermestid beetle and I – III stage are susceptible to stink bug, reduviid bug, wasp, red ants, black ants and praying mantis. In case non insect predators several centre’s has been reported viz., birds, lizards, squirrel and rat. On the basis of above mentioned information, microclimate / weather should be modified by brushing date, canopy cover of tasar food plants, continuous monitoring of silkworm during rearing period and timely applying management practice.

Mitigation and adaptation of these problems (parasites, predators & environmental conditions) during rearing period of silkworm is a challenging task in Tasar culture. A solution to these problems is not only enhancing the quality and quantity of tasar silk production but also improve the socio-economic status of the farmers/ tribal people.

Current status of major predators and parasites in different tasar growing areas

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Centre</th>
<th>Major pest</th>
<th>Minor pest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jharkhand State</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>CTR&amp;TI, Ranchi</td>
<td>Stink bug and crow</td>
<td>Reduvid bug, wasp, praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td>2</td>
<td>BSM&amp;TC, Kharsawan</td>
<td>Stink bug and wasp</td>
<td>Reduvid bug, praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td>3</td>
<td>BSM&amp;TC, Kathikund</td>
<td>Stink bug and wasp</td>
<td>Reduvid bug, praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td>4</td>
<td>BSM&amp;TC, Madupur</td>
<td>Reduvid bug and stink bug</td>
<td>Praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td>5</td>
<td>RSRS, Dumka</td>
<td>Stink bug and wasp</td>
<td>Reduvid bug, praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td></td>
<td>Chhattisgarh State</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>BSM&amp;TC, Pali</td>
<td>Yellow fly, reduvid bug and yellow fly</td>
<td>Reduvid bug, praying mantis and uzifly</td>
</tr>
<tr>
<td>2</td>
<td>BSM&amp;TC, Ambikapur</td>
<td>Stink bug, Reduvid bug and yellow fly</td>
<td>praying mantis and uzifly</td>
</tr>
<tr>
<td>4</td>
<td>CTSSS, Kota</td>
<td>Stink bug, Reduvid bug and yellow fly</td>
<td>praying mantis and uzifly</td>
</tr>
<tr>
<td>5</td>
<td>RSRS, Jagdalpur</td>
<td>Stink bug, Reduvid bug and yellow fly</td>
<td>praying mantis and uzifly</td>
</tr>
<tr>
<td>S. No.</td>
<td>Centre</td>
<td>Major pest</td>
<td>Minor pest</td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Odisha State</td>
</tr>
<tr>
<td>1</td>
<td>BSM&amp;TC, Sundergarh</td>
<td>Reduvid bud</td>
<td>Stink Bug, Reduvid bug, praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td>2</td>
<td>BSM&amp;TC, Nabarangpur</td>
<td>Stink bug</td>
<td>Reudivid bug, praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td>3</td>
<td>BSM&amp;TC, Baripada</td>
<td>Stink bug Reduvid bug and wasp</td>
<td>praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bihar State</td>
</tr>
<tr>
<td>1</td>
<td>BSM&amp;TC, Bhagalpur</td>
<td>Stink bug</td>
<td>Reduvid bug, praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Madhya Pradesh</td>
</tr>
<tr>
<td>1</td>
<td>BSM&amp;TC, Balaghat</td>
<td>Stink bug</td>
<td>Reduvid bug, wasp, praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maharashtra</td>
</tr>
<tr>
<td>1</td>
<td>BSM&amp;TC, Bhandara</td>
<td>Stink bug</td>
<td>Reudivid bug, wasp, praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td>2</td>
<td>RSRS, Bhandara</td>
<td>Stink bug</td>
<td>Reudivid bug, wasp, praying mantis, uzifly and yellow fly</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>West Bengal</td>
</tr>
<tr>
<td>1</td>
<td>BSM&amp;TC, Patel Nagar</td>
<td>Wasp</td>
<td>Stink bug Reduvid bug Praying mantis, uzifly and yellow fly</td>
</tr>
</tbody>
</table>

1. PEST INFESTATION AND THEIR MANAGEMENT OF TASAR SILKWORM

1-A, ENDO-PARASITOIDS OF TASAR SILKWORM

1-A, Endo – parasite, 1-B, Predators & Non Insect Predators

(i) Classification

![Classification and symptoms of Uzi fly](image)

(ii) Geographical Distribution: Uzi fly, *B. zebina* is widely distributed in tropical tasar region of India, China, Thailand, Bangladesh and Japan. An epidemic outbreak of its population occurred in Bastar (Chattishgarh), Nowrangpur (Orissa) and Kharsawan (Jharkhand), and caused over 40% loss to tasar silkworm crop. It is also reported in North-Eastern India infesting Muga silkworm. Several species of lepidopteran caterpillars have been recorded as hosts of *B. zebina*.

(iii) Life Cycle: Adults are blackish gray in colour. Male is longer in body length (about 14 mm) than female (about 12mm). The head is triangular in shape. On the dorsal side of the thorax, there are four longitudinal black bands. It has got bare bristles on the antennae and bristles of big size on the ventrolateral side of the abdomen. The abdomen is conical with four segments and has got two white stripes. The first abdominal segment is black and the remaining are grayish–yellow in colour. Life span of adult fly varies with sex and season. Male survives for about 10–15 days and female lives for 3–4 days longer than males. The wings are typical tachinid type with marginal spiny projection. Male can be distinguished from the female by the presence of external genitalia covered with brownish orange hairs on the ventral side of the abdominal tip. The width of the frons of the male fly is narrower than that of the female one. Longitudinal lines on the dorsum of the thorax of the male are more vivid than female. The pulvilli of male are longer than female. Adults exhibit definite courtship behavior. Males have no distinct orientation posture towards the females and they strike the resting and walking females. Mating strike by male is followed by agitated state of the female before the pair establishes the successful genital contact. Sometimes mating takes in the air. Premating period is about 6–8 hours. The adults are polygamous; they mate 3–8 times in the entire
life. Mating generally takes place during early morning or in the late evening. The duration of mating ranges half an hour to two hours. A minimum of one hour mating is required for full fecundity and maximum hatchability. Mating is not a prerequisite for egg deposition since virgin female can also lay unfertilized eggs.

Oviposition starts two days after their emergence. Female uzifly approaches the host larvae and after repeated survey settles down on the body of host. At the time of releasing the eggs, the female fly bends her abdomen in such a way that the tip of her abdomen touches the host integument. After releasing one egg, the female fly withdraws its posture; walks over the host body and releases egg at different locations on the silkworm body in similar manner. A single mated female fly lays about 300–500 eggs over a period of 8–10 days. Eggs are macro type and creamy white in colour. A single egg measures 0.49–0.60 mm in length and 0.28–0.32 mm in width. They are oblong in shape and hatch in about 2–3 days after oviposition depending upon the climatic condition. Once hatched, the maggot penetrates into the body of the silkworm leaving black spot (lesion or scar) on the skin of larvae.

Maggots pass through three instars. In the first two instars, they develop just below the skin of the host body and in the final instar they leave this site and move in to the body cavity. Maggots of first and second instars are yellowish – white in colour, while the third instar maggots are creamy – white in colour. The full-grown maggot is nearly 16 mm in length. Maggots have eleven body segments. The mature maggots escape from the host body by piercing the integument by its pro – thoracic hooks in about 10 – 12 days. They feed on various tissues of the silkworm body and the host larva dies by the time the maggots are mature to escape out from the host body. The mature maggots come out after killing the host.

Fig: 3- Life cycle of Uzi fly
The escaped matured maggots which are negatively phototropic and positively geotropic, pupate in about 20–24 hours. They pupate inside ground or in any dark place or in loose soil. The pupae are nearly 12 mm in length and dark brown in colour. Adults emerge out in about 12–15 days. The male adults always emerge out earlier than females.

(iv) Symptoms: The silkworm larvae infested up to early fifth instar die before they reach the spinning stage. If the infestation takes place in the late fifth instar, the mature maggot comes out by piercing the cocoon and thereby rendering the cocoon unfit for mass reeling. Infested silkworm can be identified by the presence of black scar on the part of the skin where the maggot penetrates in to the body of the host larvae. Sometimes, an eggshell is left behind in the center of the black scar. At the initial stage of infestation minute creamy white oval eggs smaller than pinhead are observed on the skin of the larvae.

(v) Period of Occurrence: The incidence of this parasitoid starts from August and goes on increasing to reach its peak by the end of January. During the first crop the incidence of this parasitoid is comparatively less.

(vi) Management: For the prevention and control of Uzi fly an integrated approach involving physical, chemical and biological methods is suggested.

IPM Package for the control of Uzi fly, Blepharia Zbina Walker

Mechanical:
- Uzi fly infested / dead silkworm larvae should be collected and destroyed.
- Uzi fly maggots / Pupae should be collected from rearing field / grainage house and destroyed.
- Flimsy and uzi fly infested cocoons should be harvested early and stifled or sun dried.
- Sticky trap (Lassa - adhesive) should be used for collecting and killing the adult uzi flies.

Chemical:
- Bleaching powder solution (2%) as an ovicide can be applied on silkworm body to kill uzi fly eggs. This treatment has to be repeated four to five times.

Schedule of spray:
- IV instar : III rd day once
- V instar : III, V and VII day once each (if larval duration is prolonged, one additional spray should be done on IX day).

Biological:
- Nesolynx thymus (Hymenoptera: Eulophidae) a bio- control agent of uzi fly to be released at the rate of 1,00,000 adults for 100 dfls of silkworm rearing.
- Schedule of parasitoid release:
  - Once at the time of cocoon harvest : 30000 adults
  - Once after seven days of cocoon
  - harvest in rearing field : 40000 adults
  - Once after seven days of cocoon
b. ICHNEUMON FLY, *Xanthopimpla pedator* (Hymenoptera: Ichneumonidae)

The ichneumon fly is a parasite of tasar pupae inflicts about 5% crop loss. The adult fly is 2-2.5 cm in length with two pairs of transparent wings and a pair of prominent antennae. The insect is yellow in colour having dorso-lateral black spots on each sternum. The pro-thoracic shield also bears four black spots. The female fly has nearly 1 cm long prominent needle like ovipositor with two long styles.

(i) Classification

(i) Geographical Distribution: Ichneumon fly is widely distributed in tropical tasar region of India especially, Jharkhand, Orissa, Chattishgarh, West Bengal and Andhra Pradesh. An epidemic of its population occurred in almost all tasar zones.

(iii) Life Cycle: The female fly lays eggs inside the larval or pupal body by inserting its ovipositor through freshly formed flimsy cocoon shell. The eggs are small with hard chorion. Only one egg is deposited in each host body. The maggot after hatching consumes the entire pupal content of silkworm except the skin and then pupates itself. The adult parasite makes its way through the anterior portion of the cocoon shell rendering it soft, which facilitates its emergence.

<table>
<thead>
<tr>
<th>Developing stages</th>
<th>Body length (mm) Range</th>
<th>Body width (mm) Range</th>
<th>Duration (days) Days from oviposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>First instar (L1)</td>
<td>3.6-4.0</td>
<td>0.8-1.0</td>
<td>2-3</td>
</tr>
<tr>
<td>Second instar (L2)</td>
<td>8.3-11</td>
<td>1.7-2.0</td>
<td>3-5</td>
</tr>
<tr>
<td>Third instar (L3)</td>
<td>11.5-14</td>
<td>4.2-6.0</td>
<td>7-8</td>
</tr>
<tr>
<td>Fourth instar (L4)</td>
<td>17-22</td>
<td>09-12</td>
<td>9-12</td>
</tr>
<tr>
<td>Fifth instar (L5)</td>
<td>35-40</td>
<td>13-15.5</td>
<td>13-16</td>
</tr>
<tr>
<td>Prepupa</td>
<td>19-23</td>
<td>6.3-8.6</td>
<td>17-18</td>
</tr>
<tr>
<td>Pupa</td>
<td>21-23</td>
<td>6.1-6.4</td>
<td>19-20</td>
</tr>
<tr>
<td>Adult</td>
<td>20-22</td>
<td>5.1-5.5</td>
<td>20-22</td>
</tr>
</tbody>
</table>

(Source: Project – ARE-4710, submitted final report 2019)
(iv) **Occurrence**: It parasitises on tasar silkworm of both first and second crops, the incidence is higher during second crop i.e., from October to December. The incidence gradually decreases and comes to almost nil by middle of January.

(v) **Symptoms**: Hole on the cocoon near peduncle is the critical identifying symptom for this predator.

(vi) **Damage**: 5–10% cocoon loss is generally observed.

(Vii) **Alternate host of the yellow fly**
A survey was conducted at farm of CTR&TI, Ranchi, BSMTC, Kharsawn, MSM&TC, Chennure, PPC, Kharsawan, Chaibasa, Debrasai, Hatgamaria, Noamundi, Chakradharpur, Bharbharia and their adjoining areas for assessing the alternate host of *Xanthopimpla pedator* during off season of tasar silkworm for survival and its multiplication. In these survey identified the secondary host (Moon moth) of yellow fly at BSM&TC, Chennure.
Control measures:

- Trapping of adult flies with the help of insect catching net.
- Collection and killing of adults emerged in the grainage house and surrounding places.
- Fitting of wire mesh on doors and windows of the grainage house to prevent flies escape in the nature for further multiplication.
- Use of nylon net at the time of spinning
- Use of repellent such as Citronella/turpentine oil nearby spinning bushes
- Sorting and stifling of infested cocoons immediately after harvest.

C. Dermestid beetle, *Dermestes ater*

Dermestid beetle is a minor endo-parasitoid which not only reduces cocoon production but also reduces the quality & quantity of silkworm seed. Both the grubs and adults feed on the pupa resulting in damaged and seedless cocoons. The female beetles lay eggs in the floss of cocoons. Due to its attack, the pupae are damaged subsequently affecting their quality.

(i) Classification

(ii) Life cycle of Dermestid beetle

**Egg:** The eggs were small, round and creamy white in color when laid latter turns to pale yellow at the time of hatching. The egg incubation period was $7.33 \pm 0.33$ days. Grubs: The newly hatched grub was milky white in color with dark bristle and later turned to light brown. The colour of the grubs gradually turned darker after each moult. They fed on silk fiber, dead pupa, dead moth and cocoon shell. The first instars lasted for 3-4 days with an average of $3.33\pm 0.33$ days. After completion of first instar they settled for first molt, the duration of first molt was 03 days. Second instar grubs were reddish brown in color and fed on dead silk moth and cocoon shell. Second instars ranged from 3-5 days with an average of $3.66\pm 0.66$ days. Second molting duration lasted for 3 days. Third instars grubs were bigger in size and dark brownish black in color. The third instar duration ranged from 4-6 days with an average of $4.66\pm 0.66$ days. The third molting duration lasted for 4 days. The fourth instars duration varied from 5 - 6 days with an average of $5.33\pm 0.33$ days. Fourth molt Duration was 5 days. The fifth instar grubs were black in color, the instar duration ranged from 20 - 21 days with an average of $20.33\pm 0.33$ days. The molting duration of
fifth instar was 20 days. The sixth instar duration ranged from 29-30 days with an average 29.66 ± 0.33 days. The grubs were black in color and fed on dead silk moth, cocoon shell, dead pupa and silk fiber. Sixth instar grubs settled for moult during which it transformed into pupa.

**Pupa:** The pupa was enveloped by the larval skin, which is not shed, but with a split along the dorsum. The pupa was oval shaped, light yellow in color and pupal duration was 7-8 days with an average of 7.33 ± 0.33 days. After completion of pupal duration the adult emerged.

**Adult:** The adult beetle was black in colour and measured 8mm in length and elongate in shape. They were observed to feed on dead pupa, moth, silk fiber and cocoon shell.

**Adult longevity:** In laboratory the longevity of adult beetle ranged from 8-14 days with an average of 11.33 ± 1.76 days. (Table 2)

---

**Fig: 10- Life cycle of Dermestid beetle**

**Table 3- Life cycle of Dermestid beetle**

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Mean(days)</th>
<th>Particulars</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incubation</td>
<td>Period 7.33 ±0.33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>I Instar</td>
<td>3.33 ±0.33d</td>
<td>I Moult</td>
<td>3.0</td>
</tr>
<tr>
<td>II Instar</td>
<td>3.67 ±0.67d</td>
<td>II Moult</td>
<td>3.0</td>
</tr>
<tr>
<td>III Instar</td>
<td>4.67 ±0.67d</td>
<td>III Moult</td>
<td>4.0</td>
</tr>
<tr>
<td>IV Instar</td>
<td>5.33 ±0.33cd</td>
<td>IV Moult</td>
<td>5.0</td>
</tr>
<tr>
<td>V Instar</td>
<td>20.33 ±0.33b</td>
<td>V Moult</td>
<td>20.0</td>
</tr>
<tr>
<td>VI Instar</td>
<td>29.96±0.33a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pupal Stage/ VI Moult</td>
<td>7.33 ±0.33c</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total duration from egg to adult</td>
<td>143 days</td>
<td>Total Mouling duration</td>
<td>35.0</td>
</tr>
<tr>
<td>Adult longevity</td>
<td>11.33±1.76</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>F-VALUE</td>
<td>155.089 **</td>
<td>F value</td>
<td>558.150 **</td>
</tr>
</tbody>
</table>

**Significant at 1%**

d. **Nematodes, Agamermis mylittensis antheraea in tasar silkworm**

The severe infestation of nematodes have been reported from various tasar silkworm rearing areas in the states of Telangana...
and Odisha Chinnor, Warangal and Nabarangpur. Various authors have reported moderate to severe infestation of the unidentified genera of nematodes in tasar silkworms from major tasar rearing areas of India (Griyaghey and Das, 1982; Chaudhuri et al. 1995; Yadav, 2014). Mondal (1986) recorded a nematode parasite and presumed that it may be a Hexamermis sp.

Poinar (1975) has mentioned the infestation of Indian tropical tasar silkworm, Antheraea mylitta (Drury), by a nematode parasitoid. Fifth instar larvae of the tasar silkworm are found to be infested with a nematode parasitoid (family Merminthidae) during the first generation (rearing season) of the year (i.e., July-August). The first rearing season of the year generally commences in July, with the larvae reaching fifth instar in August. It is discovered that fifth instar larvae of the first generation is infested by Nematodes parasitoids, while first, second, third, and fourth instar larvae do not show any symptoms of infestation. First generation infestation appears to be related to the high percent relative humidity and high temperature and associated heavy rainfall during July and August. No nematode infestation was detected in the second generation larvae reared during September-October, a period when temperature, rainfall, and percent relative humidity are comparatively low.

Numerous thin, threadlike nematodes are observed inside mature fifth instar larvae after dissecting their abdomens (Fig.11). The nematodes were whitish, with smooth skin, pointed at both ends, with an unsegmented body (Fig. 12). The length of adult nematodes ranged from 166 to 294 mm. Most of the fat body mass and silk glands of the host were utilized by the nematodes. Infested silkworms gradually lose their ability to grip the host plant; ultimately, the larvae fall from the plant. The body of the infested silkworm becomes shortened from the shrinkage of the outer body wall as the parasitoid utilizes the tissue inside the body of the host. Finally, the infested larva dies, and the threadlike adult nematodes exit the host body through its anal opening. Infested silkworms were unable to spin the silk necessary for cocoon production. Only the larvae of the silkworm were found to be infested by nematodes. In contrast, pupal and adult stages of other insects are known to be nematode hosts (Anderson & Laumond 1992, Mannion & Jansson 1992, Poinar 1992).

**Fig: 11&12- Nematods infected tasar silkworm and Nematodes treads**


**Management of Nematodes in tasar culture**

- Keep the plantation free from weeds.
- Maintain proper drainage in rearing field as rain followed with high humidity is conductive for nematode transmission.
- Flame gunning of the rearing field before brushing.
- Two times deep ploughing of rearing fields at 15 days interval during summer months to expose the nematode stages to solar radiation.
- Apply FYM @ 2kg/plant + Neem cake/Karanj Cake @ 50g/plant in soil which provides the necessary substrates for rapid growth of the nematodes antagonistic organisms.
- Provide adequate quantity of NPK fertilizers to strengthen the plant vigour, Urea has the nematocidal property.
- In heavily infested soil apply Carbofuran(Furadan) 3g or Rugby (Cadusofos) 10g @ 2-4g/plant near the base of plant soil. The foliage of treated plant can be utilized for rearing after 45 days of Insecticide/Nematicide application.
- Application of lime and Bleaching powder (9:1) around tasar food plant is also effective for nematode management. Spray of 1.5% urea solution 30 days before brushing on the plant foliage, as Ammonia inhibits nematode population.
- Burning of infested silkworm larva and rearing waste/stubble etc. during rearing to check further spread.
- Foliar spray of 0.02 to 0.03% Phenamiphos No1 or 0.005 to 0.01% Phenamiphos No2 on silkworm feed can successfully kill the nematodes inside the insect and on leaves and retains its activity on leaves up to one month and does not harm the silkworm.

**Sources:** [http://www.cttiranchi.co.in/Files/pdf/11d74492-4bb8-4a99-bc18-b40cf80a244c.pdf](http://www.cttiranchi.co.in/Files/pdf/11d74492-4bb8-4a99-bc18-b40cf80a244c.pdf)

1. **B. PREDATORS OF TASAR SILKWORM**

   The major predators of tasar silkworm are viz., Stink bug, Reduviid bug, Praying mantis, Wasp and Red Ant which reduce the quality and quantity of tasar cocoon production.

   a. **Stinkbug, Canthecona furcellata:** (Hemiptera: Pentatomidae)
Canthecona bug is the most harmful predator and is responsible for about 15% of the crop loss particularly during early instar larvae (chawki worms). The adult are of peculiar appearance having brownish triangular body. The size of the adult is about 15mm in length and it has a long sting on the mouth. It is also known as pentatomid bug. The female is broader than the male and carries mid–ventrally a pink spot on the sternal part of the fifth segment.

(i) Classification

(ii) Geographical Distribution: Stinkbug is widely distributed in tropical tasar region of India. An epidemic of its population occurred in Baripada (Orissa) and Dumka (Jharkhand) and caused high crop loss of tasar silkworm.

(iii) Life Cycle: Egg laying starts in 24 hours after mating. On an average single mated female lays 200 – 300 eggs in batches of 40 – 70 usually on the under surface of the leaves or on the twigs. Oviposition continues for 6-7 days. Each egg mass consists of four to five rows of 8-15 eggs. The eggs, which are silvery initially, turn coppery just before hatching. The hatching takes place in about 6 days.

The nymphs pass through five instars. The abdomen of the nymph is red with black markings. The thorax and pronotum of first three instars are black, while in fourth and fifth instars they are reddish in colour. The legs, proboscis and antennae of all the nymphal stages are black. The entire nymphal period is about 18 days, and during this period the nymph starting from 1.5 mm attains a length of 9.5 mm. The adults copulate on 3 – 4 days of the last nymphal moult. Longevity of adult is 13–19 days.

The predator lives on the haemolymph of the host, which it sucks by piercing the larval body by its proboscis. Sucking may continue for about 15-20 minute at a stretch. It has been observed that single bug can kill 130-225 tasar silkworms of first to third instars throughout its life.

(iv) Nature of damage: Both young and adults of the stink bug suck the haemolymph of silkworm leading to their death.

(v) Period of Occurrence: June to January.

(vi) IPM Package for the control of Stink bug

Mechanical control:
Collect and destroy the silverish shiny and blackish egg clusters. Manual collection and killing of nymphs and adults.

Biological agent:
The release of Psix straiticeps (Scelionidae: Hymenoptera) and Trissolocus sp. as bio-control agents acts as important egg parasites of C. furcellata. (Sharma, et.al, 2004)

b. Reduvid bug, Sycanus collaris: (Hemiptera: Reduviidae)
Reduvid bug, Sycanus collaris is also most harmful predator and is responsible for about 15% of the crop loss, particularly during early instars of silkworm in some areas of Chattishgarh. The adult bug is black in colour with approximately 2.5 cm length. The head is long conical and mouth parts are modified into a long prominent proboscis, which lies in a cross striated groove between front coaxes while in rest.

(i) Classification

(ii) Geographical Distribution: Reduvid bug is widely distributed in tropical tasar region of India. An epidemic of its population occurred in Kathaghora, Raigarh (Chattishgarh) causing about 30% crop loss of tasar silkworm.
(iii) **Life Cycle**: Egg laying starts in 36 hours after mating. On an average single mated adult female bug lays about 300 eggs in the batches. Oviposition continues for about 10 days. The hatching takes place in about 6 days.

The nymphs pass through five instars. The entire nymphal period is about 25 days. Both the nymphs and adults suck the haemolymph of silkworm. The adults copulate in 4-5 days after the last nymphal moult. Longevity of *S. collaris* is about 20 days. The predator lives on the haemolymph of the host which sucks by piercing the larval body by its proboscis. It has been observed that a single bug feeds on and kills about 200 tasar larvae of first to third instars throughout its life.

(iv) **Nature of damage**: Both young and adults of *S. collaris* suck the haemolymph of the larvae by piercing its proboscis into the body of the host (silkworm) larvae.

(v) **Period of Occurrence**: August to October.

**Control measures of reduvid bug**

- Use of nylon net (mesh size 2 mm), especially during chawki rearing to prevent silkworm from the attack of reduvid bug.
- Mechanical collection and destruction of reduvid bug in the rearing field throughout rearing period and especially at the time of incidence of the reduvid bug by using sticky country made adhesive (lassa) glued to bamboo pole or other sticks.
- Collection and destruction of egg mass /nymphs and adults of reduvid bug.

*(c) Praying mantis, *Hierodula bipapilla*: (Dictyoptera: Mantidae)*

The praying mantis causes near 5% damage to the tasar silkworm crop during the early larval period. Its body is larger (5-8 cm) and green in colour with one pair of prominent raptorial fore legs in which tibia works in opposite to the femur like blades of a pair of scissors and both are partially spun. This is used for seizing and cutting the pray.

The pro-thorax is long and the wings are well developed, the hind pair being membranous and bigger in size. Mating habit of the mantis is very peculiar. Even if the male is attacked by female, eating a portion of its body, this does not interfere with effective mating.

(i) **Classification**

*Phylum: Arthropoda*

*Class: Insecta*

*Order: Dictyoptera*

*Family: Mantidae*

*Genus: Hierodula*

*Species: bipapilla*

Fig: 15- Classification and symptoms of Praying mantis

(ii) **Geographical Distribution**: Praying mantis is widely distributed in tropical tasar region of India.

(iii) **Life Cycle**: The eggs of mantis are laid in ootheca, which are constructed by the females on the plants. One female can make more than three oothecae. These are about 3-4 cm long having about 24 egg chambers arranged in two longitudinal rows. The number of nymphal stages is not constant and varies from 4-6. Nymphs and adults of praying mantis feed on younger tasar silkworms (I–III instars). They can inflict injury to only fourth and fifth instar larvae. The silkworm larvae however, die if the injury is deep. The total life cycle is about one year.

(iv) **Nature of damage**: Both nymph and adults eat the silkworm.

(v) **Period of Occurrence**: From the month of June the incidence of *H. bipapilla* goes up slowly and reaches its peak during the first week of October. The incidence again decreases gradually, and by first week of November the population almost comes to nil.

**Control measures of praying mantis**

- Use of nylon net (mesh size 2 mm), especially during chawki rearing to prevent silkworm from the attack of praying mantis.
- Mechanical collection and destruction of praying mantis in the rearing field throughout rearing period and especially at the time of incidence of the praying mantis by using sticky country made adhesive (lassa) glued to bamboo pole or other sticks.
- Collection and destruction of oothecae and adults of praying mantis.

*(d) Wasp, *Vespa orientalis*: (Hymenoptera: Vespidae)*

*Vespa orientalis* has been observed hiding away for the winter in holes in buildings. The nests are in trees or at the foot of tree or attached to the beam of a house. Their stings are very painful and should be avoided if possible. The most common wasps in India and is found in old buildings and walls where they construct their combs. These nests, sometimes, are very large and extend deep into loose masonry in old buildings. The communities are very populous. The fertilized female hides away till the cold passes and...
then starts laying eggs. In this way the same nest may be tenanted year after year.

The *V. orientalis* is 2-3 cm long with abdomen having yellow and dark brown bands, well developed poisonous stings and clubbed antenna. The wings are longitudinally folded in repose.

(i) **Classification**

![Classification and symptoms of Wasp](image)

(ii) **Geographical Distribution:** Wasp, *V. orientalis* is widely distributed in tropical tasar region of India.

(iii) **Nature of damage:** The wasp feeds on caterpillars, mantids, grass hoppers and other insects. But in a silkworm rearing field defenseless tasar larvae are the choice and they predate it not only for self but also collect and deposit them to their comb cells where large number of young ones waiting for crushed insects to eat.

(iv) **Period of occurrence:** July to November

Control measures of wasp

- Use of nylon net (mesh size 2 mm), especially during chawki rearing to prevent silkworm from the attack of wasp.
- Mechanical collection and destruction of wasp in the rearing field throughout rearing period and especially at the time of incidence of the wasp by using sticky country made adhesive (lassa) glued to bamboo pole or other sticks.
- Collection and destruction of nests and adults of predators.

(e) **Red ants, Oecophylla smargdina:** (Hymenoptera: Formicidae)

(i) **Classification**

![Classification and symptoms of Red ant](image)

(ii) **Geographical Distribution:** Red ant is widely distributed in tropical and temperate tasar regions of India.

Control measures of Red Ant:

(i) Use of nylon net (mesh size 2 mm) especially during chowki rearing to prevent silkworm from the attack of red ant.

- Mechanical capturing of red ant in the rearing field throughout rearing period and especially at the time of incidence of the red ant by manually.
- The rearing trees should be cleaned of ants and nests of ants before brushing or transfer of silkworms on it.
iv) The base of the trees should be dusted with an insecticide (Methyl-parathion 2% dust) to prevent ant attack.

v) **Black ants, *Myrmicaria brunnea*:** (Hymenoptera: Formicidae)

(i) **Classification**

![Phylum: Arthropoda
Class: Insecta
Order: Hymenoptera
Family: Formicidae
Subfamily: Myrmicinae
Genus: Myrmicaria
Species: M. brunnea](image)

Control measures of black Ant:

i) Use of nylon net (mesh size 2 mm) especially during chowki rearing to prevent silkworm from the attack of red ant.

ii) Mechanical capturing of red ant in the rearing field throughout rearing period and especially at the time of incidence of the red ant by manually.

iii) The rearing trees should be cleaned of ants and nests of ants before brushing or transfer of silkworms on it.

iv) The base of the trees should be dusted with an insecticide (Methyl-parathion 2% dust) to prevent ant attack.

3. **Non Insect Predators**

**Birds:**

Birds are very common in tasar fields and often cause larval mortality. The birds, viz. crow, Rufous treepie (*Dendrocitta vagabunda*) and common hawk cuckoo (*Cuculus varius*) (Figure 16 a, b) feed on the larvae of *A. mylitta*. These birds prefer to attack third to fourth stage larva, while, sometimes they also attack on fifth instar.

**Garden lizard:**

Garden lizard (*Callotes versicolor*) is a diurnal reptilian, also observed in the fields of tasar silkworm on tasar host plants (i.e. *Terminalia*) and it feeds on the early stage larvae of *A. mylitta*.

**Mammalian predators**

Some of the mammalian predators such as squirrels and rats create serious problems in tasar sericulture. The attack by squirrels is also serious during field rearing; they attack mature hanging cocoons on tasar host trees and cause damage to the cocoons by cutting the cocoon shell (Figure 16 c).

**Rat (*Rattus rattus*)**

Rat attacks are very common in grainage house where the cocoons are damaged (Figure 16 d).

Birds, rats, lizards and squirrels were observed to be very common predators of tasar silkworm, as reported in earlier studies. Nevertheless, birds with their continuous presence and active food searching in rearing fields predate on large numbers of tasar silkworm larvae. Mammalian predators also attack the harvested seed cocoons, where they cut the cocoon shell and feed on the pupae of *A. mylitta*.

![Fig-18: Classification and rearing of Black Ant](image)

![Fig-19: a, Rufous treepie (*Dendrocitta vagabunda*); b, Common hawk cuckoo (*Cuculus varius*); c, Tasar cocoon damaged by squirrel; d, Tasar cocoon damaged by rat attack, Sources: Gathalkar and Barsagade, 2016.](image)
FOREWARNING OF PEST OF TASAR SILKWORM

Forewarning word consisting two words i.e. fore and warning. Word fore means advance and warning means advice. So, definition of pest forewarning is “advance information about severity of pest in tasar silkworm. Forewarning of predators and parasite of tasar silkworm is an important technique to reduce the crop loss, cost of protection and pollution load from tasar ecosystem.

<table>
<thead>
<tr>
<th>The crop must be a cash crop (economic yield)</th>
<th>Silkworm is economic insect for Tasar culture.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The insect must have potential to cause Economic damage</td>
<td>Predators and parasite are causes economic loss in Tasar culture.</td>
</tr>
<tr>
<td>Irregular (uncertainty)</td>
<td>Pest are uncertainty in Tasar culture</td>
</tr>
<tr>
<td>Effective and economic control known (options to growers)</td>
<td>IPM options use in Tasar culture</td>
</tr>
<tr>
<td>Reliable means of communication with farmers</td>
<td>Communications on website or message send through mobile for Tasar farmers.</td>
</tr>
<tr>
<td>Farmer should be adaptive and have Purchase power</td>
<td>No need of money to adapt technology</td>
</tr>
</tbody>
</table>

FOREWARNING MODEL FOR SILKWORM PEST

1. Thumb Rule
2. Growing Degree Day model
3. Phenology Model
4. Computer Software Model
5. Statistical Model (Regression/ Correlation)
6. Weather based prediction
7. Pest calendar

1. Thumb Rule
This approach is simple and extensively used to describes the forecasting of the pests and diseases based on past historical data. For example, chances of virosis infection is more when weather condition
- High temperature
- High humidity
- Rainfall

2. Growing Degree Day Approach
This method is based on the assumption that the pest becomes inactive below a certain temperature known as base temperature. Growing degree day is worked out as \( \Sigma GDD = (\text{mean temperature} - \text{base temperature}) \). GDD is used in the model as explanatory variable. This method requires proper knowledge of base temperature and initial time from which accumulation is to start. Degree-day (DD)-DD is way of measuring of insect growth and development in response to daily temperature. Degree-day models have long been used as part of decision support systems to help growers predict spray timing or when to begin pest scouting. This model is highly effective for forewarning of susceptible stage of silkworm and severity of pest in tasar culture.

3. Phenology Model:
Stages of silkworm are called silkworm phenology. The stage of silkworm which is most vulnerable for pest is called susceptible stage. Information regarding the susceptibility of silkworm to pest...
can help in identifying the best times to spray and can contribute to developing efficient approaches for pest management. For example, I – III stage are susceptible to stink bug, reduviid bug, wasp, red ants and praying mantis; III, IV, V stages are susceptible to uzi fly and spinning stage is susceptible to yellow fly.

4. Computer Software Model

The models/ methodology is developed for forecasting of pest which is generally run by experts. In the present era, Information and Communication Technology (ICT) plays a vital role in disseminating the results to the potential users. ICT has revolutionized the way information is stored, accessed and analyzed. ICT is also an important enabler in research activities to accomplish tasks faster, more efficiently and effectively. Web enable decision support system is provide the necessary information regarding pest situation about 2 to 4 days ahead and plant protection advice as per integrated pest management (IPM) principles.

5. Statistical Model (Regression/ Correlation)

Regression Model

Regression model taking as dependent variable like pest parameter and independent variable like weather, silkworm stages, population of natural enemy etc are used. These variables are used in original scale or a suitable transforms scale such as COS, log exponential etc.

Correlation Studies:

The weather elements play an important role in success or failure of the cocoon production. The weather requirement varies differently at different phenophase and hence, the study of individual weather element prevailed during different phenophases was conducted by studying the degree of association between cocoon production versus weather elements. The weather elements maximum temperature (Tmax.), minimum temperature (Tmin.), morning time relative humidity (RH-I), noon time relative humidity (RH-II), wind speed etc. are included. The correlation coefficients for each treatment are estimated through pearson correlation techniques.

6. Weather based prediction of pest

“Weather health” is one of the most crucial prerequisite for successful incidence of insect pests as their bionomics is intimately related with congenial weather parameters. For example (temperature), each pest has a threshold temperature (lower and upper) where development of pest is zero. Above lower and below higher a range which indicates maximum development of pest, this range of temperature is congenial temperature for that pest. Three components are essential for emergence and severity of pest viz., host, pest and environmental condition. Forewarning refers to prediction of forthcoming infestation of pest in numbers which would cause economic damage to the crop. On the basis of interactive approach between weather and predators'/parasite data, congenial weather condition which is favorable for high infestation of pest is assessed. Weather based forewarning for predators can help growers to be in preparedness at times of anticipated economic damage by predators and to optimize the time of insecticidal application for increased production and profit. Finding of congenial weather is robust for use in tasar advisory for tasar farmers at regional level.

7. Pest Calendars

for CTR&TI, Ranchi, REC, Hatgamaria, REC, Kathgora and REC, Bangriposi. These region specific calendars could help farmers to protect silkworm from parasite and finally enhances the income of tasar farmers.
### Monthly weather condition

<table>
<thead>
<tr>
<th>Months</th>
<th>Tmax (°C)</th>
<th>Tmin (°C)</th>
<th>RH I (%)</th>
<th>RH II (%)</th>
<th>Rf (mm)</th>
<th>Weevil</th>
<th>Stink bug</th>
<th>Wasp</th>
<th>Uzifly</th>
<th>Yellow fly</th>
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<td>32</td>
<td>14</td>
<td>88</td>
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<td>++</td>
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<td>Nov</td>
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### Month wise pest and parasite severity at REC, Katghora during rearing period

<table>
<thead>
<tr>
<th>Month</th>
<th>Tmax (°C)</th>
<th>Tmin (°C)</th>
<th>RH I (%)</th>
<th>RH II (%)</th>
<th>Rf (mm)</th>
<th>Weevil</th>
<th>Stink bug</th>
<th>Wasp</th>
<th>Uzifly</th>
<th>Yellow fly</th>
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### Month wise pest and parasite severity at REC, Bangriposi during rearing period

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<tr>
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<th>Tmax (°C)</th>
<th>Tmin (°C)</th>
<th>RH I (%)</th>
<th>RH II (%)</th>
<th>Rf (mm)</th>
<th>Weevil</th>
<th>Stink bug</th>
<th>Wasp</th>
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</tbody>
</table>

Note: Pest severity Low (+), Moderate (+++) and High (++++)

### Low cost and eco-friendly technology for pest management

The application of scientific knowledge to the practical aims of human life is called “technology”. There are three conditions which are requires to fulfil any technology. These condition are technology should be eco-friendly, cost effective and social acceptable. Low cost and eco- friendly technologies are not only reduces the cost of silkworm protection but also it reduces the pollution load from tasar ecosystem. Tasar farmers easily adapt these technologies due to low cost investment for higher tasar cocoon production. In tasar culture, selection of suitable brushing date, brushing direction, brushing host plant and assessment of congenial weather condition for outbreak of pest are not only reduce the cost of protection and increase the cocoon production but also effective for tasar silkworm production and protection under the impact of climate change and its scenario in region and season specific (I, II and III crop).

### Table 9, Low cost and eco-friendly technology for production and protection of tasar silkworm

<table>
<thead>
<tr>
<th>Technology</th>
<th>Adaptation in tasar culture</th>
<th>Reason for adaptation</th>
<th>Output</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brushing date of tasar silkworm</td>
<td>Adjust brushing date (early, normal or late) as per requirement</td>
<td>Provide optimum climate / weather condition during silkworm rearing time at regional level.</td>
<td>Higher tasar production under climate change and its scenario</td>
<td>J. Singh, et. al., 2017</td>
</tr>
</tbody>
</table>
1.1. **Effect of brushing date and direction on tasar cocoon production and silkworm protection**

Brushing date is very important parameter in tasar silk production management decision, especially in regions having environmental restrictions such as sooner and later coldness and sever. The date of brushing has a significant effect on numbers of cocoon production, cocoon weight, shell weight, silk ratio percentage and pest infestation in tasar culture. Therefore, the proper brushing date play an important role for optimum utilization of climatic factors such as temperature and humidity by silkworm and also consistent with the rearing period. Tasar silk production response not only to the inclement weather that delayed planting date, but also the times when the weather is favourable, it is important, therefore, selection of brushing date (optimum weather condition for silkworm growth and development) at regional level not only increase the quantity and quality of cocoon, but also reduced the pest infestation on tasar silkworm. An experiment were conducted at PPC, Kathikund and RSRS, Warangal for assessment of brushing date and brushing direction on silkworm production and silkworm protection and finding of the experiment are given below.

(i) **PPC, Kathikund**

Brushing of tasar silkworm was done on three dates viz., 16th, 21st, and 26th at an interval of 5 days in four directions viz., North, South, East and West. Regular monitoring of weather data’s (maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall and it converted into weekly), cocoon quality (numbers of cocoon, cocoon weight, shell weight and SR%) and pest infestation (reduvid bug, canthecona bug and wasp) were recorded. The cocoon production showed decreasing trend in late brushing of tasar silkworm viz., first date of brushing > second date of brushing > third date of brushing whereas pest infestation showed increasing trends in late brushing viz., first < second < third date of brushing respectively. In case of directions, cocoon quality showed deceasing trends viz., east > north > south > west direction whereas pest infestation showed increasing trend viz., east < north < south and < west direction respectively. The congenial weather condition for predator was favorable for high infestation of predators during 31st standard meteorological week (SMW). During this period, weekly mean maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and rainfall were 32.67°C, 24.67°C, 87.17%, 58.50%, < 83 mm, respectively.

![Fig. 21, Effect of brushing date and direction on silkworm production at PPC, Kathikund](image)
An experiment was conducted at RSRS, Warangal during first crop in 2019 to assess the suitable brushing date and direction for higher quantity and quality of cocoon production / dffs. In this experiment we brushed tasar larvae on different date of brushing viz., I, II, III, IV and direction viz., North, South, East and West.
respectively. The numbers of cocoon/DfIs, ERR (%) and cocoon wt (g) were given in table number 3. The cocoon/DfIs, ERR (%) and cocoon wt (g) showed decreasing trend with brushing date of tasar silkworm viz., second date of brushing > third date of brushing > first date of brushing > fourth date of brushing in all direction whereas direction wise showed decreasing trends viz., North > South > East > West direction in all brushing date respectively. On the basis of experimental finding we can advise Warangal region of Telangana farmer to brush their larvae from 20 to 25 July in north / south direction for higher cocoon production.

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Brushing date</th>
<th>North</th>
<th>South</th>
<th>East</th>
<th>West</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield/Cocoon</td>
<td>I (15 July)</td>
<td>54.30</td>
<td>37.60</td>
<td>36.00</td>
<td>31.33</td>
</tr>
<tr>
<td></td>
<td>II (20 July)</td>
<td>78.00</td>
<td>76.67</td>
<td>71.00</td>
<td>61.25</td>
</tr>
<tr>
<td></td>
<td>III (25 July)</td>
<td>61.33</td>
<td>53.67</td>
<td>58.33</td>
<td>59.33</td>
</tr>
<tr>
<td></td>
<td>IV (30 July)</td>
<td>35.00</td>
<td>28.00</td>
<td>33.33</td>
<td>22.75</td>
</tr>
<tr>
<td>ERR (%)</td>
<td>I (15 July)</td>
<td>36.22</td>
<td>25.11</td>
<td>24.00</td>
<td>20.89</td>
</tr>
<tr>
<td></td>
<td>II (20 July)</td>
<td>52.00</td>
<td>51.11</td>
<td>47.33</td>
<td>40.83</td>
</tr>
<tr>
<td></td>
<td>III (25 July)</td>
<td>40.89</td>
<td>35.78</td>
<td>38.89</td>
<td>39.56</td>
</tr>
<tr>
<td></td>
<td>IV (30 July)</td>
<td>23.33</td>
<td>18.67</td>
<td>22.22</td>
<td>15.17</td>
</tr>
<tr>
<td>Cocoon wt (g)</td>
<td>I (15 July)</td>
<td>11.75</td>
<td>10.50</td>
<td>10.38</td>
<td>10.13</td>
</tr>
<tr>
<td></td>
<td>II (20 July)</td>
<td>11.50</td>
<td>10.00</td>
<td>11.33</td>
<td>11.38</td>
</tr>
<tr>
<td></td>
<td>III (25 July)</td>
<td>11.88</td>
<td>11.13</td>
<td>12.13</td>
<td>10.88</td>
</tr>
<tr>
<td></td>
<td>IV (30 July)</td>
<td>11.71</td>
<td>10.54</td>
<td>11.21</td>
<td>10.79</td>
</tr>
</tbody>
</table>

Sources: RSRS, Warangal

Impact of climate change on tasar silkworm pest

The impacts of climate change can be positive, negative or neutral, since these changes can decrease, increase or have no impact on insect pests and diseases, depending on specific location of each region or period (Das, et al., 2011). Tasar silkworm pests are mainly damaged parasitoid and predators which are beneficial (natural enemy) for management of agricultural and forest plant protection. Parasites and predators are likely to undergo diverse effects due to changes in atmospheric CO2 levels, increase in temperatures and shifts in precipitation. Among parasitoids, many hymenopteran wasp parasitoids which are relatively host-specific and are considered as specialists are more sensitive to changes in their host emergence times or developmental rates than tachnid flies which feed on several host insects and are likely to be less susceptible to the asynchrony with their hosts induced by climate change. Variability in rainfall reportedly has an adverse influence on parasitism levels of several caterpillar pests (Prasad Y.G and O.M Bambawale, 2010).

Effect of elevated temperature on parasitoid and predators

It is predicted that a 1°C rise in temperature would enable species to spread 200 km northwards or 140m upwards in altitude (Parry et al., 1989). All species will be under strong selection pressures, which may be different from those exerted when the climate is stable. Natural enemies are no exception. Exposure to temperature extremes even for short periods is likely to influence parasitoid survival and host searching ability (Scott et al., 1997). Temperature influenced the fecundity and sex ratio of Campoletis chloridae, an ichneumonid larval parasitoid of H. armigera (Dhillon and Sharma, 2009). Short exposure to higher temperatures can eliminate endosymbiotic bacteria like Wolbachia and Buchnera which influence several aspects of parasitoid reproduction (Thomas and Blanford, 2003).

Fluctuations in parasitoid abundance and observed wide ranges in field parasitisation levels may be attributed to climatic conditions. In case of predators, however, it could be different. For example, it has been predicted that coccinellids reduce aphids more strongly in hot summers than in moderate summers (Skirvin et al., 1997). Overall, there is lack of a clear understanding of the dynamics of matching thermal requirements of parasitoids, predators and their hosts as a tritrophic system. It is generally perceived that natural enemies are relatively more sensitive to climatic variability than their herbivore hosts. Perhaps this is explained by higher intrinsic rates of population increases following decimation by herbivores relative to natural enemies (Thomson et al., 2010). Each species has to be analyzed separately to understand and predict the influence of either gradual or abrupt increase in temperatures (Table 1).

Effect of rainfall variability on parasite and predators

Stireman et al., (2005) analyzed the frequency of parasitism in 15 Lepidoptera rearing programs from a broad spectrum of climatic regimes and locations located between southern Canada and central Brazil. The meta analysis indicated that the variability in precipitation was a key factor influencing parasitism. A higher variability in rainfall led to a decrease in parasitism. Studies carried out till now indicate that the interactive effects of changes in CO2,
temperature and rainfall on natural enemies can be complex and hence it is difficult to predict their combined effects.

**Effect of elevated carbon dioxide on Natural predators and parasitoid**

Yin et al. (2009) conducted an experiment under 750 ppm CO2 concentration involving Helicoverpa armigera Hubner larvae reared on milky grains of wheat and its larval parasitoid Microplitis mediator, widely used in its bio-control. No significant change in parasitisation rate of M. mediator was found.

The development of the parasitoid wasp, Glyptapanteles liparidis, of gypsy moth, Lymantria dispar, feeding on three different tree species fumigated with 540+20 ppm CO2 was not adversely affected by changes in food quality when compared to ambient CO2 (Schafellner and Schopf, 2008). Coll and Hughes (2008) investigated the effects of elevated CO2 on H. armigera and an omnivorous bug, Oechalia schellenbergii, Guerin-Meneville which not only feeds on plants but also preys on the bollworm. Bollworm larvae feeding on elevated CO2 -grown pea plants, *Pisum sativum* at 700 ppm were significantly smaller than those reared on plants grown under ambient-CO2 conditions. The omnivorous bug required prey to complete its development, and performed best on a mixed plant-prey diet, regardless of CO2 level. The bugs performed best when fed with larvae from the elevated-CO2 treatment apparently because these prey were smaller and thus easier to overcome. Taken together, results indicate that elevated CO2 may benefit generalist predators through increased prey vulnerability, which means that pest species are likely to be under higher risk of predation.

The effects of elevated CO2 on natural enemies are essentially indirect and mediated through changes in herbivore hosts that feed on plants with altered nutritional quality. The effects are mainly reflected in the form of changes in natural enemy fitness, development, mortality and abundance, and differ between parasitoids and predators. Within the parasitoid category, the specialists that are host-specific are likely to be more adversely affected than generalists that survive on a variety of host insects. Very few research experiments have been conducted under controlled conditions with elevated CO2 to investigate the effects on tritrophic systems.

**Table -- Influence of temperature changes on natural enemies**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nature of effect</th>
<th>Natural enemy</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival</td>
<td>Reduced when exposed to abrupt change</td>
<td>Egg parasitoid, <em>Trichogramma carverae</em> Oatman and Pinto</td>
<td>Scott <em>et al.</em>, 1997</td>
</tr>
<tr>
<td></td>
<td>Reduced at lower (&lt;12°C) and higher temperatures (&gt;35°C)</td>
<td><em>Campoletis chlorideae</em> Uchida on chick pea pod borer, <em>Helicoverpa armigera</em></td>
<td>Dhillon and Sharma, 2009</td>
</tr>
<tr>
<td>Distribution range</td>
<td>Lower mortality of herbivore due to escape from parasitoids in the expanded range</td>
<td>Parasitoids of Argus butterfly, <em>Aricia agestis</em> Dennis &amp; Schiffermuller</td>
<td>Menendez <em>et al.</em>, 2008</td>
</tr>
<tr>
<td>Host searching ability</td>
<td>Decreased at higher temperatures</td>
<td>Egg parasitoid, T. carverae</td>
<td>Thomson <em>et al.</em>, 2001</td>
</tr>
<tr>
<td>Fecundity</td>
<td>Reduced at temperatures above threshold (&gt;35°C)</td>
<td>Egg parasitoids, T. pretiosum Riley and <em>Trichogrammaidea bactrae</em> Nagaraja</td>
<td>Naranjo, 1993</td>
</tr>
<tr>
<td>Diapause</td>
<td>Prevention of diapause induction due to changes in day length and temperature</td>
<td>Coccinellid predator, <em>Harmonia axyridis</em></td>
<td>Soares <em>et al.</em>, 2008</td>
</tr>
<tr>
<td>Phenological asynchrony</td>
<td>Poor synchronization in emergence time between parasitoid and its host</td>
<td>Leaf miner parasitoids</td>
<td>Grabenweger <em>et al.</em>, 2007</td>
</tr>
<tr>
<td>Natural / Biological control</td>
<td>Poor parasitisation during hot and dry weather</td>
<td>Egg parasitoid, <em>Trichogramma</em> on borer, <em>Ostrinia nubulalis</em></td>
<td>Cagan <em>et al.</em>, 1998</td>
</tr>
</tbody>
</table>

Sources: Prasad Y.G and O.M Bambawale 2010
Effect of abiotic factors on silkworm predators and parasitoid at different location of tasar growing states

<table>
<thead>
<tr>
<th>Source:</th>
<th>Final report of Project Code: PRE 4692), funded by Central Silk Board</th>
</tr>
</thead>
</table>
- Directional approach for management of tasar silkworm pest 
- Application of botanical repellant for management of silkworm pest. 
- Region and season specific assessment of assessment of predators and parasitoid infestation under climate change and its scenario. |

References:


Griyaghey UP and Das PK (1982): Disease and pests of tasar silkworm and its food plants, Workshop on tasar culture and sericiculture.
tasar silk industry, Base Paper-4, CTRTI, 4-5th May 1982, Ranchi. p. 13


Recent Approaches in Tasar Silkworm Disease Management

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Introduction

Tropical tasar silk is produced by the larvae of *Antheraea mylitta* Drury. Being wild in nature and reared outdoor on its primary food plants *Terminalia tomentosa, T. arjuna* and *Shorea robusta.* Silkworm larvae often suffer from various diseases causing heavy losses to the economy of the silk industry. Virosis, pebrine, muscardine and bacteriosis are the commonly prevalent diseases caused respectively by different pathogens *Antheraea mylitta* Cytoplasmic Polyhedrosis Virus (AmCPV), a reovirus, *Nosema mylittensis* (Microsporidia), *Penicillium citrinum* and *Penicilium varioti* (Fungus) and different types of bacteria. The diseases in silkworms are primarily due to the pathogens and certain stress factors, which promote the disease development during silkworm rearing. Survey reports from different sericultural areas in India have revealed that the crop loss is often due to the diseases. In India, the extent of tasar crop loss due to the silkworm diseases is nearly 40% (Sahay et al., 2000). The estimated crop loss due to pebrine, virosis, bacteriosis and muscardine is 20-25, 25-30, 10-15 and 2-5% respectively of total crop loss due to diseases ((Sahay et al., 2000).

“Prevention is better than cure” is the correct approach to be adopted under integrated disease management. It is true for all forms and types in case of silkworms as they have short larval duration and curative measures after occurrence of the disease seldom give the desired results. For effective control of the occurrence and spread of disease, precautionary measures are imperative, especially in case of tasar culture, where the silkworms are exposed to the natural environment. Continuous disturbance in the a biotic and biotic factors form the environment, adversely influence the cocoon production qualitatively and quantitatively. The ubiquitous presence of the infectious organism in the environment makes the silkworms vulnerable to infection. Once a few worms are infected, it spreads within the host and the worms release pathogens through excreta or dead worms which contaminate the environment including food plant and the silkworm by direct contact leading to secondary infection in the silkworm population. This may ultimately lead to epidemic outbreak of disease, unless some preventive or curative measures are adopted.

In view of economic importance of tasar silkworms, its protection from the invasive pathogens becomes absolutely necessary. Preventive measures during the grainage and rearing help to a considerable extent in bringing down the incidence of diseases. The occurrence and spread of diseases are closely related to the constitution of the silkworms, pathogens and the environmental conditions. Under preventive measures, strict disinfection to reduce pathogen load in the environment, identification and rejection of diseased worms to eliminate risk of disease transmission and invigoration of silkworms to enhance resistance to diseases are given due weight age.

Tasar Silkworm Diseases

In tasar silkworm, Pebrine, Virosis, Bacteriosis and Muscardine are commonly prevalent diseases as shown in table below.

<table>
<thead>
<tr>
<th>#</th>
<th>Name of the disease</th>
<th>Causative pathogen</th>
<th>Estimated loss(%)</th>
<th>Typical Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pebrine</td>
<td><em>Nosema mylittensis</em></td>
<td>25-30</td>
<td>Appearance of black pepper like spots on the body from 4th instar onwards in advanced condition of disease</td>
</tr>
<tr>
<td>2</td>
<td>Virosis</td>
<td><em>Antheraea mylitta</em> Cytoplasmic polyhedrosis virus (AmCPV)</td>
<td>25-30</td>
<td>Hanging head downwards and remains attached with twig with caudal legs and oozing out drops from mouth with obnoxious odor.</td>
</tr>
<tr>
<td>3</td>
<td>Bacteriosis</td>
<td>Gram positive bacteria like <em>Seratia</em> and <em>pseudomonas</em></td>
<td>10-15</td>
<td>Show three types symptoms Chain type of excreta, Anal lip sealing and rectal protrusion</td>
</tr>
<tr>
<td>4</td>
<td>Muscardine</td>
<td><em>Penicillium citrinum</em> and <em>Paecilomysis varioti</em></td>
<td>Less than 5</td>
<td>White cadaver on the body and mummification</td>
</tr>
</tbody>
</table>

Pebrine

Pebrine (a French word)) is the name most frequently used to designate the microsporidian disease of the silkworms. Tasar silkworm, *Antheraea mylitta* D. is susceptible to pebrine disease caused by *Nosema mylittensis,* a microsporidia belongs to Phylum Protozoa, Class Sporozoa, and Family Nosemetidae. Pebrine infection common to all stages of tasar silkworm occurs throughout the year and prevails almost all tasar regions. Pebrine infection has been reported from almost all the tissues of the silkworm. This disease is more violent/severs due to its transovarial transmission causing vertical infection and death of worms due to primary infection. In case of secondary infection larvae succeed to spin the cocoons but its impact on the pupa and adult stages is detrimental to quality seed production.

Symptoms

Silkworm: Diseased worms lose their appetite, show disparity...
in growth leading to unequal in size, become sluggish and slow, irregular moulting with increased moul duration in many. From 3rd instar onwards, in severe case black pepper like spots appear over the whole body of silkworm. Considerable mortality is observed after 2nd moult.

**Pupa:** Pupa infected with pebrine looks flaccid, light in weight with shrunken and deformed abdomen.

**Moth:** Infected moths are generally deformed with crumpled wings and scale less abdomen.

**Egg:** Infected eggs have less muconium leading to poor adherence to substratum, majority of them remains unfertilized, light in weight and poor fecundity.

---

**Black pepper like spots**

**Moth with crumpled wings**

**Moth with scale less abdomen**

---

**Pebrine infected tasar silkworm**

**Transmission and spread of Pebrine disease**

The primary infection is by transovarial transmission. Transovarial transmission of pathogen resulting from the infected eggs laid by the pebrinated female moth. The secondary infection is by transovam transmission and by feeding on contaminated food during larval stage.

1. **Transovarial:** In the transovarial mode of transmission the pathogen is transmitted along with the egg cytoplasm. As the yolk cell migrates to form the ovum in the ovary of the infected mother moth, the intermediary stages of the pathogen migrates along with the yolk cells and get engulfed in whole egg. Han and Watanabe (1987) studied the transovarial transmission of two microsporidia in *Bombyx mori*. The examination of dead egg and newly hatched larvae showed that *Nosema bombycis* is transmitted transovarially by all infected females. The entry of pathogen to the egg through micropyle can not occur as the size of the infective stage is larger than the former. The size of the spore (5.80b x 2.32 ) is much bigger in comparison to that of sperm head (4.3 x 0.5 ) of *A. mylitta* as well, hence the possibility of transmission of *Nosema* spore through male is ruled out.

It is observed that transovarialy infected silkworms may also spin the cocoons but the seed production is affected.

2. **Transovum:** Transovum infection takes place due to contamination of egg chorion, a portion of which is eaten away by the larvae at the time of hatching (Iwashita et al., 1990)

3. **Peroral:** Peroral infection takes place mainly through feeding of contaminated leaves. The larvae thus per orally infected during 1st and 2nd instar show symptoms of poor growth and black peppery spots in late 4th and 5th instar and die or spin the cocoons. In tasar silkworm it is observed that if the larvae are infected in 3rd instar, the larvae show symptoms in late 5th instar and spin the cocoons.

**Secondary contamination and role of Alternate hosts in spread of pebrine in tasar silkworm:**

The soil, bark and leaves of the food plant in rearing site are the main source of secondary contamination during rearing of silkworm. I a study Sahay et al. (2007) reported that soil and leaf samples contain microspordian spores after each rearing in spite of thorough disinfection of the rearing field. He further, mentioned that the silkworm pests have also shown presence of microsporidian spores in *Canthecona sp. (72.22%), Sycanus sp. (9.09%), Xanthopimpla sp. (18.18%) and ichneumon fly (2.80%) which are the main source of secondary contamination in rearing field. The pebrine spores harvested from *Canthecona sp*. And *Sycanusre sp.* were found pathogenic to silkworm.

**Epizootiology**

Several factors influence the development and incidence of diseases. These may be biotic including those inbuilt in silkworms and a biotic available in the environment. In the broad sense, epizootics means the diseases as occur in groups of animals rather than individual. Epizootics, like epidemics, are concerned with three primary factors.

1. The infectious agent with its variable virulence and infectivity.
2. The susceptibility or resistance of the individuals that compose the population at risk.
3. An efficient means of transmission.

**Detection of pebrine**

The basic requirement in management of pebrine disease in tasar culture is the disease diagnosis. The symptoms of the disease are atypical and the formation of characteristic spores alone is the most reliable diagnostic feature. The spores of *N. mylittensis* could be observed in the homogenate of the infected egg, larva, pupa and...
moth. For a successful crop, detection of pebrine pathogen is a must. The presence of pathogen in the silkworm, rearing field and grainage house should be examined thoroughly to prevent carryover of the pathogen. Though some detective methods are in practice, they should be carried out without ambiguity.

1) **Predictive Test:** The silkworms which show irregular growth, late in molting and poor in health, and their faeces should be subjected for microscopic examination for detection of pebrine spores. This type of test should be done once during I and II instar and other during IV and late V instar.

2) **Testis Examination:** Before consignment of harvested cocoons dissection of randomly selected pupae (0.1 to 1.0% of stock based on the size of the lot) for testis examination should be done to ascertain the continuance of the stock for seed preparation.

Randomly selected male pupa is cut dorsoventrally from posterior to anterior end with scissor. Remove the fat body with help of forceps and pore the water forcibly with the help of bottle. Two small grain like cream colour testis lie dorsally below the hard chironion between 7th and 8th abdominal segment. Take out the testis carefully with the help of forceps, put on glass slide on previously dropped 2% KOH solution, cover with cover slip and press gently so that testis burst and the pebrine spores are released out. Examine for the pebrine spores with the help of microscope at 600 X magnification.

3) **Pupae Examination:** Pebrine detection in pupa is very difficult as pupa has high fats content. Alternatively the rudimentary gut may be employed for this purpose. 1.0% Sample of pupae may be collected from the cocoon lots. Lower middle portion of individual pupa (6th to 8th segment) is cut with the help of scissors and homogenized with 1.0 ml of 0.6% K$_2$CO$_3$ solution and centrifuged at 4000 rpm for 5 minutes. The supernatant is discarded and 5-6 drops of 2% KOH solution is added to the sediment, which dissolves fat globules and makes the observation easy. One drop of dissolved sediment is examined under the 600 X magnification of compound microscope. In the slide if rice grain size, oval shaped, bluish bright pebrine spores are observed, the entire eggs laid by that mother moth is considered pebrinised and is rejected. Slide having no *Nosema* spores indicative of disease freeness and the eggs layed by the moths are retained as disease free laying (dff) for rearing.

**Pebrine Visualization Technology (PVT):** PVT has been recently developed by CTR & TI, Ranchi for easy and quick identification of pebrine spores during mother moth examination. In this technology slides are observed on computer screen in place of eye piece of microscope. Pebrine visualization solution developed to clean the cellular debris and other non pebrine artifacts in smear on slide and make pebrine spore prominat to visualize on computer screen.

**Prick method of mother moth examination:** P$_1$ units are producing commercial seeds for the rearers and keeping in view the vast requirement of disease free layings, voluminous amount of seed cocoons are processed for dff production. For such a large number of cocoons modified centrifuged mother moth examination technique is practically not feasible, therefore mother moth examination by prick method has been suggested to cater the need of commercial seed.

This method of examination is popularly known as “Prick and See” method as it involves the pricking of the mother moth first and then sees through the microscope for pebrine spore identification. For large scale moth testing, the moth’s abdomen is prick from 3/4 segment with the pointed bamboo stick/tooth pick, inserted inside up to 7th segment, rotated inside the body and body fluid collected directly and mixed with previously dropped 0.5% K2CO3 on glass slide and examined under microscope. Prick method is advised only for commercial seed production because it is not 100% full proof method.

**LAMP Technique**

LAMP technique is used in rapid diagnosis of viral, bacterial and parasitic diseases. It helps in the identification of genus and species-specific parasites. In a LAMP assay, the reaction takes place in a single tube containing buffer, target DNA, DNA polymerase and primers. The tube is incubated at 64°C in a regular laboratory water bath or heat block that helps in maintaining a constant temperature. The amplified product can be detected by naked eye as a white precipitate or a yellow-green color solution after addition of SYBR green to the reaction tube.

The LAMP technique is first time employed to diagnose microsporidiosis at various developmental stages of the mulberry silkworm. In this study, the polar tube protein 1 gene of *Nosema*
**CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE**

**bombycis** was cloned, characterized and utilized for the development of rapid and simple loop mediated isothermal amplification assay (LAMP) for detection of microsporidiosis in silkworm *B. mori*. The LAMP reaction conditions were optimized to 65 °C for 60 min. The developed method demonstrated a higher sensitivity and the detection limit was found to be 2-fold higher than conventional PCR.

This is the first report on loop mediated isothermal amplification assay that could be used to diagnose microsporidiosis at various developmental stages of the silkworm. This method serves as a robust alternative technique to conventional PCR and aids in the rapid diagnosis of *N. bombycis* infecting mulberry silkworm.

Pebrine spores as seen under light microscope at 600 X

**Pebrine spore**

The infective stage of *Nosema* is spore which consists of sporoplasm with one to two nuclei, a long polar filament cycled inside the spore and a spherical spore membrane. Spore size varies from 5.80±1.16 µ in length and 2.3±0.46µ in breadth. It appears as a very bright oval body. The spore is stained with giemsa stain. Fully developed spore appears as a thick walls structure having clear space or vacuoles at each end. It consists of an outer covering spore membrane which encloses the sporoplasm. Sporoplasm contains two vacuoles and nuclei. A polar capsule is also present which is sac like structure and bulges in to spore cavity. A small opening at anterior end, a micropile through which polar filament is ejected out (Patil *et al*, 1993)

14 types of *Nosema* spores varying morphologically in shaped and size have been reported from different geographical regions which are pathogenic to tasar silkworm.

<table>
<thead>
<tr>
<th>#</th>
<th>Spore size</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.73 ± 0.26 µm x 2.75 ± 0.24 µm</td>
<td>NS1</td>
</tr>
<tr>
<td>2</td>
<td>4.62 ± 0.24 µm x 2.64 ± 0.26 µm</td>
<td>NS2</td>
</tr>
<tr>
<td>3</td>
<td>4.40 ± 0.22 µm x 2.86 ± 0.26 µm</td>
<td>NS3</td>
</tr>
<tr>
<td>4</td>
<td>4.35 ±0.24 µm x 2.80 ±0.26 µm</td>
<td>NS4</td>
</tr>
<tr>
<td>5</td>
<td>4.25 ± 0.20 µm x 2.97 ± 0.50 µm</td>
<td>NS5</td>
</tr>
<tr>
<td>6</td>
<td>4.22 ± 0.22 µm x 2.75 ± 0.26 µm</td>
<td>NS6</td>
</tr>
<tr>
<td>7</td>
<td>4.07 ± 0.33 µm x 2.97 ± 0.25 µm</td>
<td>NS7</td>
</tr>
<tr>
<td>8</td>
<td>3.96 ± 0.27 µm x 2.97 ± 0.25 µm</td>
<td>NS8</td>
</tr>
<tr>
<td>9</td>
<td>3.63 ± 0.27 µm x 2.64 ± 0.24 µm</td>
<td>NS9</td>
</tr>
<tr>
<td>10</td>
<td>3.52 ± 0.48 µm x 2.53 ± 0.36 µm</td>
<td>NS10</td>
</tr>
<tr>
<td>11</td>
<td>4.18±0.32 µm x 2.75±0.26 µm</td>
<td>NS11</td>
</tr>
<tr>
<td>12</td>
<td>4.95±0.26 µm x 2.97±0.24 µm</td>
<td>NS12</td>
</tr>
<tr>
<td>13</td>
<td>5.17±0.35 µm x 2.75±0.26 µm</td>
<td>NS13</td>
</tr>
<tr>
<td>14</td>
<td>3.96±0.33 µm x 2.64±0.33 µm</td>
<td>NS14</td>
</tr>
</tbody>
</table>

**Table : Varying sizes of the microsporidian spores**

**Pathogen stability**

Pebrine spores are extremely resistant to abiotic conditions and remain viable for a maximum period of 255 days in under tropical conditions. Apparently, spores coated with tissues and present
under humid conditions have been found to be viable for several years. It is reported that, the spores are kept in dark, they remain viable even for as long as 7 years. On direct exposure to sunlight the spores remain viable for 6 to 7 hours and when treated with hot water it survives for just 5 minutes. When resistance of spores to different disinfectants was examined, they are found to remain viable for 10-30 minutes in a solution of corrosive sublimate.

**Life cycle or Vegetative stages:** After ingestion of the spore by the silkworm, the polar filament is extruded due to higher alkalinity and presence of alkaline ions in the midgut. The two nuclei of the spore divided producing four nuclei and at the same time the sporoplasm with two nuclei is injected into the midgut tissue through the avaginated polar filament. The polar filament left behind subsequently degenerated. The planot which is a globular body without membrane passes between the epithelial cells of host intestine and then into haemocoel, where they multiply by binary fission. The planot initially infects fat bodies, trachea, silkgland, integument, gonad, nerve and dorsal blood vessels. When cytoplasm of host cell is exhausted, schizonts are arranged in parallel rows. Each schizont elongates and develops into a sporoblast and finally into spore. Then cell wall collapses and the spores are liberated.

**Management of Pebrine disease**

The basic requirement in management of pebrine disease in silkworm is the disease diagnosis. The symptoms of the disease are atypical and the formation of characteristic spores alone is the most reliable diagnostic feature. The spores of pebrine disease can be observed in the homogenate in the infected egg, larva, pupa and moth.

**Pebrine disease free production:** From the survey it is clear that diseases noticed during rearing primarily due to brushing of diseased layings. The individual mother moths should be subjected to intensive microscopic examination to produce only pebrine free laying. Washing and disinfection of the eggs should be carried properly with the use of depuratex to check the spread of disease from the eggs.

**Disease monitoring method:** Monitoring of pebrine in seed and commercial crop rearings are important steps in prevention of epizootics of the disease. Due to outdoor rearing in open environment, chances of availability of pathogen for secondary contamination are increased. It is recommended to monitor properly the seed crops for pebrine disease. Grainage houses dust, unhatched and dead eggs, egg shells and silkworm faeces may be be examined for pebrine spores. Regular inspection of seed cocoon lots by sample pupae examination by the disease monitoring team during 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> crop is recommended so immediate corrective measure can be taken and further spread of disease can be checked.

**Thermotherapy:** Treatment of 40°C for 10 hrs to the infected eggs collected after 24 hrs of oviposition is considerably effective in combating the disease. Transovarily infected silkworm eggs of 72 hrs old treated with HCl (Sp. gra. 1.05) at 40 °C for 5 - 10 minutes gives good results.

**Chemotherapy:** Several chemicals have been tried for the control of this disease and some of them have been found effective in controlling the diseases to a considerable extent. Feeding of Benomyl, a fungicide to the infected worms at 100-150 ppm doses has been found effective in containing the disease (Sahay et al, 2008). Administration of 0.1% Bengard and 0.005% Carbestine/ Carbendazim to the infected worms from II stage onwards is highly effective in controlling the disease. A drug formulation contains systemic fungicide and antiprotozoal drug has been developed and patented as well.

**Virosis (Cytoplasmic polyhedrosis)**

Entomopathogenic viruses are grouped as occluded and non-occluded viruses and are classified into the following families (Harapp and Payne, 1979)

1. Baculoviridae
2. Poly-DNA-Viridae
3. Reoviridae
4. Poxviridae
5. Iridoviridae
6. Paroviridae
7. Picornaviridae
8. Rhabdoviridae
9. Ascoviridae
10. Birnaviridae
11. Calciviridae
12. Tetraviridae
13. Nodaviridae

Viruses in the family baculoviridae and Reoviridae are unique as they form certain characteristic polyhedral bodies, occlusion bodies or inclusion bodies at certain stages of development. The polyhedral bodies are called polyhedra and the disease is called polyhedrosis. The occluded viral disease caused by baculoviridae are known as nuclear polyhedrosis and those by reoviridae as cytoplasmic polyhedrosis. These polyhedral bodies occlude virions and offers protection.

Among the silkworm pathogens, virus causes comparatively higher level of mortality in most of the tasar culture areas. Bad weather, ineffective disinfections and poor management leads to outbreak of the disease and severe crop loss. Virosis accounts for 25-30% of the total crop loss from diseases (Sahay et al, 2000) and pose a serious threat to tasar culture. It is difficult to control once the worms become infected. The virosis prevails throughout the year but is intensive during 1<sup>st</sup> and 2<sup>nd</sup> crop during rainy season. The severity is far less during 3<sup>rd</sup> crop.
**Pathogen:** The cytoplasmic polyhedrosis in tropical tasar silkworm is caused by Cytoplasmic polyhedrosis virus, an occluded Reovirus virus of the family Reoviridae. The cytoplasmic polyhedrosis virus (CPV) causing virosis disease in tropical tasar silkworm *Antheraea mylitta* is abbreviated as AmCPV.

Cytoplasmic polyhedrosis virus (CPV) particles found in polyhedral occlusion bodies (POIBs). The occlusion bodies are spherical and are readily stained by hot giemsa solution. Polyhedra ranged widely in size from 0.5 to 1.5 μm. Polyhedra may be tetrahedral or hexahedral in shape. The double shadowing technique has shown that polyhedra are icosahedral. The polyhedra are not dissolved in water and it is heavier than water. The virus particles are spherical, 65 – 85 nm in diameter. Capsid consists of thin layer with apical projections contiguous with hollow tubes leading to the virus core. Double stranded (ds) RNA is only type of nucleic acid in virus particles. The major polypeptide in CPV polyhedra has a molecular weight of 25 – 30 x 10^3.

**Scanning Electronmicrophotograph of Cytoplasmic Polyhedra**

**Isolation and Purification of Polyhedral Bodies:** Completely whitened mid-gut obtained from cytoplasmic polyhedrosis infected silkworm at an advanced stage of infection are placed into a beaker and stirred vigorously in distilled water with a glass rode or homogenized with a magnetic stirrer. The polyhedral suspension is then filtered through a cheese cloth. The filtrate is centrifuged at 4000 rpm for 10 to 15 minutes. The sediment washed and re-suspended in distilled water. This process is repeated 3 or 4 times. The final pellet is suspended in sterilized distilled water and purity of the polyhedral suspension is examined with light microscope. The purified polyhedra should be stored at 5°C.

**Symptoms:** In general the CPV infects mainly the larvae. Affected silkworms exhibits the symptoms of slow growth, and greatly lag behind normal larvae in the development. There are no very clear symptoms at initial stage of infection, but they can be recognized by their small size, loss of appetite and sometimes disproportionate large head or long bristles. Later, the polyhedra developing in the gut get frequently regurgitated or voided in large quantities with the faeces. In about 6 hours of infection the feeding ceases and the larva becomes immobile. After another 12 hours body loses its natural shape, distends lengthwise and turns brownish. The larva dies in about 24 hours after appearance of symptoms. On death it hangs head downwards remains attached to the host twigs with its claspers and a dark brown fluid oozes out as drops from the mouth. The dead larva emits obnoxious odor at this stage. In another 24 hours it becomes a mass of melted tissue. The larvae have been observed to succumb during the larval stage and initial spinning stage and even after pupation or during moth emergence. The dead pupae melt typically making the cocoons stained. The infected moths possess flacid body with crumpled small wings. The cocoons formed by the infected larvae are flimsy.

**Virosis infected tasar silkworms**

**Pathogenesis:** The most common route of infection by AmCPV in tasar silkworm is *per-oral*. The transovum transmission of pathogen may also occur in silkworm. Virus contaminated leaves of food plant may be an important source of infection during silkworm rearing. The Tasar silkworm larvae reared outdoors are infected with virus, the wind and rain may scatter the virus from the contaminated faeces and disintegrated dead larvae.

**Site of infection and Disease development:** The polyhedra on ingestion begins to dissolve within 0.5 min and is dissolved completely within 3 min liberating the virions. The dissolution is assisted by the alkainity in the gut. Cytoplasmic polyhedra virus (CPV) infects cytoplasm of cylindrical cells of midgut epithelium. The posterior portion of the mid-gut becomes white. The replication cycle of the cytoplasmic polyhedrosis virus is divisible into four stages viz., entry of the virus into the host cell, multiplication of the virus, formation of the polyhedra and release of polyhedra and virus from the cell.

**Entry of the virus into the host cell:** Cytoplasmic polyhedrosis infection occurs through the food contamination with polyhedra. The ingested polyhedra are also dissolved by the gut juice in the midgut lumen and virions are liberated. Invasion into the mid-gut first occurs in the posterior end and disease progresses towards
anterior end. Penetration of the virus into the host cell occurs by formation of certain postulates of penetration (Hosaka, 1964). The postulates in sequence are attachment of the viral projection to the surface of the host cell much more close attachment of particles to the cell surface appearing to penetrate through the projections into the cytoplasm and inoculation of the virus characterized by the release of core substance into the cell.

**Multiplication of virus:** The virus capsules arise from a mass (virogenic stroma) which is formed in the cytoplasm of the infected cell. At an early stage of infection the virogenic stromata are found just below the brush border, and few mature virus particles arise from their surface. With the advance of the infection many virogenic stromata of unidentified form grow out towards the base of the host cell, and numerous free virions and small polyhedra are distributed irregularly over their surfaces. As the stromata continue to grow, they fuse and form large matrices in the cell. Finally, the stromata are known to regress and remain as small remnants within the large masses of polyhedra.

**Formation of Polyhedra:** The viral multiplication and occlusion body formation are almost inhibited during the larval moult (Watanabe and Aruga, 1971). The polyhedral protein is synthesized in the cytoplasm and increases from the apical to basical regions (Kawase and Miyajima, 1968). The proteins appear like threads and small masses on minute granules linked to gather by fine filaments. Numerous threads of polyhedral proteins are usually found scattered in the cytoplasm, and are specially abundant in the area of formation of the polyhedra. The polyhedral formation starts on the surface of the virogenic stroma and the number of mature virions increases considerably. At first many threads of polyhedral proteins diffuse into a relatively large mass of virions/viral particles and form pre-polyhedra. Loosely assembled proteins are then arranged and crystallized tightly to form a polyhedron. Once crystallization is over, the polyhedron further grows through the accumulation of threads and masses of protein granules along the crystalline lattice occluding the virions simultaneously.

**Release of Polyhedra:** Due to pressure exerted by the Polyhedral occlusion bodies (POBs) in cytoplasm, the columnar cell wall ruptures releasing numerous POBs into gut lumen. The damaged epithelial cell get discharged into the mid-gut lumen and thrown out through faeces (Inoue and Miyajima, 1978).

**Diagnostic procedures**

**Histopathology:** The mid-gut of an insect is a barrier to invading particles. The barriers involves the chemical composition of the midgut fluid, a non specific surface inhibitor, and the peritrophic membrane. The regeneration of midgut epithelial cells has been considered as an immune factor to protect the insect from viral infection. The degree of cellular regeneration varies with insect strains and the virus doses. The insect midgut epithelium has a regenerative ability to heal injuries by invasive pathogens particularly viruses. This ability is closely involved in the resistance of the insect and development of disease. Histopathological studies of the mid-gut epithelium of the mulberry silkworm infected with CPV showed that the CPV multiplies in the cytoplasm of columnar cells. Almost all the infected cells were discharged. The cellular cells fell off into the mid-gut lumen.

**Serological Methods**

Serology is a branch of immunology concerned with in vitro antigen – antibody reactions. It attempts to quantify these reactions by keeping one reagent constant and diluting the other. Some of the important serological reactions include, agglutination reaction, precipitation reaction, immune florescent reaction, ELISA and DIBA. These techniques can also be used in the area of sericulture for diagnosis and identification of pathogens especially viruses. In India very less work has so far been done on study of silkworm viruses using serological techniques. Serological techniques are employed in silkworm viruses for their identification, to observe strain differences, to locate the site of infection or to know the target tissue infected and to estimate the virus concentration in the fluid.

**Epizootiology**

The severity of the cytoplasmic polyhedrosis is influenced by several factors such as the pathogen, susceptibility of silkworm, nutrition, environmental factors, etc.

a). Resistance and susceptibility: In general, the silkworm breed or the breed of different geographical origin do differ in the degree of susceptibility to pathogens (Singh et al, 2003, 2008). The susceptibility of the larvae to pathogen infection changes during each instar. Early instars are highly susceptible than later instars (Sahay et al, 2006). The larvae, soon after ecdysis during which the peritrophic membrane have not yet formed in the mid gut are more susceptible to the virus infection. Males are less susceptible to CPV than females. Resistance to CPV is controlled by multi factorial gene system (Jia – long, 1987). The breed susceptibility in tasar silkworm, Antheraea mylitta to AmCPV and Bombyx mori to Densovirus virus have been studied by (Singh et al, 2003, 2008) and attempts have also been made to induce resistance in silkworm against specific infections and the attenuated viruses have been observed to induce resistance to infection in silkworm. Attenuated BmNPV and AmCPV as oral vaccination suppresses the development of polyhedrosis in silkworm to an extent of 80% (Nataraju, 1995; Nataraju et al, 2000; Singh et al., 2011).

b). Latent infection and induction: The various factors controlling the induction of latent CPV are: (1) Genetic factors, (2) Environmental factors, (3) Chemicals, (4) Nutritional factors (quality of leaf), (5) Physiological factors especially the condition of the mid gut which in turn is controlled by both genetic and environmental factors.

c). Spread and Transmission: CPV contaminated leaves of food plant may be an important source of infection during silkworm rearing. The tasar silkworm larvae reared outdoors are infected with CPV, the wind and rain may scatter the virus from the contaminated faeces and disintegrated dead larvae. CPV particles
which are occluded in the polyhedra are able to withstand adverse conditions such as desiccation, sunlight and moderate temperature for long period. The CPV infect *Bombyx mori* can persist for one year (Aruga, 1971). The virion when present outside the polyhedra are generally destroyed by adverse environmental conditions. Generally CPV is transmitted from one individual to another though mouth (per oral transmission), egg (transovum transmission) and cross contamination by alternate hosts.

d). Nutrition: Nutrition apparently plays an important role in the inhibition of virus epizootics in general. The quality of the leaf of *Terminalia arjuna* and *T. tomentosa* may be very important in activating the CPV in the tasar silkworm. Feeding of larvae on bad quality leaves cause higher incidence of CPV. Feeding of matured larvae on tender juicy leaves, which are deficient in nitrogen, increases susceptibility to CPV. Besides, an imbalance between nitrogen and carbohydrates in the food induce polyhedrosis.

a) Starvation: Starvation of silkworm larvae may affect the multiplication of the virus and the number of polyhedra formed in the mid-gut.

**Influence of Temperature and Relative humidity:** Environmental factors may have some influence on the incidence of CPV during the rearing of silkworm. Among various physical factors temperature and relative humidity has received most attention as far as its effect on epizootics. High temperature associated with high relative humidity predispose the disease. Certain environmental factors that affect the egg may be associated with the incidence of CPV in the larval stage. Conditions during hatching and the temperature of incubation appear to influence the incidence of CPV. To reduce the incidence of CPV, the silkworm eggs should be incubated under optimal environmental conditions i.e. in respect of temperature (28 - 30°C), high relative humidity (70 – 80 %) and hydrochloric acid treatment. The natural epizootics of the diseases are very common in overcrowded population.

**Alternate hosts**

The pathogenicity of silkworm CPV to several lepidopteran insects is known. The virus retains its infectivity for silkworm after passes through various insects.

**Dissolution and inactivation of CPV**

Polyhedra of CPV is dissolved in 2% formalin, chloroform and chloroform-n-butanol (1:1). 0.5% calcium hydroxide and in an alkaline medium at high pH 10.8 or above.

**Control Measures**

1. Tasar Keet Oushadh (TKO) for dusting on the body of worm is recommended, this may be done once in II, III & IV instar and twice in V instar, for which 1.5 kg/100 dfls TKO is required.

2. Foliar application of fresh solution of 0.01% sodium hypochlorite (2.5 ml/ltr) on the worms while they are on the bushes once each in II, III, IV instars (24 hrs after moult) and twice during V instar (at an interval of 5 days). The estimated requirement is 50 ml of sodium hypochlorite for 100 dfls rearing.

3. Application of Jeevan Sudha during 1st, 2nd and 3rd instar.

**Bacterial Diseases**

Bacteria are prokaryotes. The entire organism consists of a single cell with a simple internal structure. Unlike eukaryotic DNA, which is neatly packed into a cellular compartment called the nucleus, bacterial DNA floats free, in a twisted thread-like mass called the nucleoid.

There are three basic bacterial shapes, Round bacteria are referred to as cocci (singular: coccus); cylindrical, capsule-shaped bacteria as bacilli (singular: bacillus); and spiral bacteria are aptly called spirilla (singular: spirillum). Cocci can also associate with one another in different configurations: combinations of two or diplococcus; a linear chain or streptococcus; and a cluster or staphylococcus.

**Entomopathogenic bacteria**

Over 200 strain of bacterial genera including *Enterobacter*, *Serratia*, *Pseudomonas* and *Proteaus* spp. Have been isolated from diseased insects and most of them found facultative pathogens whose pathogenicity is dependent on the stress factors affecting the host insect (Lysanko, 1983). The diseases in insects caused by bacteria are generally classified as bacteremia, septicaemia and toxaemia. Bacteremia is the result of multiplication of bacteria in the gut of insect without production of toxins. Generally non-pathogenic bacteria in symbiotic association with the insect often cause diseases. The pathogenic bacteria invading the haemocoel, multiplying and producing toxins to kill the insect. Most frequently cause septicaemia. Toxaemia occurs when the bacteria produces toxins in the gut. These bacteria confine to the gut lumen.

**Classification of Entomopathogenic Bacteria**

Bacteria are the most common microorganisms associated with insects. A significant number of them are pathogenic and cause considerable damage in rearing of economically important insects such as honey bee, lac insect, silkworm etc. Entomopathogenic bacteria occur in the families Bacillaceae, Pseudomonaceae, Enterobacteriaceae, Streptococccaceae and Micrococccaceae of order Rickttsiales and class Mollicutes.

**Bacteriosis in tasar silkworm**

Tasar silkworm is susceptible to various bacterial pathogens that cause a number of diseases to this important insect. The disease is commonly known as bacteriosis. Death of worms due to bacteriosis occurs in every stage of its life cycle. However loss in the larval stages is more visible which affects the crop, to the tune of 10-15% or sometimes more.

**Occurrence:** The occurrence of bacterial disease in Tasar silkworm is more pronounced during June – Sep. than that of the
other seasons.

**Symptoms:** Symptoms caused by different bacteria are atypical and are of general type. The initial symptoms in the larvae are immobility and sluggishness. Diseased larvae lose appetite and become irritable. With the advancement of disease worms become flaccid (soft), long and thin followed by loss of gripping ability. Distinct features develop in tasar silkworm larva are:

**Chain type excreta:** The faecal beads excrete out of the anal aperture embedded in a jelly like substance in the form of a chain and the larva hangs obliquely.

**Rectal protrusion (Swelling of anus):** The rectum protrudes out as transparent bag filled with haemolymph. The anal lips dilate and the body contracts lengthwise.

**Sealing of anal lips:** Soil coloured sticky semisolid fluid oozing from colon seals the anal lips. The larvae shrink lengthwise.

In all the cases the body colour becomes darker, infected larvae stops feeding, does not respond to the external stimuli, falls and dies.

**Pathogen of Bacteriosis:** *Streptococcus faecalis* and *S. faecium* bacteria are the most common bacteria associated with bacterial disease of digestive organ in silkworm *Bombyx mori*. These are round and appear in chain or beaded form with 2 or more cells joining together. They are gram positive and measure 0.7 – 0.9 µm in diameter.

On the basis of microscopic observations, rods and cocci were considered to be the pathogen of bacteriosis of tasar silkworm. *Bacillus* sp. was thought to be the causative agent for sealing of anal lips, *Micrococcus* sp. responsible for rectal protrusion and *Bacterium* sp. associated with the chain type of excreta (Sen et al, 1969). For identification of bacteria pathogens causing various types of bacteriosis in *Antheraea mylitta* D. systematic study was conducted by Roy et al (2008) and Singh et al (2010). From the study, it has been referred that *Serratia marcesens*, a gram negative, rod shaped bacterium is the causal agent of bacteriosis of tasar silkworm showing chain type of excreta. Anal lip sealing is caused by a gram negative rod identified as *Proteus vulgaris*. *Pseudomonas mendocena* is associated with another type of common bacterial disease rectal protrusion.

**Mode of Infection:** The bacteria infect silkworm and several insects primarily through mouth and digestive tract. In insect, infection through egg, integument and trachea are also reported. The pathogen may also gain entry through parasitoids and predators. Under stress conditions such as unfavorable temperature and humidity, abnormal nutrition, other microbial infection etc, the bacteria may multiply in the gut to large number before invading the haemocoel. Bacterial pathogens cause damage or death of host by enzymatic means or by biochemical reactions. Successful infection depends on significant correlation between pathogenicity of the bacterial strain and their respective ability to produce certain enzymes. In the digestive tract, the bacteria produce enzymes such as chitinase, lecithinase and proteinase which act on the midgut epithelium and enable the bacteria to enter hemocoel. Bacterial exotoxins and endotoxins also play an important role in invasion of the digestive tract. A fall in the gut pH has been reported (Iizuka, 1972a, b, Ono and Kato, 1968; Ono and Ichikawa, 1963; Kovalenko, 1970; Pathak and Sharma, 1996).

**Mixed Infection:** Mixed infection occurs simultaneously or one after the other and interaction between the two or more pathogens involved in the incidence of diseases (Matsumoto et al, 1985; Govindan et al, 1990) Mixed infection of bacteria and viruses are common in causing flacherie in mulberry silkworm.

**Silkworm Immunity:** Immunity is an added ability or vital function of an individual added naturally or artificially to resist invasion and development of a foreign particle inside the body. Insects do not possess the ability to produce antibodies, a class of proteins called immunoglobins, and do not use immunoglobins against foreign antigens, several haemolymph induced antibacterial proteins have been reported which are produced in insects in response to bacterial invasion. The defence mechanism in insects is classified into two broad groups. The first one is non-specific immunity, which consists of structural and passive barriers like cuticle, gut physiochemical properties and peritrophic membrane. The second one is specific immune system involving cellular and humoral immunity. Cellular reactions involve phagocytosis, nodulation and encapsulation.
against bacteria, fungi, nematodes invaders. Humoral reactions involve induction of immune proteins such as lysozymes, lectins and antibacterial and antifungal proteins.

The possibility of induced resistance is an important aspect. Antibacterial activities have been induced in the haemolymph of silkworm larvae by the injection of wide variety of gram-positive and gram-negative bacteria. In some cases, heat killed bacteria is also effective as an inducing agent. Detection of antibacterial substances of the silkworm gut, *Bombyx mori*, *Antheraea pernyi* and *A. Mylitta* have been reported (Iizuka, 1983; Engstrom et al, 1984; Nagaraju and Radha, 1990; Nagaraju et al, 1992; Abraham et al, 1995; Yasui and Shirata, 1995; Sridhar et al, 2000).

Management of bacterial diseases

A healthy silkworm is generally more resistant to infection than stressed one. Stress brought about by the malnutrition, metabolic imbalance, physical and other factors result in weakened larvae and increased susceptibility to bacterial infection. In order to check the outbreak of the bacterial diseases in silkworm, it is essential to eliminate the stress factors as much as possible by feeding silkworm with highly nutritious leaves and rear them under congenial and hygienic environment.

Various antibiotics have been used to suppress bacterial diseases in silkworm. Streptomycin, aureomycin and tetracycline, Neomycin, Tetracycline have been reported to suppress the bacterial disease in silkworm. Various antibiotics have been used to suppress bacterial diseases in silkworm. Streptomycin, aureomycin and tetracycline, Neomycin, Tetracycline have been reported to suppress the bacterial disease of digestive organ (Afrikan, 1960; Radha et al, 1980; Baig et al, 1990)

For preventing outbreak of Bacterial diseases, dusting of slaked lime and bleaching powder (9:1) once in each instar and thrice in 5th instar on the ground under bushes and over the bushes have been found effective. Application of TKO is also effective in controlling bacterial infection. Application of Leaf Surface Microbe (LSM) a biological control found effective to control of bacteriosis in tasar silkworm (Roy et al, 2009; Madhusudan et al, 2013).

**Muscardine or Mycosis**

Muscardine or mycosis is the disease in insects caused by fungi. Several species of fungi cause infection of which *Penicillium citrinum* and *Paecilomyces varioti* cause muscardine disease in tasar silkworm. These are found throughout the world and most contagious. These are named based on the colour of the mycelium together with conidia on the surface of the cadaver as white or yellow. The loss due to muscardines in tasar silkworm ranges 2 – 5 % (Sahay et al, 2000). The incidence of muscardine is noticed particularly in silkworm rearing during September to November.

**Causative agents:** Muscardine or mycosis in tasar silkworm is caused by the infection of *Penicillium citrinum* and *Paecilomyces varioti*. Belongs to Kingdom Fungi, Division Eumycota, Sub division Ascomyxtina, Class: Plectomycetes, Order Eurotiales, Family Eurotiaceae.

**Characters**

Hyphae more or less cottony masses, hyaline, septate, smooth, 2.5 – 3.0 u in diameter. Phialids (sterigmata) are crowded, 8 – 11 X 2 – 2.5 u. Conidia uninucleate, globose, 2.5 – 3.0 u diameter, capitate, catenate, packed in solid divergent coloumns. Mature conidia are easily carried of in the air and germinate on the host by producing germ tube. Matulae club shaped, 14-16.7 u in length and 4.8 u in breadth.

**Infection**

The source of infection includes dead silkworms, contaminated leaves of food plant, infected insects etc. The disease is spread by contact and by air and contaminated food. The common routes of infection are integument, trachea and wounds. Infection occurs by penetration of the host integument by germ tube produced by conidium within a trachea or on the body surface. These germ tubes force their way into the body through spiracles or integment by mechanical force or enzymatic action or both.

**Symptoms**

The infected larva becomes inactive and loses its appetite. The colour turns pale and the body gets hardened. In about 12-14 hours the larva hangs with its anterior or posterior half obliquely downward giving a characteristic dorsal bending. The worm at this stage looks very hard and pale and dies in another 6-8 hours. Eight hours after death the worms become spongy and very fragile. In the next 16-18 hours a white encrustation appears round each segmental ring and the larva gets more compressed laterally. After another 24 hours the encrustations cover whole the body. The dead worms become completely compresses laterally. The white encrustation turns slightly greenish powdery material after 24 hours indication the formation of conidiospores. The dead larva becomes dry, brittle and mummified.

![Muscardin infected tasar silkworm](image)

**Life Cycle**

Asexual stage is the most prominent consisting of conidia born on characteristic heads of conidiophores. Certain cells of the submerged mycelium become larger and thick walled and they are called as foot cells. The foot cell gives rise to a single, straight or some times curved, septate or non septate conidiophore. Conidiophore is usually unbranched peg like, multinucletate, cylindrical outgrowths called phialides (sterigmata). Phialides are in single series or the primary series of phialid gives rise to generally two, rarely up to four branches which together form the secondary series of phialides. Conidia are formed in chains from the tips...
of phialids. The unbranched conidial chain bears the youngest conidium just next to phialide. The conidia are easily carried off in the air and germinate on the host by producing germ tube.

We do not know much about the sexual stage of *Penicillium citrinum*, but the cleistothecia of many species of *Penicillium* gives a clear idea of the sexual stage of this fungi in general. The mycelium which may have produced conidia earlier begins to bear sex organs viz. archicarp, the female organ and antheridium, the male organ side by side. The later twisting around the former and coming in close contact with trichogyne. Normal fertilization takes place and ascocarp-cleistothecium is formed. The resting spores (ascospores) formed sexually are of distinct advantage to the organism as they remain viable under conditions in which they do not survive.

![Life cycle of Penicillium citrinum causal organism of muscardine](image)

**Paecilomyces variotii**:
Belongs to order Moniliales and family Moniliaceae. Hyphae are hyaline, septate. Conidia (2.9 x 2.5 μ) are oval or spherical. Germ tube forms attachment (appressorium) before penetrating into the host body. Later mycelia ramify in the internal system.

**Symptoms:** As the disease progresses, the silkworm loses appetite. Becomes inactive and in many cases produces several black specks on the skin. But relatively large specks appear around the spiracles. Vomiting and diarrhoea are also noticed. The white efflorescence starts initially on the intersegment region in a day or two after death. The cadaver looks white in the beginning but turns yellowish with the production of the conidia. The incubation period is 5-10 days.

**Prevention and Control**
Though no curative measures have been discovered, the muscardine in tasar silkworm can be controlled by adopting preventive (prophylactic) measures.

**Formalin**: It is formaldehyde gas dissolved in water. This is highly penetrative and fungicidal. 0.06% formalin solution on the body of the larvae should be sprayed before transfer when there is a outbreak of the disease.

**Tasar Keet oshadh (T.K.O)**: T.K.O. is evolved by C.T.R. & T.I., Ranchi for dusting on the body of silkworms. As a practice, dusting of T.K.O. may be done once in II, II & IV instar and twice in V instar on the body of the larvae before transfer. For 100 dfis rearing 1.5 kg of T.K.O. is required.

**Sodium hydroxide (NaOH)**: Spraying of 0.5% NaOh on the worms 24 hours after each moult out is an useful prophylactic measure.

**Integrated Management of Silkworm Diseases**
The microbes such as virus, protozoa, bacteria and fungi cause the infectious disease in silkworm such as virosis (cytoplasmic polyhedrosis), pebrine, bacteriosis and muscardine in all the rearing seasons. While the pathogens are the primary cause for all infectious diseases in silkworm, there are several inherent, environment and nutritional factors influencing survival of pathogen, the susceptibility of the host to infection and development of disease. In addition, the inherence of susceptibility to different diseases in silkworm are controlled by polygenes. There is no breed completely resistant to all diseases.

As a first step in management of diseases in silkworm, it is most essential to prevent the contamination of tasar food plants that is the feed of the silkworm. All pathogens with the exception of fungus enter the host through the Arjun/Asan/Sal leaves. To eliminate the contamination of food plants it is essential to eliminate the disease causing pathogens from the rearing environment. Having understood the impact of various factors associated with the host, pathogen and environment in disease development, the integrated strategy to prevent the diseases in silkworm rearing are much effective.

**Causes for diseases in tasar silkworm**
The tropical environment coupled with unhygienic conditions tends to promote faster multiplication of pathogens. Common reasons for the same are non-practice of effective disinfection for both rearing place and appliances, non- sterilizing of eggs before incubation and improper incubation, contamination during the rearing, supply of poor quality leaf, unhygienic conditions, lack of required environmental conditions, inadequacies in following improved rearing techniques.

Continuous rearing without practicing effective disinfection methods and proper disposal of diseased worms helps in the accumulation and persistence of pathogens which form continuous source of contamination. Therefore, contamination either during incubation/ hatching stage or rearing periods are the main causes for diseases.
to develop during rearing. Hence it is necessary to remove pathogens in all possible ways from rearing environment.

Usage of disease free layings: From the survey it is clear that diseases noticed during rearing primarily due to brushing of diseased layings. For production and supply disease free layings, proper individual mother moths examination and disinfection of selected layings in depuratex is essential.

Elimination of pathogens from rearing environment: The right approach to eliminate the pathogens from the rearing environment to conduct disinfection of the rearing environment prior to the commencement of silkworm rearing. Disinfection is an activity, which results in the destruction of specific pathogenic organisms.

Removal of pathogens from rearing appliances: Pathogens are present in all the rearing appliances. Appliances used during rearing are the primary source of pathogen contamination. To eliminate the pathogens from the appliances they should be disinfected in 2% formalin solution for at least 30 minutes and must be completely dried under direct sunlight before using for next rearing.

Disease management module for Prevention and control measures of tasar silkworm diseases

As there are no curative measures against diseases in tasar silkworm, different preventive methods are followed to protect the silkworm from diseases. Among different preventive methods, disinfection and maintenance of hygiene are the important. Utmost care should be taken by way of prophylactic measures which are listed below.

Before Rearing
1. If possible, burning or flame gunning of rearing field during March – April.
2. The ground area in and around rearing site should be made cleared of bushes and weeds before start of rearing.
3. Practice disinfection of silkworm rearing field, with 5% bleaching powder. A spray of 1.0% slaked lime solution in addition of usual disinfection should be done in case of high incidence of disease. Disinfection of rearing field thoroughly (ground and bushes) with dust of slaked lime and bleaching powder (9:1)
4. Silkworm egg surface must be disinfected with 5% Depuratex solution.
5. The rearing appliances should be thoroughly disinfected with 2% formalin or 5% bleaching powder solution.
6. Elevated site should be selected for brushing the hatched worms.
7. Over mature, diseased and tender leaves should be plucked before brushing the hatched worms.

During rearing
7. Avoid overcrowding of worms on bushes especially during IV and V instars.
8. Practice hygienic measures during rearing. Ensure the measures for destruction of diseased silkworms.
9. Identify and pick out infected larvae in the early stages.
10. Feed quality leaves.
11. At an interval of 4-5 days sprinkling of mixture of bleaching powder and slaked lime (1:9) under the rearing bushes should be done.
12. The water logging in the rearing site should be avoided so as to check increase in the humidity.
13. The silkworm litter under the tree, the diseased and dead worms are the main source of infection as such they should be disposed off daily in a deep pit or should be burnt in far off place.
14. Fresh solution of 0.01% sodium hypochlorite (2.5 ml/ltr) should be sprayed on the worms while they are on the bushes once each in II, III, IV instars (24 hrs after moult) and twice during V instar (at an interval of 5 days).
15. The estimated requirement is 50 ml of sodium hypochlorite for 100 dfls rearing.
16. Tasar Keet Oushadh or jeevan suraksha may be dusted on silkworms body during transfer
17. (TKO) for dusting on the body of worm is recommended, this may be done once in II, III & IV instar and twice in V instar, for which 1.5 kg/100 fls TKO is required.
18. Foliar Application of LSM during 2nd instar is effective against bacterial diseases
19. Application of Jeevan Sudha during 1st, 2nd, 3rd instar is effective against virosis disease in tasar silkworm.

After Rearing:
Disinfection of complete rearing field with slaked lime and bleaching powder (9:1) must be taken within one week of harvesting of cocoons.

Formulations developed for management of tasar silkworm diseases

Depuratex for cleaning and surface sterilization of tasar silkworm: Depuratex, is an ideal disinfectant, used for the surface cleaning and sterilization of tasar silkworm eggs. It is cost effective, user friendly and easily adoptable to achieve qualitative and quantitative seed production of tasar silkworm. It not only ensures proper cleaning and disinfection but also reduces the danger of egg damage due to scrubbing effect. Prepare 5% concentration solution of Depuratex disinfectant (50 ml Depuratex + 1000 ml of clean and fresh water). Take tasar silkworm eggs after the mother moth examination in nylon net. Dip the tasar silkworm eggs in the prepared 5% Depuratex disinfectant solution. Allow the eggs in the solution for 10 minutes provided with frequent stirring. Take out the eggs along with the nylon net and rinse/smooth rub in the running water for one or two minutes. Spread the disinfected tasar silkworm in thin layer on the news paper/ blotting paper and allow the egg for drying.
Jeevan Sudha: Jeevan Sudha is a botanical formulation developed from medicinal plants for containment of virosis in tasar silkworm (Singh et al., 2008, 2010). Total requirement of Jeevan Sudha powder is 300 gram for rearing of 200dfls. Instar wise requirement of Jeevan Sudha is 50, 100 and 150 g during 1st, 2nd and 3rd instar respectively. 1.0% aqueous extract is used as foliar spray. Soak the required quantity of the Jeevan Sudha in clean water as per required doses for 10 – 12 hrs (overnight) and filter it using muslin cloth and squeeze completely. Spray filtered solution on the foliage of bushes used for feeding the silkworm larvae, once each in 1st, 2nd and 3rd instar during feeding stage.

Tasar Keet Oushad (T.K.O): TKO is a tasar silkworm body disinfectant. TKO is used for controlling muscardine and virosis. It is dusted on the larvae out of each moult and on the 4th day of fifth instar at the rate of 3g (I-III instar) to 5g (IV & V instars) per sq. ft. TKO contains of para-formaldehyde, benzoic acid and slaked lime in the ratio of 0.5: 2.0: 97.5. For 1.0 kilogram of TKO, 5g of Para formaldehyde, 20g of benzoic acid and 975g of slaked lime are mixed uniformly and thoroughly. The TKO thus prepared should be kept in air tight container or polythene bag and sealed to avoid absorption of moisture

Jeevan Suraksha: Jeevan Suraksha is a combination of lime, bleaching powder, turmeric in the ratio of 8.5:1:0.5, respectively. The dust formulation is used as dust application during rearing. Application is done on food plant along with silkworm and on ground below bushes. The application is done once during 2nd, 3rd, 4th and 5th instar 24 hours after moult, and during the transfer of worm. 3.00 kg Jeevan Suraksha is required for 100dfls rearing.

Leaf surface microbe (LSM), for tasar silkworm diseases management: Leaf surface microbe (LSM) is developed and used for biological control of tasar silkworm diseases (Roy et al., 2009). Leaf surface micro (LSM) of tasar food plants has strong antagonistic action against bacterial and viral pathogens of tasar silkworm. LSM is used as foliar spray in soil water once during 2nd instar. For making water suspension 4-5 kg of soil from ½ feet depth is taken from rearing field in a bucket and thoroughly mixed with 10 liters of water and allowed to settle for about 12 hours (Overnight). On the next day, take the clean water from the upper layer of the bucket. Mix the content of the supplied LSM ampoule with 5 liters of the freshly prepared soil water.

Sodium hypochlorite to check virosis and bacteriosis in tasar silkworm: Foliar application of 0.01% Sodium hypochlorite checks the virosis and bacteriosis diseases of tasar silkworm (Sahay et al. 2008). Prepare solution of Sodium Hypochlorite (NaOCl) by mixing 2.5 ml of NaOCl in 1 liter water. Spray NaOCl solution on the bushes once in each instar from 2nd to 4th and twice in 5th instar after a gap of 5-7 days.

When sodium hypochlorite comes in contact with viruses, bacteria and fungi, it oxidizes molecules in the cells of the germs and kills them. High alkalinity of sodium hypochlorite dissolves polyhedral proteins leading death of viruses. The compound in solution is unstable and easily decomposes, liberating chlorine, which is the active principle. Chlorine penetrate the germs cell membrane and change the permeability to release of macro molecules like DNA, proteins etc leading to death of germs.

Disinfectants for tasar culture
Disinfection is an integral part of tasar silkworm rearing aimed at destruction of disease causing pathogens. The elimination of pathogen from the silkworm rearing environment is achieved by disinfection of rearing environment using physical and chemical disinfectants. Adoption of physical disinfection of rearing site, drainage houses and appliances will encounter practical problems to ensure complete disinfection. The physical method involves disinfection by heat treatment through sunlight, steam and flame gun while chemical method of disinfection is achieved by fumigation, dusting and spraying of chemical disinfectants. The disinfection of silkworm rearing environment is the most important activity involving meticulous cleaning and uniform spraying of specific quantity and concentration of chemical disinfectant.

Choice of disinfectants
Choice of chemical disinfectant for use on contaminated surface or waste depends on a number of factors.

1. Number and nature of microbes to be destroyed (spores/vegetative cells).
2. Purpose of treatment (disinfection/sterilization).
3. Types of items to be disinfected.
4. Contact time and temperature required for disinfection.
5. Toxicity to individual, culture system, environment, residual toxicity and effect on items such as fabric and metal.
6. pH, temperature, hardness of available dilution water.
7. Simple and easy to use.
8. Requires less time.
9. Cheap and easy to obtain.
10. Fairly stable and homogenous.

The first choice to be a good disinfectant is that the disinfectant should preferable has broad-spectrum activity with the potential to kill a wide range of microorganisms. It should kill microorganisms of all kind, particularly the pathogens, although destruction of others, which are considered harmless to human and animals, is sometimes also important. Many non pathogens attack organic matter, producing chemical, which may be highly odorous, corrosive or staining. Elimination of such organisms is certainly a plus factor to be desired from any product.

Action of disinfectants on silkworm pathogens
There are various methods through which different disinfectants act on the microbes. A few important processes involved in the course of disinfection are:

a) Oxidation: Chlorine compounds viz., hypochlorite, bleaching powder, chlorine dioxide etc. act against the pathogens on the principle of oxidation. If oxygen is liberated in the chemical reaction destruction of organism may take place.
b) **Hydrolysis**: Concentrated acids viz., HCl, alkalies and hot water treatment act against pathogens on this principle. In hydrolysis, water is added in the reaction, followed by splitting of molecule – which has an anti-germicidal effect.

c) **Combining with protein**: Some of the heavy metals which are used as a disinfectant viz., mercury, silver etc., combine directly with the protein of the pathogens and upset the balance of their protoplasm, causing the eventual death of these pathogens.

d) **Coagulation of cellular protein**: When the disinfectants are applied, they coagulate the colloidal protoplasm. During this process, severe physical and chemical shocks develop which kill the microbes.

**Disinfection in tasar culture**

Various chemical disinfectants viz., formaline (vail *et al*, 1968; Ignoffo and gracia, 1968), sodium hypochlorite (Sahay *et al*, 2008), quarternary ammonium compound (Waterhouse, 1959), iodine compounds, (Venkata reddy *et al*, 1990) Lime, phenolic compounds (Henga, 1977), calcium hydroxide (Patil, 1991), chlorinated lime (Balvenkatasubbaiah *et al*, 1993), Chlorine dioxide (Balvenkatasubbaiah *et al*. 1994, 1996, 1999) have been reported for their germicidal action against a few or all silkworm pathogens. Efficacy of certain disinfectants including bleaching powder, slaked lime and formalin has been tested and found effective against virosis and pebrine diseases of tasar silkworm (Singh *et al*, 2005, 2006). Singh *et al* (2004, 2006) reported that wood ash solution is also a good disinfectant against viuses and bacteria and it can be used as an alternate of slaked lime. Silkworm body disinfectants are also effective to reduce the disease incidence in silkworm (Baig *et al*, 1980; Sahay *et al*, 2005). Among the various disinfectants, however, the use of formalin, bleaching powder, slaked lime, and chlorine dioxide are in practice in many sericulture countries.

**Formalin**: Formalin is commercially available as 36-38% formaldehyde in solution form. It is a clear and colourless solution with irritating odour, pungent and suffocating. A mixture of 2% formalin is an effective solution that can be used for disinfection purpose as spray. Pathogens are killed by the strong reducing action of formaldehyde, the active ingredient in formalin solution. It forms formic acid utilizing the oxygen from the cells leading to the death of the germ. Formalin is effective only in closed houses like grainages, which can be made airtight and it is faster and more pronounced at temperature above 25°C and humidity more than 70%. Fumigation of formalin and potassium permanganate is best suited for the closed area like grainage. Fumigation is carried with a solution of 2 liters of commercial formalin, 500gm potassium permanganate and 3 liters of water. Desired solution of formalin can be prepared by formula.

\[
\text{No. of parts of water to be added to one part of formalin} = \frac{\text{Available conc.} \cdot \text{Required conc.}}{\text{Required concentration}}
\]

**Bleaching powder**: Bleaching powder is white amorphous powder, with a pungent smell of chlorine. It is a mixer of calcium hypochlorite \(\text{[Ca (OCl)}_2\text{]}\), calcium chloride \(\text{[CaCl}_2\text{]}\) and small amount of calcium hydroxide \(\text{[Ca (OH)}_2\text{]}\). Pathogens are killed by three way action of bleaching powder i.e. oxidizing action of nascent oxygen, leak out of macromolecules of cell membrane by chlorine and high alkalinity of calcium hydroxide. Hypochlorite in combination with weak acid \((\text{CO}_2\text{ in air})\) and water produces hypochlorous and hypochloric acid. Hypochlorous acid is unstable and resolves in to hydrochloric acid and nascent oxygen. The oxidation reaction by nascent oxygen is germicidal (Anon, 1975). Hydrochloric acid also aids in the release of chlorine which is also germicidal. Chlorine alters the permeability of cell membrane of germs by which allows leaking out the macromolecules like nucleic acids and proteins. The main component of bleaching powder is calcium hydroxide, which is germicidal, also dissolves the polyhedral proteins to release and disintegrate the of viruses. For effective disinfection, a high-grade bleaching powder with an active chlorine content of 34% is recommended. It should be stored in sealed bags, away from moisture, failing which it will lose its affectivity. The action of bleaching powder is optimal on contact under wet conditions and therefore the surfaces of equipment and walls should be drenched with this solution.

**Slaked lime (calcium hydroxide)**: Slaked lime is calcium hydroxide \(\text{(Ca(OH)}_2\text{)}\). Slaked lime is very useful disinfectant in tasar culture especially against viruses. The slaked lime application in the form of dust absorbs moisture and can be used to regulate humidity and maintain hygiene. Application of lime dust in combination with bleaching powder (9:1 ratio) in and around drainage house, rearing bushes and premises improves hygiene in the environment. Burnt limestone (Calcium Oxide) is hydrated with water to give calcium hydroxide and slaked lime powder.

**Chlorine dioxide**: Chlorine dioxide as gas is well known as most powerful anti-microbial agent and its advantage as a hard surface disinfectant widely recognized. As, chlorine dioxide is highly toxic and very unstable. Chlorine dioxide gas has been stabilized in solution form. Stabilized chlorine dioxide is superior disinfectant than chlorine in many respects (Balvenkatasubbaiah *et al*, 2006). It is stable, 2.5 times more effective than \(\text{Cl}_2\), and 50 times than hypochlorite. 500 ppm stabilized chlorine dioxide in combination with 0.5% slaked lime is effective on all silkworm pathogens.

**Exercise**

Further, exercises for tasar silkworm disease management are also felt on the following.

1. The spore wall proteins of microsporidia may play important role in recognition of the host during the invasion process of pathogen. Hence, studies are needed to characterize the spore wall proteins of *Nosema mylittensis* causing pebrine disease in tasar silkworm and employing bioinformatics (In Silico) approaches such as molecular modeling, active site analysis and docking of potent inhibitors which may be useful to control the pebrine disease.

2. There is a demand for more effective bio-control agents that can not only control the virus and bacteria but at the same time are user and environment friendly. There are many reports
where the Secondary Metabolites from microbes are playing a significant role in the control of viruses and bacteria. Hence, studies are needed to explore the metabolites of bacteria of soil and leaf surface of tasar host plants for controlling virosis bacterial infection in tropical tasar silkworm.

3. Till date, individual mother moth examination is being done during grainage operation. It is very tedious, cumbersome, time consuming, which is next to impossible where minimum 4 to 5 lakhs cocoons are processed in BSMTCs, PPCs, etc. Hence, further studies are needed on mechanization of mass mother moth examination using conveyer belt, a series of scanners for identification of penrine spores. Besides, there is a scope of artificial intelligentsia by training of computer for identification of pebrine spores.

References
Use of monoclonal antibodies to BmNPV for early detection of the nuclear polyhedrosis disease in *Bombyx mori* L. Sericologia, 36:75 – 83.


Introduction

Tasar silkworm A. mylitta produces tasar silk of commercial importance. This species is endemic and distributed in different geographical regions of India in the form of ecological races (44 ecoraces). They show variations in their phenotypic traits such as fecundity, voltinism, cocoon weight, silk ratio and also in their host plant preference. The traditional approaches emerge to be reaching the natural biological limits of the silkworm with regards to its growth rate, silk yield and fecundity. Thus, it is becoming increasingly important to turn to the new approaches of genetic engineering, bio-technological exploration with endeavor for speedy growth of tasar silk industry in order to produce better silkworm strains and novel technology for various bio-active products. Tropical tasar culture is confined to mainly in India; hence, the biotechnological study is not colossal. Therefore, biotechnological interventions for speedy growth tasar silk industry are needed. Several problems still continue to retard the growth of the tasar silk industry; some imperative problems needs modern bio-technological interventions for quality linked silk production. The quality and yield of silk depend on availability of healthy silkworms, which itself depends on high-quality feed and disease free stocks. Traditionally, strain improvement technique has been used in breeding methods for production of innovative high yielding strains. There is no consistency in cocoon yield per dfi. Various emerging fields has been recognized for bio-technological interventions The key problems are gradual decrease in number of ecoraces and its specific identification. Therefore, to understand the genetic closeness and also for the identification of the wild silkworm ecoraces, development of molecular marker is important using SNP genotyping and whole genome sequencing are necessary. Sal flora utilization through gut symbionts is another important area for exploration. Although, Sal flora is available abundantly (70-84%) but its effective utilization is less due to plant metabolites and other unknown factors which affects the digestion, leads to poor survivability of commercial ecorace of tasar silkworm i.e Daba. The gut-symbionts have diversified functions like digestion, disease resistance, pheromone production, improvement of silk quality etc which were elucidated in detail in other insects but unexplored much in A. mylitta. Functional characterization of these gut symbionts in sal based ecoraces in comparison with commercial Daba and augmenting the gut flora which are lacking in the commercial Daba thereby improving the fitness. This will create clear cut and viable option for effective utilization of Sal flora by the commercial A. mylitta ecoraces in future. Likewise, there are many areas for this kind of work in tasar silk industry. Eco friendly proteolytic enzymes such as cocoonase and other plant and bacterial protein can be used to minimize the harsh and energy demanding chemical treatments. (Bhardwaj et al., 2015; Bhattacharjee et al., 2016; Bhattacharjee et al., 2015; Bhattacharjee et al., 2016; Bhattacharjee et al., 2016a.; Biswa et al., 2015; Braslavsky et al. 2003; Chakraborty et al., 2015; Chakraborty et al., 2015; Chakraborty et al., 2015; Chaturvedi et al., 2016; Chouhan et al., 2017; Dashora et al., 2017; Devi et al., 2017; Fang et al., 2017; Guan et al., 2017; Hazra et al., 2016; Jena et al., 2016; Jiayao et al., 2016; Kar, et al. 2005; Kundu et al., 2016; Mahendran et al. 2006; Michelmore, et al. 1991; Panda et al., 2015; Panda et al., 2015a; Renuka and Shamitha 2016; Saha and Kundu 2006; Saha et al. 2008; Sahoo et al., 2015; Sahu et al., 2015; Sahu et al., 2016; Sharma et al., 2016; Srivastava, et al. 2002; Sudha et al., 2015; Wang et al., 2016; Wang et al., 2017; Welsh and Mcclelland, 1990). Hence, following bio-technological interventions for tasar textile industry is needed in this field also.

Bio-technological Approaches: Although the institute There are four major sectors in tasar silk culture i.e. Host plant, Silkworm, Post-cocoon technology and Byproduct utilization. Many of the problems pertain to seed production, rearing technology, training and transfer of technology has been solved by using conventional and modern approaches. Yet several problems still continue to check the growth of the industry, some imperative problems need modern bio-technological interventions for quality linked silk productivity. The quality and yield of silk depend on availability of healthy silkworms, which itself depends on high-quality feed and disease free stocks. Traditionally, strain improvement has used breeding methods for production of innovative high yielding strains. There is no consistency in cocoon yield per dfi. The traditional approaches emerge to be reaching the natural biological limits of the silkworm with regards to its growth rate, silk yield and fecundity. Thus it is becoming increasingly important to turn to the new approaches of genetic engineering, bio-technological exploration with endeavor for speedy growth of tasar silk industry in order to produce better silkworm strains and novel technology for various bio-active products. During recent past, (Bhardwaj et al., 2015; Bhattacharjee et al., 2016; Bhattacharjee et al., 2015; Bhattacharjee et al., 2016; Bhattacharjee et al., 2016a.; Biswa et al., 2015; Braslavsky et al. 2003; Chakraborty et al., 2015; Chakraborty et al., 2015; Chaturvedi et al., 2016; Chouhan et al., 2017; Dashora et al., 2017; Devi et al., 2017; Fang et al., 2017; Guan et al., 2017; Hazra et al., 2016; Jena et al., 2016; Jiayao et al., 2016; Kar, et al. 2005; Kundu et al., 2016; Mahendran et al. 2006; Michelmore, et al. 1991; Panda et al., 2015; Panda et al., 2015a; Renuka and Shamitha 2016; Saha and Kundu 2006; Saha et al. 2008; Sahoo et al., 2015; Sahu et al., 2015; Sahu et al., 2016; Sharma et al., 2016; Srivastava, et al. 2002; Sudha et al., 2015; Wang et al., 2016; Wang et al., 2017; Welsh and Mcclelland, 1990). Hence, following bio-technological interventions for tasar textile industry is needed in this field also.
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

al., 2015; Sahu et al., 2016; Sharma et al., 2016. Srivastava et al., 2002; Sudha et al., 2015; Wang et al., 2016; Wang et al., 2017; Welsh and Mcclelland, 1990) various emerging fields have been recognized for bio-technological interventions.

+ In nature about 87% of sal flora and 13% of Asan and Arjun plants are available but tasar silkworm survival on sal is very less, therefore, there is need to explore the reason for less survival percentage.
+ Environmental chances sometimes severely affect the seed preservation and productivity, this impact is more pronounced during recent past due to global warming, to tackle this problem, it is needed to develop temperature tolerant breeds of tasar silkworm.
+ Development of high yielding plant varieties and its fast multiplication to minimize the gestation period.
+ Full proof disease control method and effective yardstick for identification of healthy stocks are very much required.
+ Termination of diapause as per need of the industry and introduction of egg diapause to utilize the best option of suitable season.
+ There is urgent need for by-product utilization and adequate product diversification using bio-technological tools.
+ Production of recombinant/analogue/variant based bioactive enzyme cocoonase and its utilization in production of organic silk.
+ Morpho-physio-molecular characterization of tasar host-plant, tasar silkworm ecoraces, genome sequencing of Antheraea mylitta, genome sequencing of T. arjuna and T. tomentosa.
+ Genetic and molecular characterisation of ecoraces, promoting their conservation, development of productive breeds lines, evolution of thermotolerant breed of tassar silkworm.
+ Molecular characterisation of disease causing pathogens, development of disease resistant varities farm friendly method of disease detection and ecofriendly management. Development of bio indicator. It is opined that, aforesaid R&D area urgently needs bio-technological exploration and endeavor for sustainable growth of Tasar silk Industry. (Pandey et.al 2018)

Bio-technological intercession for host plants:
Establishment of innovative persona (nutrition value, drought, disease resistant & reduction of gestation period) and in aiding unadventurous plant breeding programs using molecular tools in crucial area for biotechnological intervention in tasar host plants (Table 1, Pandey et al., 2018)

The quality of silk production mainly depends on the feed, seed, breed management and new-fangled persona like enrichment of nutritional value through transgenic plant is highly essential for tasar culture. Host plant is relentlessly overstated with gall infestation; stem borer and leaf spot diseases. For rearing of tasar silkworm on new plantation requires 5-6 years, which is very hurting for poor farmers. Tasar host plant grows in non-irrigated land, in this connection drought confrontation varieties is highly vital. In this connection bio-technological tools are required for reduction of gestation period of tasar host plants (Table 1).

Table 1: Prospective inventory for bio-technological exploration in field of tasar silkworm host plants (Pandey et.al 2018)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Tasar culture area to be explored</th>
<th>Bio-technological exploration needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Exploitation of Sal flora (Shorea robusta)</td>
<td>Tasar silkworm and host plant molecular interaction, characterization and meta-genomic study of tasar food plants and silkworm gut bacteria/symbionts.</td>
</tr>
<tr>
<td>2.</td>
<td>Germ-plasm molecular hub for tasar food plants.</td>
<td>Genomic DNA bank and molecular characterization.</td>
</tr>
<tr>
<td>3.</td>
<td>High yielding and drought tolerant varieties</td>
<td>Overture of resistant gene linked for drought.</td>
</tr>
<tr>
<td>4.</td>
<td>Sal food plants useful zone identification and interaction with tasar silkworm.</td>
<td>Genotyping of zonal catalogue for Sal flora</td>
</tr>
<tr>
<td>5.</td>
<td>Characterisation of disease causing pathogens</td>
<td>Molecular characterization of disease causing pathogens of host plants.</td>
</tr>
<tr>
<td>8.</td>
<td>Identification of leaf, amino acid, protein and other substances linked silk production.</td>
<td>Molecular cataloging of leaf content linked to silk conversion ratio. Developing plants having such ingredients for enhancing silk production.</td>
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</tbody>
</table>
Prospective inventory for bio-technological exploration in field of tasar silkworm:

It is felt that, bio-technological interventions for the better growth and development tasar silk industry is needed (Table 2, Pandey et al., 2018). Tasar silkworm *A. mylitta* produces tasar silk of commercial importance. This species is endemic and distributed in different geographical regions of India in the form of ecological races (44 ecoraces). They show variations in their phenotypic traits such as fecundity, voltinism, cocoon weight, silk ratio and also in their host plant preference. The key problems are gradual decrease in number of ecoraces and its identification. Therefore, to understand the genetic closeness and also for the identification of the wild silkworm ecoraces, development of molecular marker is important using SNP genotyping. Sal flora utilization through gut symbionts is another important area for exploration. The gut symbionts have diversified functions like digestion, disease resistance, pheromone production, improvement of silk quality etc which were elucidated in detail in others insects but unexplored in *A. mylitta*. Functional characterization of these gut symbionts in sal based ecoraces in comparison with commercial Daba and augmenting the gut flora which are lacking in the commercial Daba thereby improving the fitness. This will create clear cut and viable option for effective utilization of Sal flora by the commercial *A. mylitta* ecoraces in future. Likewise there are many areas for this kind of work in tasar silk industry (Table 2).

### Table 2: Prospective inventory for bio-technological exploration in field of tasar silkworm (Pandey et al 2018)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Tasar culture area to be explored</th>
<th>Bio-technological exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tasar silkworm <em>A. mylitta</em> genome study.</td>
<td>Whole genome sequencing of Tasar silkworm <em>A. mylitta</em> initiated.</td>
</tr>
<tr>
<td>2.</td>
<td>Genotyping of available tasar silkworm ecoraces.</td>
<td>SNP genotyping of various ecoraces of <em>A. mylitta</em> using NGS initiated.</td>
</tr>
<tr>
<td>4.</td>
<td>New breed development</td>
<td>Utilization of molecular breeding tools in development of robust tasar silkworm breeds.</td>
</tr>
<tr>
<td>5.</td>
<td>Seed cocoon preservation in adverse condition.</td>
<td>Digital sensor and modified signalizing stimuli system for better grainage yield.</td>
</tr>
<tr>
<td>7.</td>
<td>Germ plasm/gene bank station for tasar silkworm</td>
<td>Cryopreservation of genomic DNA and various germplasm for upcoming application in bio-technological research.</td>
</tr>
<tr>
<td>8.</td>
<td>High yielding and disease tolerant races</td>
<td>Development of high yielding and disease tolerant races of tasar silkworm using bio-technological tools.</td>
</tr>
<tr>
<td>9.</td>
<td>High yielding races in term of fecundity and silk yield</td>
<td>Introduction and over-expression of fecundity and silk gene for better productivity.</td>
</tr>
</tbody>
</table>
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Tasar culture area to be explored</th>
<th>Bio-technological exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.</td>
<td>Developing bioindicators for pupal health</td>
<td>Bio-molecular indicators to access the health status of tasar silkworm using biotechnological approaches.</td>
</tr>
<tr>
<td>15.</td>
<td>Tasar silkworm embryo and semen preservation.</td>
<td>Using molecular approach, cryopreservation of embryo and semen for molecular breeding and artificial insemination.</td>
</tr>
</tbody>
</table>

Some of the other crucial areas for bio-technological approaches: There are few other crucial areas which need urgent bio-technological interventions in tasar:
1. Production of disease resistant silkworm through RNA-Interference is urgently required.
2. Disease diagnosis through antibody, PCR & LAMP based technique is needed.
3. Production of color cocoon through transgenic silkworm is another important area.
4. Identification of diapause related genes is very much needed to regulate the diapause as per need.
5. Molecular characterization of virulent and non-virulent *Nosema* sp of tasar silkworm is urgently needed.

Prospective inventory for bio-technological exploration in field of post cocoon and waste utilization:
Identification, characterization, extraction and utilization of various post cocoon waste for value added products using biotechnological approaches is very crucial sector (Table 3, Pandey et al., 2018). There many areas for modern technological research: Focal to molecular approaches, silk bio-material bio-molecular study it preservation linked to focal art and technique, innovative fabric development useful to bio-medical studies, various traditional print library and its impact evaluation with special reference to change in silk surface molecules, development of silk bank and its bio-medical bio-physical characterization, designing of antimicrobial, fluroscent, and comfortable silk with better permanence, bio-molecular silk surface modification for through cooking/mechanical method to achieve excellent denier and tensile strength. Enzyme based indicator to identify the pure silk and development of eco-friendly chemicals/methods for effective cocoan cooking ability is another field which need thorough study. Automation based on bio-molecular properties of silk and diversification of various products and by-products using molecular and traditional approaches; development of full package in form of ancillary and final product value chain for superior return; utilization of various waste products of tasar silk industry via identification, effective extraction and characterization of bio-molecules through biotechnological approaches is very much needed. Production of higher mechanical strength fibre through insertion of spider silk gene is one of the crucial areas for bio-technological research. Spider silk is considered to be the toughest bio-polymer on Earth due to its extraordinary combination of strength and elasticity. Moreover, silk is biocompatible and biodegradable protein-based material. Recent advances in genetic engineering make it possible to produce recombinant silk in heterologous hosts and opening up opportunities for large-scale production of recombinant silks for various biomedical and material science applications. Polishing, or finishing through proteolytic enzymes is also needed crucially. Bio-technological interventions for by-product utilization, waste silk protein isolation and its prospective bio-medical application are crucially needed (Table 3, Pandey et al., 2018).

<table>
<thead>
<tr>
<th>S. No.</th>
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<th>Bio-technological exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Exploitation and utilisation of post cocoon waste</td>
<td>Identification, characterization, extraction and utilization of various post cocoon waste for value added products using biotechnological approaches.</td>
</tr>
<tr>
<td>2.</td>
<td>Conservation of various silk bio-materials, focal arts and its global digitalization.</td>
<td>Focal to molecular approaches. Silk bio-material bio-molecular study, it preservation linked to focal art and technique</td>
</tr>
<tr>
<td>6.</td>
<td>Development of antimicrobial cloths.</td>
<td>Designing of antimicrobial, fluroscent, and comfortable silk with better permanence.</td>
</tr>
</tbody>
</table>
Why Biotechnological tools are required for Tasar Industry?

- The quality and yield of silk depend on availability of healthy silkworms, which itself depends on high-quality feed and disease free stocks.
- Traditionally, strain improvement has used breeding methods for production of new high yielding strains.
- The traditional approaches appear to be reaching the natural biological limits of the silkworm with regards to its growth rate, silk yield and fecundity.
- Thus it is becoming increasingly important to turn to the new approaches of genetic engineering to produce better strains.

Molecular Markers and Bio-technological Tools:

A molecular marker is a DNA sequence with a known location in the genome and associated with a particular trait. Basically it is a variation, which may arise due to mutations, insertions, deletions or alteration in the genomic loci. These differences, collectively called as polymorphisms can be mapped and identified. The molecular markers are highly reliable and advantageous in sericulture as they provide more accurate genetic information and better understanding of genetic resources. Also they are consistent and not affected by environmental factors and a large number of markers can be generated as per the needs. Till date many types of molecular markers have been utilized to detect the variation among individual and population. There are two general types of DNA markers. One is based upon DNA- DNA hybridization (restriction fragment length polymorphism, RFLP) and others are based on amplification of DNA sequences using the polymerase chain reaction (PCR) like Random Amplified Polymorphic DNA (RAPD), Sequence Characterized Amplified Regions (SCAR), Inter-Simple Sequence Repeat (ISSR), simple sequence repeats (SSR) and single nucleotide polymorphism (SNP).

Restriction fragment length polymorphism (RFLP): Restriction fragment length polymorphism (RFLP) is a technique invented in 1984 by the English scientist Sir Alec Jeffreys during research into hereditary diseases. It is used for the analysis of unique patterns in DNA fragments in order to genetically differentiate between organisms – these patterns are called Variable Number of Tandem Repeats (VNTRs). Genetic polymorphism is defined as the inherited genetic differences among individuals in over 1% of normal population. The RFLP technique exploits these differences in DNA sequences to recognize and study both intraspecies and interspecies variation. Restriction endonucleases are enzymes that cut lengthy DNA into short pieces. Each restriction endonuclease targets different nucleotide sequences in a DNA strand and therefore cuts at different sites. The distance between the cleavage sites of a certain restriction endonuclease differs between individuals. Hence, the length of the DNA fragments produced by a restriction endonuclease will differ across both individual organisms and species.

The procedure basically involves digestion of total cellular DNA with a restriction endonuclease which reduces the genome to a large pool of restriction fragments of different sizes, the restriction fragments are then separated by their size on an agarose gel by electrophoresis and finally hybridization by incubating with cloned and labeled probes. Despite the fact that it is less widely used now, there have been numerous benefits to RFLP analysis. It plays an important role in allowing us to find out where a specific gene for a disease lies on a chromosome. It is useful to determine or confirm the source of a DNA sample such as in paternity tests or criminal investigations. In genetic mapping to determine recombination rates that show the genetic distance between the loci and identify a carrier of a disease-causing mutation in a family.

Random amplified polymorphic DNA (RAPD): Random amplified polymorphic DNA (RAPD) were the first of the PCR-based markers and were developed independently by Welsh and McClelland (1990). The RAPD technology provides a quick and efficient screen for DNA sequence based polymorphism at a very large number of loci. This is considered as the most convenient molecular marker as no prior DNA sequence information is needed for designing PCR markers.
Primers are usually just 10 base pairs long and are of random sequence. Outline of RAPD technique is depicted below.

Isolation of genomic DNA

Denature double stranded DNA sample to single stranded DNA molecule

Anneal RAPD Primers

Complimentary strand synthesis

RAPD fragments are separated by electrophoresis and visualized by staining with EtBr

Basically, it is based on the fact that, from every individual a particular set of fragment of DNA can be generated which represents polymorphism and can be used as a molecular marker of a particular species. Although RAPD is easy and rapid, there are some disadvantages of this technique too. RAPD cannot be used for distinguishing homozygosity and heterozygosity of an individual and also data is not reproducible.

RAPD is used for many purposes, ranging from studies at the individual level (e.g. genetic identity) to studies involving closely related species. RAPD is also been applied in gene mapping studies to fill gaps not covered by other markers. Variants of the RAPD technique include Arbitrarily Primed Polymerase Chain Reaction (AP-PCR) which uses longer arbitrary primers than RAPDs, and DNA Amplification Fingerprinting (DAF) that uses shorter, 5-8 bp primers to generate a larger number of fragments. Multiple Arbitrary Amplicon Profiling (MAAP) is the collective term for techniques using single arbitrary primers.

Sequence Characterized Amplified Regions (SCAR): Michelmore (1991) was the first to introduce this technique, in which RAPD marker termini are sequenced and longer primers of 22–24 nucleotide bases long are designed for specific amplification of a particular locus. It shows similarity with STS markers in construction and application. The presence or absence of the band represent variation in sequence. SCARs are advantageous over RAPD markers as they detect only a single locus. Their amplification is less sensitive to reaction conditions and they can potentially be converted into codominant markers. SCARs exhibit several advantages in mapping studies (codominant SCARs are informative for genetic mapping than dominant RAPDs). Map based cloning as they can be used to screen pooled genomic libraries by PCR. SCARs allow comparative mapping or homology studies among related species, thus making it an extremely adaptable concept in the near future. The main advantage of SCARs is that they are quick and easy to use. In addition, SCARs have a high reproducibility and are locus-specific. Due to the use of PCR, only low quantities of template DNA are required.

Inter-Simple Sequence Repeat (ISSR): Inter-Simple Sequence Repeat (ISSR) involves amplification of DNA segment present at an amplifiable distance in between two identical microsatellite repeat regions oriented in opposite direction. Inter-Simple Sequence Repeat usually 16-25 bp long as primers in a single primer PCR reaction targeting multiple genomic loci to amplify different sizes of inter-SSR sequences. The microsatellite repeats used as primer can be either dinucleotides or tri-nucleotides. ISSR markers are highly polymorphic and are used on genetic diversity, gene tagging, phylogeny, evolutionary biology and genome mapping studies.

ISSR PCR is a technique, which overcomes the problems like high cost of AFLP, low reproducibility of RAPD, and the flanking sequences to develop species specific primers for SSR polymorphism. ISSR segregate mostly as dominant markers following simple Mendelian inheritance. However, they have also been shown to segregate as codominant markers in some cases, thus enabling distinction between homozygote and heterozygote. ISSR have been used since 1994 for a wide range of organisms in DNA fingerprinting, diversity analysis and genome mapping. ISSR is quick, simple, highly reproducible and the use of radioactivity is
not essential. ISSR markers usually show high polymorphism, and with the most important advantage that no prior information about genomic sequence is required.

**Simple Sequence Repeat (SSR):** Simple sequence repeats (SSRs) or microsatellites, are polymorphic loci present in DNA that consist of repeating units of one to six base pairs in length. One common example of a microsatellite is a (CTT) repeat, where n is variable among different alleles. These markers often present high levels of inter- and intra-specific polymorphism, particularly when the tandem repeats number is 10 or greater. The repeated sequence is often simple, consisting of two, three or four nucleotides (di-, tri- and tetra- nucleotide repeats) and can be repeated many times (Fig.1). Microsatellites can be amplified for identification by PCR using the unique sequences of flanking regions as primers. The most common way to detect microsatellites is to design PCR primers that are unique to one locus in the genome and that base pair on either side of the repeated portion. Therefore, a single pair of PCR primers will work for every individual in the species and produce different sized products for each of the different length of microsatellites. The PCR products are separated either by slab gel electrophoresis or capillary gel electrophoresis in an automated sequencer.

Microsatellites have proved to be versatile molecular markers, particularly for population analysis, but they are not without limitations. With the abundance of PCR technology, primers that flank microsatellite loci are simple and quick to use, but the development of correctly functioning primers is often a tedious and costly process. Microsatellites developed for particular species can often be applied to closely related species, but the percentage of loci that successfully amplify may decrease with increasing genetic distance.

![Figure 1: Principle of microsatellite based barcoding](image)

**Single Nucleotide Polymorphisms (SNPs):** Single nucleotide variations in genome sequence of individuals of a population are known as SNPs. SNPs are the most abundant molecular markers in the genome. They are widely dispersed throughout genomes with a variable distribution among species. The SNPs are usually more prevalent in the noncoding regions of the genome. Within the coding regions, when an SNP is present, it can generate either non-synonymous mutations that result in an amino acid sequence change, or synonymous mutations that not alter the amino acid sequence. Synonymous changes can, however, modify mRNA splicing, resulting in phenotypic differences.

Improvements in sequencing technology and an increase in the availability of the increasing number of EST sequences have made analysis of genetic variation possible directly at the DNA level. The majority of SNP genotyping analyses are based on: allele-specific hybridization, oligonucleotide ligation, primer extension or invasive cleavage. Genotyping methods, including DNA chips, allele-specific PCR and primer extension approaches based on SNPs, are particularly attractive for their high data throughput and for their suitability for automation (Fig. 2). They are used for a wide range of purposes, including rapid identification of crop cultivars and construction of ultra high-density genetic maps.
Next Generation Sequencing: A new generation of non-Sanger based sequencing technologies has been evolving on its promise of sequencing DNA at unprecedented speed, thereby also having enabled impressive scientific achievements and novel biological applications. These techniques have made it possible to conduct robust population-genetic studies based on complete genomes rather than just short sequences of a single gene. Rapid progress in genome sequences of various plant species through next generation sequencing will further extend our understanding how genotypic variation translates into phenotypic characteristics. A comparative genomic approach is extraordinarily useful for identifying functional loci related to morphological, geographical and physiological variation, and thus next generation sequencing technology will enable us to better understand the process of plant evolution. Next generation platforms do not rely on Sanger chemistry as did the first generation machines used for the last 30 years. The first of this kind of 2nd generation of sequencing technique appeared in 2005 with the landmark publication of the sequencing-by-synthesis technology developed by 454 Life Sciences based on pyrosequencing. Commercial 2nd generation sequencing methods can be distinguished by the role of PCR in library preparation. There are four main platforms; all being amplification-based: (i) Roche 454 GS FLX, (ii) Illumina Genome Analyzer IIx, (iii) ABI SOLiD 3 Plus System and (iv) Polonator G.007. Common principles of these second generation sequencing technology are illustrated in Figure 3.
The single-molecule sequencing method (also known as 3rd generation or next-next generation) is independent of PCR. This mode of sequencing protocol was recently developed by Helicos Genetic Analysis System using the technology developed by Braslavsky et al., 2003. Other 3rd generation sequencing systems are being developed by Life Technologies and Pacific Biosciences SMRT technology and may appear within one to two years. Oxford Nanopore Technology has been developing a label-free, electrical, single-molecule genuinely revolutionary DNA sequencing method. This technique is aimed at obviating the need for amplification or labelling by instead detecting a direct electrical signal. The developed third generation high-throughput and low-cost direct single molecule RNA sequencing method - without requiring prior conversion of RNA to cDNA - opened the door for a comprehensive and bias-free understanding of transcriptomes.

Since the advent of next generations sequencing, these techniques have been helping to uncover secondary metabolic pathways, to analyse cDNA-array based gene expression, for genetic manipulation to improve yield of desirable secondary products and molecular marker identification. For example, an Expressed Sequence Tag (EST) library from whole plantlets of medicinal plant (Salvia miltiorrhiza) was generated with the expression patterns of 14 secondary metabolic enzyme genes in different organs. Additionally, a total of 122 microsatellites were identified from the ESTs, with 89 having sufficient flanking sequences for primer design. This set of ESTs represents a significant proportion of the S. miltiorrhiza transcriptome and gives preliminary insights into the gene complement of S. miltiorrhiza, which was a very laborious task a few years back. Using 454 and Illumina EST sequencing of the parental diploid species of Tragopogon miscellus (Moscow salsify, Asteraceae), 7,782 single nucleotide polymorphisms were identified that differ between the two progenitors genomes present in this allotetraploid. Next generation high through-put Solexa sequencing technology led to the discovery of 14 novel and 22 conserved miRNA families from recent. A new variety of chickpea (Cicer arietinum), resistant to Helicoverpa armigera (Pod borer), has been developed with the help of valuable information retrieved from next generation sequencing.

**Application of molecular markers in genetic characterization of A. mylitta:** The pronounced phenotypic and behavioral variations of A. mylitta ecotypes have made it difficult to identify ecotype specific phenotypic markers. Therefore, there was a need to identify genetic markers for a specific phenotype to differentiate ecotypes. Are these ecotypes genetically distinct from each other? Do the ecotypes form structured population? Are any of these ecotypes in decline? These questions are of considerable importance to the biology of A. mylitta. With these points in mind, several genetic characterization studies were carried out with various molecular marker systems like RFLP, RAPD, SCAR, ISSR and SSR or Microsatellite in various A. mylitta ecotypes.

(Bhardwaj et al., 2015; Bhattacharjee et al., 2016; Bhattacharjee et al., 2015; Bhattacharjee et al., 2016; Bhattacharjee et al., 2016a; Biswa et al., 2015; Braslavsky et al., 2003; Chakraborty et al., 2015; Chakraborty et al., 2016; Chrouhan et al., 2017; Dashora et al., 2017; Devi et al., 2017; Fang et al., 2017; Guan et al., 2017; Hazra et al., 2016; Jena et al., 2016; Jiayao et al., 2016; Kar et al., 2005; Kundu et al., 2016; Mahendran et al., 2006; Michelmore, et al. 1991; Panda et al., 2015; Panda et al., 2015a; Renuka and Shamitha 2016; Saha and Kundu 2006; Saha et al., 2008; Sahoo et al., 2015; Sahu et al., 2016; Sharma et al., 2016; Srivastava, et al. 2002; Sudha et al., 2015; Wang et al., 2016; Wang et al., 2017; Welsh and Mcclelland, 1990).

Mahendran et al., 2005, studied the genetic variability and phylogenetic relationship among the different ecotypes of A. mylitta, PCR-amplified Mbol fragment from different ecotypes showed 99–100% sequence identity at nucleotide level. However, restriction RFLP studies using this Mbol fragment as probe have shown polymorphic pattern among the ecotypes (Fig. 4). Phylogenetic relationships of different ecotypes obtained on the basis of RFLP pattern supported the phenotypic and geographical relations. The RAPD markers have been used for detecting genomic variations between ten various ecotypes of A. mylitta such as, Andhra local, Bhandara local, Daba, Modal, Nalia, Laria, Raily, Sarihan, Sukinda and Tira (Fig. 5). Eighty random decamer primers were used for RAPD amplifications. Reported that genetic distance values ranged from a minimum of 0.0108 between Modal and Nalia ecotypes to a maximum of 0.0244 between Modal and Andhra local. The RAPD profiles obtained using A14, BC07, and C17 primers substantially differentiate all 10 commercially important eco-races and the phylogenetic tree obtained from the data closely follows their geographical separations (Saha et al., 2008).

Saha and Kundu (2006) developed the SCAR markers for the identification of A. mylitta ecotypes. They selected seven RAPD bands that identified eight of the ten ecotypes. These identified RAPD fragments are sequenced and primers are designed for SCAR markers. Others of the seven sets of primers, a single primer pair produced polymorphic SCAR bands that diagnose five of the ten ecotypes (Fig. 6).

Genetic variability and genetic structure among populations of semi-domestic bivoltine (DB), trivoltine (DT) and nature grown wild populations (DN) were revealed through ISSR markers. Considerable intra- and inter-population variability was observed in all three populations. The population structure analysis further suggests that the semi-domestic populations of Daba ecotype are at the threshold of differentiating themselves and high genetic variability present within wild Daba population of A. mylitta (Fig. 7) (Kar et al., 2005). Srivastava et al. (2009) evaluated the genetic diversity in different population of Raily ecotype of A. mylitta using ISSR markers. All the primers exhibited polymorphism which is an indicative of the genetic variation in individual Raily silkworm. Among the populations, total polymorphism recorded was 76%. Nei’s gene diversity (h) ranged from 0.194 to 0.337 exhibiting high heterozygosity.

Chakraborty et al. (2015) analyzed the population structure of...
different ecoraces of *A. mylitta*. A total of 154 individual moths belonging to eight different ecoraces were screened at each locus. A significant isolation by distance has been observed. They investigated the number of possible population clusters using distance method, Bayesian algorithm and self-organization maps (SOM). The first two methods revealed two distinct clusters, whereas the SOM showed the different ecoraces not to be clearly differentiated. Based on the result, it has been suggested that although there is a large degree of phenotypic variation among the different ecoraces of *A. mylitta*, genetically they are not very different and the phenotypic differences may largely be a result of their respective ecology.

<table>
<thead>
<tr>
<th>Group</th>
<th>Tool</th>
<th>Purpose of work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chatterjee et al., 2004</td>
<td>ISSR</td>
<td>Profiling of genetic variability in the ecotypes of tropical tasar silkworm</td>
</tr>
<tr>
<td>Mohandas et al., 2004</td>
<td>ISSR</td>
<td>Genetic Variability in the Natural Populations of Daba Ecorace</td>
</tr>
<tr>
<td>Vijayan et al., 2005</td>
<td>RAPD, ISSR</td>
<td>Inter and intraspecific variation in Daba, Modal and Raily ecoraces</td>
</tr>
<tr>
<td>Kar et al., 2005</td>
<td>ISSR</td>
<td>Genetic structure of Daba (BV), Daba (TV) and Wild Daba</td>
</tr>
<tr>
<td>Mahendran et al., 2006</td>
<td>RFLP</td>
<td>Genetic variability between nine commercially important ecoraces</td>
</tr>
<tr>
<td>Mahendran et al., 2006</td>
<td><em>TaqI</em> family repeat</td>
<td>Phylogenetic relationship between nine commercially important ecoraces</td>
</tr>
<tr>
<td>Saha and Kundu, 2006</td>
<td>RAPD-SCAR</td>
<td>Molecular identification of ten various tasar ecoraces</td>
</tr>
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<td>Genetic differentiation of ten commercially important ecoraces</td>
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<td>Renuka and Shamitha, 2014</td>
<td>SSR and ISSR</td>
<td>Phylogenetic analysis of tasar silkworm</td>
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<tr>
<td>Chakraborty et al., 2015</td>
<td>Microsatellite</td>
<td>Genetic analysis of Indian tasar silkmoth population</td>
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<td>SSR</td>
<td>Genetic variation in ecoraces of tropical tasar silkworm</td>
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<td>Renuka et al., 2018</td>
<td>SSR</td>
<td>Marker development for genetic diversity of tasar ecoraces.</td>
</tr>
<tr>
<td>Niranjan et al., 2018</td>
<td>RAPD-SCAR</td>
<td>Molecular marker for identifying high shell weight line of Daba BV.</td>
</tr>
</tbody>
</table>

(Reproduced from Mahendran et al., 2005)

Figure 4: Southern blot analysis of total genomic DNA of different ecoraces of *A. mylitta*. Genomic DNA was digested completely with (a) *MboI*, (b) *HindIII* restriction enzymes and hybridized with 281 bp of *MboI* fragment of Andhra Local. Lanes 1 to 9 show the digested genomic DNA of Andhra Local, Bhandara Local, Daba, Modal, Nalia, Raily, Sarihan, Sukinda and Tera ecoraces.
Figure 5: Representative RAPD bands obtained in 10 ecoraces with primer A14, lanes M: marker XIV (100-bp ladder, Roche Diagnostics); NC, negative control; 1, Andhra local; 2, Bhandara local; 3, Daba; 4, Modal; 5, Nalia; 6, Laria; 7, Raily; 8, Sarihan; 9, Sukinda; and 10, Tira.

Figure 6: The SCAR bands amplified by primer pairs SCAR10F/R. The lanes are M, 100 bp ladder (Roche); Nc, negative control; 1, Andhra locale; 2, Bhandara locale; 3, Daba; 4, Modal; 5, Nalia; 6, Laria; 7, Raily; 8, Sarihan; 9, Sukinda; and 10, Tera. The dots indicate the bands chosen to develop the fingerprint map.
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

Figure 7: ISSR band profiles in semi-domestic Daba bivoltine and trivoltine (20 individuals each), and natural wild (16 individuals) populations, M denotes molecular size markers.

Tasar Silk Industry: Biotechnological work done

- Food plants Gene bank accessions
- Several Nosema spp. Molecular characterization
- A. mylitta 17 Diapause EST sequence
- A. mylitta 8 Accessory Gland EST sequence
- Arjun and Asan molecular characterization
- Cococonase characterization
- Genetic diversity through ISSR
- Characterization of sericin

Research Area where Biotechnological Innovations are needed

- High yielding variety
- Low gestation period of food plants
- Disease resistant silkworm
- Silk-nano-particles
- Development of robust breed
- Molecular breeding
- Genetic integration
- Kits for disease identification

Future Research Areas of Biotechnological Intervention

- Thermo-tolerant breed of silkworm
- By-product utilization
- Therapeutic protein production
- Product diversification
- In-silico approaches
- Gene pool for breeding
- Anti-microbial textiles production
- High fecundity gene identification

Conclusions

The quality and yield of silk depend on availability of healthy silkworms which itself depends on high-quality feed and disease free stocks. Traditionally, strain improvement has used breeding methods for production of innovative high yielding strains. There is no consistency in cocoon yield per dfl. The traditional approaches emerge to be reaching the natural biological limits of the silkworm with regards to its growth rate, silk yield and fecundity. Several problems still continue to check the growth of the tasar silk industry hence some imperative problems need modern bio-technological interventions (Tables 1-3) for quality linked silk production. It is felt that for speedy growth of tasar silk industry, bio-technological intervention is inevitably needed in all four major sectors (host plant, silkworm. Post cocoon technology and by-product utilization) of tasar silk industry. Thus, it is becoming increasingly important to turn to the new approaches of genetic engineering, bio-technological exploration with endeavor for speedy growth of tasar silk industry in order to produce better silkworm strains and novel technology for various bio-active products.

References


Recent Developments in Tasar Silk Post Cocoon Technology
Debasis Chattopadhyay*, Z.M.S. Khan & Alok Sahay
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* Corresponding author

Abstract
Tasar silk industry spreads in various states of India, which provides employment to large population residing in rural area. This industry is having awe-inspiring impression, unique silk quality, and shiny surface as well as fundamental identity due to environment friendly culture, which provides customary livelihood for lakhs of tribal/women populace of India. Post cocoon sector (PCS) is one of the vital sectors of tasar silk industry, which not only provide the product but also gives direct quantifiable employment mainly focused to rural women populace. Interestingly, this sector maintains the various post-cocoon activities linked to traditional to modern having place/situation and time specific relevance. For instance, much latest machines and reeling equipments have been developed (motorized reeling cum twisting machine, wet reeling machine, motorized charkha,, solar operated machine like Kamdhenu, Samridhi, Buniyaad etc.) in last decade which replace the conventional "Thigh-Reeling" which is non-hygienic as well as odd looking from social point of view to a great extent. More importantly, post-cocoon sector of tasar silk industry has taken various inventive leads leading to multi-dimensional approaches by covering reeling, weaving, fabric preparation, and product diversification, module for organic silk production, pioneering fabric preparation, waste utilization, effectual module for solar utilization etc. In addition, sound initiative was also taken for mechanization in cocoon sorting, counting, grading etc. Various efforts has been taken in post cocoon sector for quality linked improvement i.e. cocoon cooking with hydrogen peroxide, soap-soda/enzyme/other chemicals, proteolytic enzyme/coconase, papaya extract and various reeling methods have been also developed like improved motorized reeling charkha, pedal cum motorized reeling cum twisting machine for reeling of reelable and pierced cocoons, dry and wet reeling processes, vegetative and lac based dyeing of tasar fabrics, waste spinning using peduncles etc. Now our prospective vision is to enhance the productivity of post cocoon sector by utilization of various effective technologies in integrated manner for sustainable growth of tasar silk industry India. Still, traditional practices are rampant in post cocoon technologies and machines used for tasar reeling, spinning in the field/clusters that are obsolete with the very low productivity and quality. Hence, the objective is to popularize latest technologies and machines for tasar post cocoon sector with an aim to achieve higher productivity and quality tasar yarns and fabrics.

Introduction
The word “tasar” is derived from the Sanskrit word “Trasara (Shuttle)” which is mentioned in literature during 1590 BC. (Jolly et al, 1979). It is a traditional symbol of Indian tribal culture. The master creations of the world famous Indian tasar belong to aboriginal (adivasi) forest people who are rearing tropical tasar silkworms for centuries. The dense humid tropical forest over the central and southern plateau is the habitat of tropical tasar silkworms. The major tropical tasar cocoon producing states are Jharkhand, Chhattisgarh, Orissa and Madhya Pradesh whereas Andhra Pradesh, Maharashtra, Telengana, Bihar and Uttar Pradesh are also producing tropical tasar cocoons. Similarly, temperate tasar silk producing states are Himachal Pradesh, Uttrakhand, Sikkim, Manipur, and Arunachal Pradesh. Tropical tasar silk cocoons are spun by Antheraea mylitta D silkworms, whereas, temperate tasar silk cocoons are spun by Antheraea pernyi and Antheraea proylei. Tasar silk industry in India is an ancient craft and all its operations from harvesting of cocoons to reeling and spinning of yarn, weaving of fabrics as well as dyeing, printing and finishing of fabrics are with cottage industry.

Post cocoon technology process

Sorting and counting of tasar cocoons- existing technique
Sorting is a process for separation of reelable and unreelable (flimsy, stained, pin hole and pierced) cocoons. Since cocoon quality has substantial influence on uniform cooking and thereby higher productivity during reeling; so this process is carried out at the initiation stage. The process is carried out manually and one skilled person can segregate about 10,000 cocoons in a day of eight hours working along with counting (Figure 1).

Grading of tasar cocoons - existing technique
The purpose of grading is to distinguish the tasar silk cocoons on anticipation of silk yarn to be produced. The shell weight as well as thickness of shell is important with a view to silk productivity. In conventional way, the reeler predict the cocoons by pressing the same by fingers and if it is tough due to high thickness then
the person realize that substantial raw silk yarn can be produced. But due to manual operation, very often the prediction fails due to drudgery. Central Silk Board has established a standard procedure as well norms for grading of tasar cocoons. In this process, the shell weight is taking into consideration. After eliminating of peduncles and pupae by dissecting; weight of cocoons' shell are measured for 50 nos. The shell weight for different grade of tasar cocoon is given in Table 1.

Table 1: Shell weight of tasar cocoon for different grades

<table>
<thead>
<tr>
<th>Type of tasar cocoon</th>
<th>Shell weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade I</td>
</tr>
<tr>
<td>Reelable</td>
<td>1.55 &amp; above</td>
</tr>
<tr>
<td>Un-reelable</td>
<td>1.50 &amp; above</td>
</tr>
</tbody>
</table>

Courtesies: CSTRI, Bangalore.

Sorting and counting of tasar cocoons- recent developments

Due to total involvement of manual operation; it is not possible for grading of entire lot of tasar cocoons as well as there is possibility for mistakes during counting. Automatic tasar cocoon sorting machine developed by Central Silk Technological Research and Training Institute, Central Silk Board, Bengaluru (Figure 2) facilitates to separate cocoons into A, B and C grade without any manpower involvement as against traditionally the cocoons are separated without the use of any equipment. This machine can separate 40,000 to 50,000 cocoons in one hour with 99% accuracy. In this machine, tasar cocoons are put in a hopper which spreads the cocoons over three stainless steel strainers of different porosity. In first strainer, ‘C’ grade cocoons (smaller size/volume) are dropped into basket, then ‘B’ grade cocoons (medium size/volume) and at last ‘C’ grade cocoons (big size/volume). The basic technique for distinguish of tasar cocoons of different grades is on volumetric principle. Shell weight characteristic is not considered for this sorting/grading process. At present, attempts are under progress for grading of tasar cocoons based on scanning and image analysis technique along with counting so that manual involvement can be overcome.

Stiffling/Drying of tasar cocoons

The object of stiffling is to kill the pupae present inside the cocoons' shells so that emergence of moth can be prevented. Since emerged cocoons cannot be used for continuous withdrawal of yarn by reeling process. Also this operation enables the cocoons for longer duration storage. Unreelable cocoons like emerged, filmsy etc which are used for spinning to produce yarn; need not to be stiffed. The conventional processes for stiffling/drying of tasar cocoons are sun and steam whereas hot air drying is recent development.

Sun drying

This process facilitates killing of pupae by prolonged exposure to hot sunshine (2 to 3 days depending upon the intensity of sun light) of freshly harvested cocoons. Though the process is very simple and cheap, but it is not advisable to follow this technique. The ultraviolet rays present in sunshine makes the cocoons' shells very hard which affect the reelability. Black cloth covers are used to avoid this lacuna but the pupae are not dried properly and the shells’ surface get soiled which affects the productivity. Moreover during raining; this technique cannot be followed.

Steam stifling

In this process the pupae of green cocoons are killed by exposure of steam for about 30 min. This process is very popular in South India. Two different techniques are followed for steam stifling:

Basket steaming

This process is very popular in small reeling establishments where very small cocoons are consumed. The green cocoons are filled in a bamboo basket in which the sides are closely woven but the bottom is loosely woven. A thick wet cloth is then tightly wrapped over the top of the basket and tied at sides by keeping the bottom free. The basket thus filled with cocoons is placed over the mouth of a vessel in which water is boiling. The steam generated from the bottom portion of vessel fills the entire basket and thus the pupae are killed within about 30 min durations. But this process requires for proper drying of cocoons after steaming operations otherwise cocoons quality gets deteriorated due to soiling of pupa and fungal contamination.

Chamber steaming

This process makes utilization of specially designated and conveniently large sized chamber. The chamber is equipped with perforated steam pipes spreads over the three surface planes. The
cocoons are kept on perforated aluminum trays and steaming is continuing with closing the doors. The steam is injected from the boiler through insulated pipes. The steaming operation takes about 15 min and this system is in practice for silk reeling units where boilers are installed. Also, this process requires for proper drying of cocoons after steaming operations otherwise cocoons quality gets deteriorated due to soiling of pupa and fungal contamination.

The lacuna for sun as well as steam drying/stifling can be overcome by hot air drying technique where all tasar cocoons are dried uniformly and no incidence are occurred for fungal contamination.

**Hot air drying**

In this process the cocoons are dried by means of hot air. This process is suitable for mulberry as well as non-mulberry (tasar and muga) varieties and thus enabling to store the cocoons for a long time. In hot Air Dryer, series of hollow plates are fixed in both right and left sides’ front of the iron walls. These plates are heated by electrical coils kept inside the same. The heat generated by these plates is circulated through the chamber by means of blower installed inside. The temperature inside chamber is controlled by thermostat (Figure 3). There are two processes hot air stifling i.e. Italian type and Japanese type. In case of Italian type, the cocoons are inserted at room (ambient) temperature. After closing the doors, temperature is raised to 90°C for about 1 hour duration with exhaust closed and blower fan in running condition. Then the cocoons are kept for about three hours in same state. After three hours, the heater is switched off and exhaust is opened with blower in operating condition. The temperature is gradually reduced to room (ambient) temperature for another one hour and the cocoons are taken off from the chamber. For Japanese system, the dryer is heated at about 100°C and then cocoons are inserted inside the chamber with blower in operating condition and exhaust is in closed state. After about four hour’s durations, the temperature is reduced to room (ambient) temperature and the cocoons are taken off for storage.

As per studies conducted by Central Tasar Research and Training Institute, low to high temperature stifling is better as compared to high to low profile in case of tasar cocoons (Table 2 and 3).

### Table-2: Hot air drying/stifling of tropical tasar cocoons

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Low to high temperature profile</th>
<th>High to low temperature profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial temperature of chamber for cocoons insertion (°C)</td>
<td>Room (ambient)</td>
<td>90</td>
</tr>
<tr>
<td>Duration for temperature rise (min)</td>
<td>60</td>
<td>------</td>
</tr>
<tr>
<td>Maximum temperature (°C)</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Holding time for final temperature (min)</td>
<td>180</td>
<td>240</td>
</tr>
<tr>
<td>Duration of reduction of temperature (min)</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Temperature for cocoons withdrawn</td>
<td>Room (ambient)</td>
<td>Room (ambient)</td>
</tr>
</tbody>
</table>

### Table-3: Performance of stifling/hot air drying for tropical tasar cocoons

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Low to high temperature profile</th>
<th>High to low temperature profile</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Daba BV</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of green cocoons taken for trial</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Total green cocoons weight (g)</td>
<td>3810.00</td>
<td>3825.00</td>
</tr>
<tr>
<td>Total dried cocoons weight (g)</td>
<td>1487.00</td>
<td>1915.00</td>
</tr>
<tr>
<td>Drying (%)</td>
<td>61.00</td>
<td>50.00</td>
</tr>
<tr>
<td>Reelability (%)</td>
<td>35.30</td>
<td>32.10</td>
</tr>
<tr>
<td>Raw silk recovery (%)</td>
<td>64.50</td>
<td>63.40</td>
</tr>
<tr>
<td><strong>Modal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of green cocoons taken for trial</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Total green cocoons weight (g)</td>
<td>2884.00</td>
<td>2910.00</td>
</tr>
<tr>
<td>Total dried cocoons weight (g)</td>
<td>1212.00</td>
<td>1520.00</td>
</tr>
<tr>
<td>Drying (%)</td>
<td>58.00</td>
<td>48.00</td>
</tr>
<tr>
<td>Reelability (%)</td>
<td>25.80</td>
<td>23.90</td>
</tr>
<tr>
<td>Raw silk recovery (%)</td>
<td>62.30</td>
<td>61.50</td>
</tr>
<tr>
<td><strong>Raily</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of green cocoons taken for trial</td>
<td>300</td>
<td>300</td>
</tr>
</tbody>
</table>
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Low to high temperature profile</th>
<th>High to low temperature profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total green cocoons weight (g)</td>
<td>4020.00</td>
<td>3987.00</td>
</tr>
<tr>
<td>Total dried cocoons weight (g)</td>
<td>1692.00</td>
<td>2117.00</td>
</tr>
<tr>
<td>Drying (%)</td>
<td>57.90</td>
<td>47.00</td>
</tr>
<tr>
<td>Reelability (%)</td>
<td>24.90</td>
<td>23.70</td>
</tr>
<tr>
<td>Raw silk recovery (%)</td>
<td>63.20</td>
<td>64.10</td>
</tr>
</tbody>
</table>

It is observed from Table 3 that, about 60% drying efficiency was found in case of low to high temperature profile with good reeling performance for Daba BV, Modal and Raily tropical tasar cocoons. Although, no difference of reeling performance being found for two stifling experiments; but the drying efficiency is significantly less for 2nd experimental trial. In first trial, the cocoons are inserted in drying chamber at ambient (room) temperature and then it is raised to 90°C for one hour duration. Then it is kept for about 3 hours and then temperature being reduced by switch off the heater with exhaust open for 1 hour duration. As there is cyclic heating treatment, tropical tasar cocoons are dried properly which can be store for long duration. But in 2nd experiment, the cocoons are inserted at 90°C temperature and kept for 4 hours. So, there is no cyclic heating arrangement for the 2nd experiment results improper drying of cocoons and chances for damage.

There are two types of hot air dryer are available i.e. stationary/batch type and another is conveyor type. In batch type, the cocoons are dried inside chamber keeping on perforated trays and only one lot can be processed for about 5 hour’s durations. But in case of conveyor type, the cocoons are kept on moving perforated conveyor belt (resistant to high temperature) which moves slowly inside the chamber at temperature 90 to 100°C. The conveyor belt has three to eight tiers inside the chamber. The batch type is popular for mulberry and non-mulberry cocoons stifling whereas the conveyor type is used for mainly mulberry variety.

**Figure 3: Hot air Drying/Stifling Machine**

**Other method of drying**

This method includes use of infrared rays, cold storage and use of poisonous gas etc. In some areas of Central India, preservation of cocoons inside the cold storage is popular as the moth cannot get emerged. As per requirement for reeling process, cocoons are taken from cold storage and used.

**Storage of cocoons**

Storage of cocoons is very important especially when the stifled cocoons have to be stored for a very long time. The storage racks need to be kept in well ventilated room and the cocoons are placed in thin layers on shelves taking care that there is proper aeration. Storage racks have to be placed above the ant wells. Since the dried pupae inside the cocoons have pretentious matter, unless the cocoons are fully dried and preserved properly, certain insects will attack the pupae and thereby damage the cocoons. The humidity of the storage room not to be exceed above 70% and temperature at about 30°C.

**Cooking of tasar cocoons**

In addition to sericin and fibroin, tropical tasar cocoons also contain calcium oxalate and tannin, which makes the surface very hard (Gheysens et al., 2011). Therefore, like mulberry cocoons; tasar cocoons are not softened by plain water boiling; besides alkaline medium is required. The conventional process for tasar cocoons' softening is treatment using sodium carbonate.

**Sodium carbonate cooking**

In this process tasar cocoons are boiled in alkaline solution for about 30 min using 10 to 15 g/l of sodium carbonate. Sometimes neutral soap (Sunlight/Lux) soap is used for cleaning of adhered materials from cocoons (Jolly et al, 1979 & Sonwalkar, 1993). After boiling, tasar cocoons are washed using hot water in order to remove presence of alkali. Since both reeling and spinning are performed in semi moist condition; drying is not performed for degummed tasar cocoons. Although, this cooking process enables uniform softening of tasar cocoons; but sometimes fibroin gets affected due to lack of precautions during boiling due to higher pH value above 11. So, the strength of silk fibre or filament being deteriorated. In addition, presence of soda eliminates total sericin from cocoons; for which cohesion between individual filaments of reeled yarn is absent which causes difficulties during preparatory and weaving process to be utilized as warp. So either twisted reeled yarns are used as warp or sizing is required during preparatory process to impart cohesion. Soda cooking is followed in tasar sector predominantly in spite of the lacuna of silk fibre quality deterioration because easy availability of chemical as well as natural brown colour retained in yarn. For softening of unreelable cocoons subjected to spinning, soda cooking is normally followed.

To overcome the shortcomings of silk fibroin deterioration during
sodium carbonate softening; enzymatic cooking process was developed.

**Enzymatic cooking**

Enzymatic treatment at temperature below 40°C enables cleavage of polypeptide bonds of sericin and thereby tasar cocoons become soft suitable for reeling/spinning process (Jolly et al, 1979 & Sonwalkar, 1993). For tropical tasar, the cocoons are boiled in plain water for 2 min and steamed at 15 lb/sq. inch pressure for 40 to 60 min. After release of pressure, the cocoons are wrapped in a porous nylon cloth and soaked in 0.1 to 0.2% Biopril- 50 (proteolytic) enzyme solution for 20 to 22 hours preferably at about 40°C temperature. After softening, the cocoons are washed in plain water for 2 min and steamed at 15 lb/sq. inch pressure for 40 to 60 min. After release of pressure, the cocoons are wrapped in a porous nylon cloth and soaked in 0.1 to 0.2% Biopril- 50 (proteolytic) enzyme solution for 20 to 22 hours preferably at about 40°C temperature. After softening, the cocoons are washed in plain water and subjected for reeling process in semi moist condition. In case of temperate tasar, the cocoons are boiled for about 1 min followed by steaming for about 30 min. The soaking is carried out using 0.03 to 0.05% Biopril- 50 solutions for 20 hours duration. The cocoons are then washed in plain water followed by wet reeling process to produce yarn. Although enzymatic degumming enables 55% raw silk recovery; but this process is not popular in tasar sector because enzyme is not available easily in rural areas as well as for long duration procedure. Also time is an important factor for this softening process, because silk fibroin affected by enzyme in case of schedule time exceeds.

The lacuna of main silk fibroin component deterioration can be overcome by cooking using hydrogen peroxide and neutral soap (with or without pressure) suitable for dry reeling as well as softening by using sodium carbonate, hydrogen peroxide and sodium silicate suitable for wet reeling.

**Hydrogen peroxide and neutral soap method (without pressure)**

In this process, cocoons are boiled in a solution of 10 ml/l hydrogen peroxide, 10 g/l neutral soap for 10 to 15 minutes followed by 30 to 60 minutes steaming in the same solution depending upon the thickness of cocoons shell (Mitra et al., 2013). Hydrogen peroxide is well known as universal bleaching agent but due to alkaline medium with pH level at about10, softening of sericin occurs and removed from silk fibroin. The main advantage of this process is residual sericin of about 4% remains in silk filament, which enables better cohesion between filaments.

**Pressurized cooking**

Duration of cooking as well as fuel cost can be reduced by following pressurized cooking process (Gahlot et al., 2012). In this process (Figure 4), cocoons kept in netted cloth are boiled for 5 to 10 minute in 10 ml/l hydrogen peroxide (50% w/w) and 10 g/l neutral soap solution followed by steaming for 20 to 30 minutes in a pressure cooker depending upon the compactness and shell weight. Then the cocoons are allowed to cool to room temperature by releasing the pressure. In this process also residual sericin remains in silk filament which enables better cohesion.

**Development of cooking process for wet reeling**

Mulberry silk contain sericin as high as 25% of its weight and easily softened in hot water but not completely removed from the silk filament. This property helps both cooking and reeling of mulberry cocoons as after softening the cocoons are placed in a basin containing warm water. It facilitates easy withdrawal of filament as long as water remains warm and when yarn is formed, the silk gum hardens to stick constituent filament together and enable high cohesion property (Somasekhar and Kawakami, 2002). On the other hand, tasar silk contain only 15% silk gum and cannot be easily softened. The vigorous chemical treatment removes most part of the silk gum (sericin) from silk filament (Munshi et al., 2015). The cooking involves plain water boiling of tasar cocoon for 30 minutes. The cocoons are then allowed to cool before soaking in a solution containing 15ml / liter hydrogen peroxide, 8 g/l soda and 15 g/l sodium silicate at a temperature of 55°C for 30 – 60 minutes. It gives adequate softening of the cocoons to facilitate reeling in wet condition while retaining silk gum in the yarn (Gahlot et al., 2012).

The main drawback of hydrogen peroxide softening/cooking process is the elimination of natural colour of tasar silk. Hence an attempt has been taken at Central Tasar Research & Training Institute, Ranchi for development of non- peroxide cooking process so that tasar raw silk yarn can retain its’ natural brown colour without deterioration of fibre tensile characteristics. The new developed process consists of using different concentration of sodium carbonate and sodium bicarbonate along with different boiling and steaming durations (CTR&TI, 2019).

**Development of non- peroxide cooking process**

It was observed that 5 g/l of sodium carbonate and sodium bi- carbonate each with 20 min boiling followed by 30 min steaming facilitates best single cocoon quality characteristics and reeling performance with cooking efficiency about 96%, reelability 35% and raw silk recovery 65% in case of Daba cocoons. For modal cocoons; sodium carbonate and sodium bi- carbonate of 8 g/l each with 20 min boiling followed by 30 min steaming facilitates adequate softening with cooking efficiency about 92% as well as reelability of about 26 % and raw silk recovery of about 62 %. Similarly, 10 g/l of sodium carbonate and sodium bi- carbonate each with 15 min boiling and 45 min steaming provides better single cocoon quality characteristics and reeling performance with cooking efficiency about 90%, reelability 25% and raw silk recovery 60% in case of Raily cocoons. The comparative studies taken for Daba BV, Modal...
and Raily ecoraces are provided in Table 4.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Daba BV</th>
<th>Raily</th>
<th>Modal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Developed</td>
<td>Control</td>
<td>Developed</td>
</tr>
<tr>
<td>Single cocoon quality characteristics:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filament length (m)</td>
<td>1150.00</td>
<td>900.00</td>
<td>1450.00</td>
</tr>
<tr>
<td>Non-broken filament length (m)</td>
<td>235.00</td>
<td>170.00</td>
<td>190.00</td>
</tr>
<tr>
<td>Filament denier</td>
<td>10.80</td>
<td>10.50</td>
<td>11.00</td>
</tr>
<tr>
<td>Reeling performance:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reelability (%)</td>
<td>35.00</td>
<td>26.00</td>
<td>25.00</td>
</tr>
<tr>
<td>Raw silk recovery (%)</td>
<td>66.00</td>
<td>60.00</td>
<td>59.70</td>
</tr>
</tbody>
</table>

Developed: \( \text{Na}_2 \text{CO}_3 \ & \text{NaHCO}_3 \) Process; Control: \( \text{H}_2 \text{O}_2 \ & \text{Soap} \) process (without pressure)

The cost of softening for tropical tasar cocoons is substantially lower as compared to traditional sodium carbonate and soap as well as hydrogen peroxide and soap process generally followed in tasar reeling sector. Cost of cooking is reduced by about 50% for Daba BV cocoons, 45% for Modal ecorace and 35% for Raily ecorace. Moreover, tasar silk yarn is produced by reellers in remote rural areas where sodium carbonate (washing soda) and sodium bi-carbonate (edible soda) are easily available. Hence this new developed process will be very much useful for the tasar silk sectors.

Tasar peduncles degumming

Matured tasar silkworm forms cocoons by spinning process on its’ food plant leaves and hence it makes peduncle as support. The peduncles also consist of silk fibres from which yarn can be produced. As it facilitates support for spinning of cocoons; so it is very tough and vigorous alkaline boiling is required (Mitra et al, 2013). For 1 kg of peduncles, about 10 liters water is taken. Sodium carbonate of about 10 g/l being dissolved in water and the peduncles are boiled for 1 hour duration followed by hot washing and cold washing in order to remove presence of alkali. After drying, the peduncles are beaten by wooden hammer for preopening and removal of cuticles as well as other impurities. These pre opened peduncles need to be processed through coarser fillet (2 times) followed by finer fillet (2 times) for proper opening and individualization of fibres.

Reeling of tasar cocoons

Thigh reeling is the conventional process for withdrawal of filament from tasar cocoons which was predominantly followed earlier.

Thigh reeling

It is a traditional process mostly practiced by the traditional tasar weavers’ womenfolk. One woman from the weavers’ family sitting in a crossed leg position draw individual filament from 5-7 cocoons and rub on her thigh to form the yarn of targeted fineness and wind on to a bamboo made Natwa (Figure 5). This process of reeling is preceded by soda cooking of cocoons and imparts no twist to the yarn. The yarn so formed has lack of strength and cohesion and cannot be used as warp. Moreover, the productivity is low only 60 to 70 gm for which reellers are unable to earn reasonable income. Lastly, the process is not hygienic as concerned reeler mostly suffers from skin disease as well as odd looking gesture of a woman reeling on her thigh is also not well taken in the society (Mitra et al., 2013).

For overcoming the disadvantages of the Natwa (thigh) reeling process, different reeling appliances were developed like Trivedi reeling machine, Central Tasar Research Station (CTRS) reeling machine as well as Modified CTRS Multi-end Reeling machine etc (Sonwalkar, 1993). But the production is not so adequate to earn sufficient income at present scenario. Motorized reeling cum twisting machine (MRTM) developed by Central Silk Board was the first successful machine which is still popular in tasar reeling sector. Later on different reeling machines like Kamdhenu, Wet, Buniyaad and Atal reeling machines were developed for enhancement of productivity and quality.

Machine reeling

Motorized reeling cum twisting machine (MRTM)

Motorized Reeling cum Twisting Machine (MRTM) is introduced (Figure 6) in tasar reeling sector in rural areas. It is a four ends pedal cum motor operated machine working on principle of ring spindle. The spindle speed maintains at about 4000 rpm and it imparts modest twist i.e. 3 to 5 tpi in the yarn to hold constituent filaments.
together and enhances strength and cohesion that can be used in warp as a replacement of imported Korean tasar yarn (Kariyappa et al., 2005). The productivity also enhances significantly 120 to 150 gm with 60-denier filament fineness. The delivery speed can be altered between 20 to 50 m/min by adjustment of belt and step pulley in which dry reeling (semi moist) technique is followed.

**Figure 6: Motorized reeling cum twisting machine (MRTM)**

**Kamdhenu reeling machine**

This machine is a portable model of Motorized Reeling cum Twisting Machine (MRTM) with three ends (Khan et al., 2017), working on principle of ring spindle (Figure 7). The spindle speed maintains at about 2500 rpm and it imparts modest twist i.e. 3 to 5 tpi in the yarn to hold constituent filaments together and enhances strength and cohesion. By using this machine, 100 to 120 gm productivity can be achieved.

**Figure 7: Kamdhenu reeling machine**

**Wet reeling machine**

The wet reeling machine developed for producing yarn from tasar cocoons is similar to process followed for mulberry cocoons. The machine (Figure 8) has six ends and can be operated either manually or electric power (Gahlot et al., 2010 and 2012). The reeling is carried out like in a basin containing warm water of 45°C temperature. The constituent filament in this case holds together because of presence of silk gum and enhances its strength and cohesion significantly over the dry reeled yarn. The production is about 250 gm with 60 denier fineness. The reeling speed can be altered by regulating between 30 to 80 m/min depending upon the quality of tasar cocoons.

**Figure 8: Wet reeling machine**

**Buniyaad Reeling Machine**

Central Silk Technology Research Institute (CSTRI), Bangalore has developed a portable type reeling appliance which can be easily by operated by women reelers in rural areas: The machine is operated by 25W -12V DC Motor with speed of 2600 rpm. The machine can be run by using both normal electricity as well as solar power (Figure 9). The circumference of reel as 0.68m (Central Silk Technology Research Institute, 2016). Individual filament being withdrawn from single cocoons kept on tray as per required fineness. After withdrawal from cocoons, the yarn is passing through guide followed by polymer made false twisting system. This facilitates some amount of cohesion between individual filaments. Then the yarn is wound on polymer reel after passing through the
traversing guide. The reel rpm can be adjusted by regulator so that different quality cocoons can be used for yarn production. With reel speed of 70 rpm and 70 denier yarn fineness, the production can be achieved by 180 gm (70% efficiency).

**Motorized Tasar Reeling Charkha (MTRC)**

Reeling of tasar cocoons are carried out in remote rural areas under decentralized sectors. So, the main requirement of the reeling machine is the simplest driving system along with either manual or electric or solar power operated system. Central Tasar Research and Training Institute, Central Silk Board, Ranchi expedites research activities for improvement of quality characteristics of tasar cocoons as well as design and fabrication of reeling machines with simplest driving system suitable for rural tasar clusters. Twin Charkha developed by CTR&TI, Ranchi is a simplest machine not involving too many mechanisms and friction bearings (Central Silk Board, 2012). There are two wooden swifts of 1.50 m circumference mounted parallel on a common iron angle frame driven manually through handle attached with gear and bevel arrangement between the swift. The traverse mechanism for maintaining the width of laying hank on the swift is driven by thread belt and pulley arrangement. Three persons are required for operating this machine one for rotating the handle and other two for reeling. Each swift has four ends and the reelers sit on wooden stools facing the rotating swift. In the event of break the swift can be stopped without affecting or stopping the other swift by detaching swift shaft from handle drive. However one side (4 ends) of the machine has to stop during ends breaks for mending. Tasar cocoons are reeled in semi moist condition on this machine. The path of the yarn is also simple. Filament ends from required numbers of cocoons are unraveled by the direct pull generated through rotation of swift and then passes through the thread guide and traverse guide before winding on wooden swift. The production of this machine is about 1 Kg untwisted tasar yarn with 60 denier fineness for eight hours operation. So, it is about 350 gm per operator, since three persons are involved during reeling. During trials, it was found that the person rotating handle suffering from drudgery. Also, the presence of gum in the yarn makes it to stick on the surface swift bars resulting difficulty in removing the hank by collapsing it. Although in the event of casting a filament, it is dragged with other ends to the swift thereby producing hairs, loops etc in yarn hank. Since untwisted yarn is produced by this machine, the cohesion between individual filaments is very low which cause difficulties during warping and weaving process.

Based on the concept of Twine Charkha; CTR&TI, Ranchi, further designed and fabricated a modified model of New Reeling Machine (Charkha) with 4 ends which can be operated by single person (Paul, T.K. et.al.2013). A new concept of cocoon vibrator was introduced which helps to retain original shape of degummed cocoons thereby facilitates easy casting. The swift circumference is 1.5 m operated by 0.25 HP motor. Three croissure pulleys attachment through the yarn path provides better cohesion between filaments along with compactness. The yarn guides maintain the position of yarn for each end thereby uniform skein of tasar yarn. Aluminum reeling basin consists of four sections which prevents entanglement of single filament between the individual ends. The speed of the reel is at 50 m/min and 275-300gm of 60 denier tasar yarn can be produced per day by single reeler. But it was observed that, it was very difficult for reeler to identify the cocoon for which the yarn end has broken as well as for insertion of new cocoons due to cocoon tray vibration. In addition, yarn production is not possible at the places where scarcity of normal electricity exits. The lacunae as mentioned above for New Reeling Machine have been overcome by development of Pedal cum Motorized Tasar Reeling Machine (PMTRM) /Charkha by CTR&TI, Ranchi. In this machine the oscillating motion of cocoon tray (basin) is removed. In addition for each end; jetteboutte being incorporated which facilitates easy casting of tasar silk filament from single cocoon during mending of broken ends. Hence the quality of tasar yarn will be better due to fewer defects like loose ends, slabs hairs etc. It is revealed from multi location technological trials (Central Silk Board, 2015 & 2012), reeling speed can be maintained between 30m/min to 50m/min depending upon the cocoon quality. In this machine speed alteration facility by regulator has been provided which alters the motor rpm. So reeler can set the machine speed as per her/his convenience according to cocoon quality. The machine consists of simple driving mechanism which reeler can maintain and repair easily. In this context, Motorized Tasar Reeling Machine (MTRM) (Charkha) has been developed (Figure 10). The machine (Figure 8) has four ends with reel circumference 1.50 m. The power requirement is 0.25 HP. The surface speed of reel can be adjusted to 25 to 75 m/min depending upon the cocoons’ quality and production that can be achieved 350 to 400 gm with 60 denier fineness.

**Figure 10: Motorized Tasar Reeling Charkha (MTRC)**

**Atal Reeling Machine**

Non- broken filament length (NBFL) is the most important characteristics for assessment of reeling performance. The reeling speed is directly proportional to the non- broken filament length of silk cocoons (Lee, 1999). Mulberry silk yarn is produced by using state of the art reeling machines with higher speed (Somashekar and Kawakami, 2002) whereas tasar is reeled at very low speed by using conventional machines (Sonwalkar, 1993 & Kariappa et al., 2005). Maximum values for non- broken filament length...
(NBFL) exist in the lower range with respect to its average value for tropical tasar cocoons because of excessive breaks during filament withdrawal (Das and Ghosh, 2007). The average NBFL for tropical tasar cocoons ranges between 150 to 175 m whereas it is above 500 m for mulberry variety due to very few breaks during reeling. This parameter establishes the reason for higher reeling speed at about 100 m/min in case mulberry cocoons as against only 30 m/min for tropical tasar cocoons (Munshi et al., 2015). In addition, due to filament lapping on delivery roller, entanglements and excessive tension during filament withdrawal; frequent stoppages are occurring which cause loss of additional productivity (Central Silk Board, 2015). Hence, an attempt has been made to design and fabricate a new tasar reeling machine in which state of the art technique can be incorporated so that the stoppages that are arising can be overcome in order to achieve improvement in productivity and quality.

The new Atal reeling machine (Figure 11) was designed and fabricated by M/s Aryan Engineering, Kanakpura, Ramnagara, Karnataka under technical guidance of Central Tasar Research & Training Institute (CTR & TI), Ranchi and Tasar Development Foundation, Deoghar (Central Tasar Research & Training Institute, 2018). Frequent stoppages during withdrawal of filament from tasar cocoons can be reduced while using new Atal reeling machine. Further reeling speed can be maintained between 50 to 70 m/min instead of present 30 m/min. Thus production can be achieved 300 to 350 gm for 8 hours with filament denier 60. By incorporation of denier control device, the size (denier) deviation is possible to maintain in the range within ±20 denier. The machine is very much user friendly for reeler while casting of cocoons at breakages, mending of broken ends as well as re-reeling of filament. The take-up speed of the reel can be kept at about 50 m/min for tasar reeling to achieve higher productivity and quality.

![Figure 11: Atal Reeling Machine](image)

**Spinning of tasar cocoons**

During reeling of tasar cocoons in addition to unreelable varieties, about 40 to 50% waste is also generated which makes a considerable quantity of tasar waste, needs to be utilized for spun yarn production (Chattopadhyay et al., 2015). The utilization of tasar waste is also very important which gives additional profit to the reellers. There are four types of spun silk yarn produced from tasar silk waste like Ghicha, Katia, Jhuri, and Balkal. For spun yarn production; Takli, Trivedi Spinning Wheel, N.R.Das Spinning Wheel and Chowdhary Spinning Wheel are the conventional spinning appliances, which were developed for conversion of yarn from tasar silk wastes (Jolly et al., 1979 and Sonwalkar, 1993). Due to low productivity and limitation of yarn fineness (count), the above mentioned techniques/machines are not popular at present in the field. Tasar silk wastes can be effectively utilized for manufacturing of spun silk yarn by using Motorized Spinning Machine (MSM), KVIC Amber Charkha set of machineries, as well as Mill Spinning Process.

There are four varieties of waste available (Chattopadhyay et al., 2005) for tasar silk as mentioned below:

1. Wastes from unreelable tasar cocoons.
2. Wastes generated during reeling.
4. Wastes from peduncles.

**Wastes from unreelable tasar cocoons**

Discarded cocoons which are unreelable because of certain defects like insect infestation, thin or flimsy, double, deformed, cut cocoons, pierced cocoons etc. and thus are not suitable for reeling, are called unreelable cocoons (Figure 12).

![Figure 12: Waste from unreelable tasar cocoons](image)

**Wastes generated during reeling**

![Figure 13: Waste generated during reeling](image)
These wastes are produced during deflosing & reeling and the left over residues in basin (Figure 13). Deflosing wastes are generated before reeling process to find out the end of individual continuous filament for easy operation. The waste obtained during reeling on account of cocoons’ feeding after exhaustion and mending of breakages. Basin waste is the left over residue i.e. unreelable innermost shell layer. Altogether the reeling wastes constitute 30 to 40% of silk fibre in the cocoon.

**Wastes generated during preparatory and weaving (hard waste/throwster waste)**

This type of wastes consist of all bits of yarn obtained during knotting and in various stages of silk yarn or fabric production i.e. re-reeling, winding, throwing, twisting and weaving, wet processing etc (Figure 14). These wastes are required to be opened by mechanical opening machine for re-use.

**Wastes from peduncles**

A small quantity of silk wastes is obtained from cocoon peduncles which are cut and separated before cooking of cocoons for reeling purpose (Figure 15). These peduncles after degumming get converted into peduncle silk waste.

**Spinning of tasar silk fibers**

At present, four types of spun yarns (Moon, M.A., 2013) are produced from tasar silk wastes i.e. Ghicha, Katia, Jhuri and Balkal. Among these varieties, Ghicha and Katia yarn is spun from mainly unreelable cocoons whereas wastes eliminated during reeling and weaving as well as peduncles waste are utilized for other varieties. The details of spinning appliances are mentioned below commonly utilized in tasar silk sectors:

**Earthen Pitcher (Matka)**

Ghicha, Jhuri and Balkal yarns are produced using Earthen Pitcher popular as Matka (Jolly et al, 1979 & Sonwalkar, 1993). Ghicha yarn is spun from unreelable cocoons. For this purpose, degumming is required for unreelable tasar cocoons. The spinner withdraws fibres strand either from unreelable degummed cocoons in semi moist condition by hand drafting and rubs on the back side of Earthen Pitcher (Matka) to insert little twist for imparting cohesion between fibres and then laying the spun yarn on a paper sheet kept on floor (Figure 16). After completion of spinning process, the spinner converts the yarns' layers into hank form by re-reeling process. In addition to hank conversion, faults present in yarn being removed during re-reeling process. Yarn count up to 15 Nm can be produced by this technique with productivity of up to 120 g per day of eight hours. Similarly Jhuri yarn is produced by using Earthen Pitcher from either reeling wastes or peduncles and count up to 8 Nm can be spun. Balkal yarn is produced from degummed tasar peduncles using this practice.

**Motorized Spinning Machine (MSM)**

Due to limitation of yarn fineness and productivity, Central Silk Board has developed Motorized cum Pedal operated Spinning Machine for enhancement of productivity and quality (Kariyappa et al, 2003). This is a simplest machine consist of small size i.e. 27.50 cm long and 25 cm high iron framed power operated machine is working on ring spindle principle (Kariyappa et al., 2003). Spindle is placed horizontally and is operated by single-phase motor of 0.25 HP. The machine is provided with mechanized traversing system to enable uniform distribution of yarn over the bobbin. This is portable model and finer count of yarn (up to 40 Metric count) with uniform twist can be spun using this device. This machine (Figure 17 a) can be effectively utilized for spinning of tasar silk waste. Tasar silk waste obtained from unreelable cocoons can be used directly in this machine whereas wastes generated during reeling and weaving need to be processed in fillet machines for parallelization and individualization of fibres before spinning on the machine.
average production from one MSM is about 200 gm of spun yarn per day of 8 hours with 75% yarn realization from unreelable tasar cocoons waste and 80% from reeling / weaving wastes. Katia yarn is produced by this spinning appliance. Other than ring and traveller mechanism; flyer twisting technique is also available in which low twisted yarn can be produced (Figure 17 b). Both types of machine can be operated by electrical motor, pedal or solar power system.

![Flyer](image1.png)

17 (a): Ring & traveller

Figure 17: Motorized Spinning Machine (MSM)

The count (Nm- metric) co-efficient of variance for spun yarns produced by the above two conventional techniques is very high (above 15%) due to manual feeding procedure of fibrous strand followed by twist insertion by rubbing on reverse side of earthen pitcher as well as by rotation of traveler through spindle rotation in Motorized Spinning Machine (MSM). This lacuna is overcome by introduction of hand operated mechanized preparatory processes in case of Amber Charkha set of machineries.

**Amber Charkha set of machineries**

Amber Charka set of machineries is very popular for producing cotton and polyester/cotton blended yarns in Khadi sector of India. All types of silk wastes are also successfully spun on these machineries (Chattopadhyaya et al., 2010). For 12 nos of Amber Charka (consists of six spindles each) (Figure 18), one no of coarser fillet, finer fillet, staple cutter, tape draw frame and roving frame each are required. The details of machineries for Amber Charkha spinning process along with productivity are mentioned in

![Amber Charkha](image2.png)

Figure 18: Amber Charkha

**Table- 5: Process sequence and productivity of Amber Charkha spinning**

<table>
<thead>
<tr>
<th>Sl no.</th>
<th>Type of Machineries</th>
<th>No of machines required</th>
<th>Production/Day/Machine (8 hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coarser Fillet</td>
<td>1</td>
<td>5 Kg.</td>
</tr>
<tr>
<td>2</td>
<td>Finer Fillet</td>
<td>1</td>
<td>5 Kg.</td>
</tr>
<tr>
<td>3</td>
<td>Staple Cutter</td>
<td>1</td>
<td>4 Kg.</td>
</tr>
<tr>
<td>4</td>
<td>Tape Draw Frame</td>
<td>1</td>
<td>4 Kg.</td>
</tr>
<tr>
<td>5</td>
<td>Roving Frame</td>
<td>1</td>
<td>4 Kg.</td>
</tr>
<tr>
<td>6</td>
<td>Amber Charkha-(6 Spindles each)</td>
<td>12</td>
<td>300 gm</td>
</tr>
</tbody>
</table>

Table – 5.

Courtesy: Chattopadhyay et al
Although the variation of yarn count is reduced by development of Amber Charkha set of machineries along with improvement of quality characteristics but due to very low productivity; mill spinning process is followed for producing superior quality yarns.

**Mill Spinning Process**

Tasar silk waste can be effectively utilized for producing of spun yarn by mill spinning process (Chattopadhyay et al., 2015). There are two different processes available in case of mill spinning i.e. Italian system and Japanese system. In Italian system, Roller and Clearer Card, Gill Box Draw Frame, Comber, Speed Frame and Ring Frame are the main machineries required in addition to degumming, drying and cocoon opener. Similarly, in case of Japanese system, Floss Cutter, Circular Dressing, Small Cutter, Spreading, Slivering Frame, Drawing Frame, Roving Frame and Ring Frame are the set of machines. For 60 kg yarn production per shift of 8 hours, about 1000 spindles capacity is required and the yarn count that can be spun from tasar waste ranges between 10 Nm to 80 Nm. The yarn realization is low for Mill spinning process i.e. about 50% due to noil (waste) elimination during combing operation for Italian system and dressing operation in case of Japanese system. The noil eliminated during processing can be utilized for spun yarn production following short staple cotton spinning process with yarn count ranging from 10 Nm to 40 Nm. The spun yarns produced by Ring Frame are processed through Autoconer/ Manual Cone Winder, Parallel Winder, Ring Doubling/Two for One Twister (TFO) and Singeing (Gassing) in post spinning processes. However, the realization is less as compared to manual process, but the quality characteristics in terms of uniformity and tensile are better. The details of machinery required for Italian system is given in Table 6 and for Japanese system in Table 7 with production capacity of 60 Kg./shift of 8 hours.

**Table-6: Details of machineries for Italian System**

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Type of Machine</th>
<th>Capacity/ Specification</th>
<th>Quantity (no)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Degumming</td>
<td>25 Kg</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Hydro extractor</td>
<td>25 Kg</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Drying Chamber</td>
<td>50 Kg</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Cocoon opener</td>
<td>------------------------</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Staple Cutter</td>
<td>------------------------</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Carding (Roller &amp; Clearer)</td>
<td>------------------------</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Gill box D/F</td>
<td>------------------------</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>Comber</td>
<td>------------------------</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Simplex (Roving Frame)</td>
<td>32 Spindles</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Ring Frame</td>
<td>500 Spindles (each)</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Cone Winding</td>
<td>36 Heads</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Assembly Winding</td>
<td>32 Heads</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Twisting (Doubling)</td>
<td>200 Spindles</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Singeing (Gassing)</td>
<td>24 Heads</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>Reeling</td>
<td>40 Heads</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table-7: Details of machineries for Japanese System**

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Type of Machine</th>
<th>Capacity/ Specification</th>
<th>Quantity (no)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Degumming</td>
<td>25 Kg</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Hydro extractor</td>
<td>25 Kg</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Pupae Rider (optional)</td>
<td>------------------------</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Drying Chamber</td>
<td>50 Kg</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Cocoon Opener</td>
<td>------------------------</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Floss Cutter</td>
<td>------------------------</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Circular Dressing</td>
<td>------------------------</td>
<td>3</td>
</tr>
</tbody>
</table>
**Sl No** | **Type of Machine** | **Capacity/ Specification** | **Quantity (no)**
--- | --- | --- | ---
8 | Small Cutter | --------------- | 4
9 | Spreading (2 LH & 2 RH) | --------------- | 4
10 | Slivering Frame | --------------- | 2
11 | Drawing Frame | --------------- | 6
12 | Simplex (Roving Frame) | 72 Spindles | 1
13 | Ring Spinning Frame | 500 Spindles (each) | 2
14 | Doubling (Twisting) | 200 Spindles | 1
15 | Assembly Winding | 32 Heads | 1
16 | Singeing (Gassing) | 24 Heads | 1
17 | Cone Winding | 36 Heads | 1
18 | Reeling | 40 Heads | 1

**Physical properties of tasar silk fibre**

The physical properties of tasar silk fibre (Kariyappa et al, 2012) are mentioned in Table 8.

<table>
<thead>
<tr>
<th>Quality parameters</th>
<th>Tropical tasar</th>
<th>Temperate tasar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Fibre diameter (microns- µ) (1/1000 mm)</td>
<td>33.00</td>
<td>17.50</td>
</tr>
<tr>
<td>Single fibre denier</td>
<td>10.00</td>
<td>5.50</td>
</tr>
<tr>
<td>Specific gravity (g/cc)</td>
<td>1.34</td>
<td>1.30</td>
</tr>
<tr>
<td>Moisture regain (%)</td>
<td>11.00</td>
<td>10.50</td>
</tr>
<tr>
<td>Single fibre tenacity (g/d)</td>
<td>1.80</td>
<td>2.50</td>
</tr>
<tr>
<td>Single fibre breaking elongation (%)</td>
<td>30.00</td>
<td>28.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quality characteristics of tasar mill spun yarns</th>
<th>Tropical tasar</th>
<th>Temperate tasar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unevenness (Um %)</td>
<td>12.00</td>
<td>13.50</td>
</tr>
<tr>
<td>Imperfections/100 Km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Thin Places (- 50 %)</td>
<td>30</td>
<td>72</td>
</tr>
<tr>
<td>- Thick Places (+ 50 %)</td>
<td>60</td>
<td>75</td>
</tr>
<tr>
<td>- Neps (+ 200 %)</td>
<td>90</td>
<td>115</td>
</tr>
<tr>
<td>Breaking Force (gf)</td>
<td>575.40</td>
<td>361.20</td>
</tr>
<tr>
<td>Tenacity (gf/d)</td>
<td>1.90</td>
<td>1.60</td>
</tr>
<tr>
<td>Young modulus (gf/d)</td>
<td>23.80</td>
<td>44.00</td>
</tr>
<tr>
<td>Breaking elongation (%)</td>
<td>11.60</td>
<td>10.60</td>
</tr>
</tbody>
</table>
Cost of production for yarns from different varieties of tasar silk wastes

**Spinning of yarn from wastes of unreelable tasar cocoons**

The cost of production for spinning of yarn from wastes of unreelable tasar cocoons (Chattopadhyay et. al, 2015) while using CSTRI MSM, KVIC Amber Charka and Mill Spinning Process (Italian & Japanese system) is given in Figure 19.

![Figure 19: Cost of production for spinning of yarn from wastes of unreelable tasar cocoons](image)

From Figure 19, it can be depicted that, the total cost of production is less while using CSTRI MSM for spinning of yarn from unreelable tasar cocoon wastes. This is due to maximum yarn realization as 75% for CSTRI MSM. The conversion cost includes cost of fuels & chemicals, electricity/power, labour wages & staff salary, maintenance of machineries, packing and overhead cost. This is minimum for mill spinning process because of higher production both in case of Italian and Japanese system. However yarn quality characteristics like uniformity, tensile strength etc are much better in case of mill spinning process as compared to CSTRI MSM and Amber Charka set of machineries.

**Spinning of yarn from reeling and weaving waste**

The cost of production for spinning of yarn from wastes generated during reeling and weaving (hard waste/throwster waste) while using CSTRI MSM, KVIC Amber Charka and Mill Spinning Process (Italian & Japanese system) are given in Figure 20.

![Figure 20: Cost of production for spinning of yarn from reeling and weaving waste](image)

Courtesy: Chattopadhyay et al.
Production of yarn from wastes generated during reeling and weaving can be done with minimum cost (Figure 15) while using CSTRI MSM or Amber Charka set of machineries. This is due to higher yarn realization i.e. about 85% for both processes. But yarn quality characteristics are better for mill spinning process both in case of Italian system as well as Japanese system.

**Spinning of yarn from tasar peduncles**

Tasar peduncle wastes can be effectively utilized by Amber Charka set of machineries because of short fibre length. The cost of production for spinning of yarn from tasar peduncle wastes is given in Figure 21.

Since, the tasar peduncle consists of only about 10% of total silk waste and realization is only 50%, so set up a spinning mill with short staple woolen or cotton spinning system is not viable from economic point of view. However, existing woolen spinning mill may produce tasar peduncle spun yarns in addition to their regular products i.e. yarn from wool noil and wastes.

**Weaving of silk fabrics**

Most of tasar silk fabrics are produced by using handlooms and conventional manual preparatory processes.

**Preparatory processes**

A series of operations are carried out before conversion from yarn to fabric using weaving machine/loom. These are called as preparatory to weaving that involves winding, doubling, twisting, re-winding, warping and pirn winding.

**Winding**

The main functions of winding are to put the yarn in a long continuous length to suit later processes and also to eliminate the defects like slubs, weak places, thick places etc. In handloom sector, manual bobbin winding process is carried out by using a Charkha (Figure 22). For warping/beaming; bobbins (in cylindrical/cheese form) are prepared by keeping the bobbin inside horizontal spindle which rotates by rope/tape through a charkha (bi-cycle rim). These bobbins are used for warping operation. Pirn winding is carried out by similar process which is kept inside the shuttle box during weaving and yarn is laid in crosswise direction of fabric for each picking motion.

**Figure 21: Cost of production for spinning of yarn from tasar peduncle waste**

<table>
<thead>
<tr>
<th>Cost of Production (Rs/Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material cost</td>
</tr>
<tr>
<td>Fuels and chemicals</td>
</tr>
<tr>
<td>Conversion cost</td>
</tr>
</tbody>
</table>

**Figure 22: Winding of tasar yarn**

Developed techniques for preparatory processes to produce tasar silk fabrics in future

Power driven winding machine consists of 50 to 100 bobbin units and double sided. On each side, there is a creel (swift holder) either below or above the bobbin. Silk hank is mounted on a swift in which tension is maintained by keeping dead weight so that thread is not pulled loosely during winding. Double flanged bobbin is mounted horizontally and driven by surface contact by the disc mounted horizontally on a long shaft to keep speed of winding uniform.
(Figure 23). Double flanged bobbins are used for winding process and during winding faults gum spots, loose ends, defective knots etc are removed. So, quality of silk yarn is improved. Normally before winding, the hanks are soaked in neutral soap and oil solution in water so as to soften the hank for smooth unwinding. Hanks are immersed for few hours and semi dried before winding. The ideal temperature for winding is 27°C±2°C and relative humidity 65%±2%. The winding speed varies depending upon the denier of silk yarn. For tasar silk yarn, 30 to 50 m/min is ideal. Production per day per end (unit) is 100 to 150 g depending upon the denier and quality of silk filament. One person can maintain 15 to 20 ends/bobbins. Similarly pirn winding machine consists of 8 to 40 ends (figure 24).

Courtesy: CSTRI, Bangalore

Figure 23: Warp winding machine for silk yarn

Figure 24: Pirn/Weft Winding machine for silk yarn

Doubling
The object of doubling is to assembly the multi threads into single strand lying parallel. Doubling improves the unevenness of yarn as well as tensile characteristics. The doubling machine is similar to winding machine (Figure 25). Bobbins produced on winding machine are placed on the creel and the required no of yarns are withdrawn which are to be doubled together passing through thread guide and yarn stop motion device and then wound on another bobbin rotates horizontally by surface contact of a shaft similar to winding machine. There is a pin through which individual thread is passing and at the time of break; the pin drops down and comes in contact with rotating drum which immediately stops the corresponding end. This machine has a capacity of 50 to 100 ends/bobbins and is double sided. The production capacity is 2 to 4 times that of winding depending upon the number of ply.

Courtesy: CSTRI, Bangalore

Figure 25: Silk doubling machine

Twisting
Silk twisting machine is of up-twister principle. There is a vertical spindle on which doubling bobbin is mounted and yarn from this is wound on to a perforated bobbin mounted horizontally and driven by surface contact. Twist is imparted on account of difference between the speed of the spindle and the winding drum. Up twister consists of two or three rows of spindles in order to save the spacing and double sided (Figure 26). The no of spindles per machine is 168 to 840.

Courtesy: CSTRI, Bangalore

Figure 26: Silk twisting machine (up-twister)

Twist of yarn can be reduced by increasing the take up speed/drum speed and vice versa keeping spindle speed as constant by altering the gearing assembly in main driving unit. Twisting is carried out for single thread or multiple threads depending upon the requirement for weaving. The production of this machine also depends upon the amount of twist; higher the twist lowers is the production rate and vice versa. Certain types of yarns like crepes and georgettes require high amount of twist. High twist causes shrinkage in the yarn and so twists setting by steam treatment. Otherwise shrinkage problems occur in fabric after withdrawing.
from loom. The direction of twist also has impact on cover of the fabric. Normally the production per spindle is 75 to 100 g (two ply) for about 60 denier yarn. Twisting affects the brilliancy of the yarn. This is because, the roughness of the thread’s surface caused by twisting and the ridges of the spirals causing shadows with loss of reflected light. As the number of twist increases, the brightness will be subdued more. Ring twisting machine (ring and traveler combination) is not used for silk filament yarn to avoid the surface distortion.

Since twisting affects the productivity of yarn, Two- for One Twister (TFO) has been developed for both filament as well as spun yarns. In case of Up- Twister as well as Ring Twister (traveler and ring combination), one twist is inserted per revolution of the spindle. But in TFO, two twists are inserted per revolution of the drum or spindle. So, productivity is enhanced about 1.5 times as compared to Up- Twister and Ring Twister. The photograph of TFO is illustrated in Figure 27. Re- winding process can be omitted after twisting in TFO since the wound package is in cone or cheese (cylindrical) form which can be directly used for warping prior to weaving. The schematic diagram for TFO is illustrated in Figure 28.

![Figure 27: Two for One Twister (TFO)](image1)

![Figure 28: Schematic diagram for Two for One Twister](image2)

**Heat setting/Steam treatment of silk yarn**

Heat setting, also termed as steaming is required in order to set the twist given to a thread so that the distribution of twist on the yarn is uniform. The tendency of any fibre is to retain to its’ original form after mechanical stress like twisting, bending etc. So, by exposing the yarn in steam (damp heat) the orientation of fibre molecules occurred according to the spiral direction of twist due to mobility and thus the twist is set in yarn. In addition, the residual sericin present in silk yarn gets partially softened by this process. Steaming is carried out in steam chambers wherein steam is allowed under certain pressure, so that the steam passes through the layers of yarn through the perforations of the bobbins. The durations of steaming depends upon amount of twist, wound bobbin weight, yarn count (denier/metric) etc. overall 15 to 30 min duration is sufficient for twist setting and steaming chamber temperature is kept at about 70°C. After the steaming the yarn is required for hot air drying at 60°C for about 10 min.

**Re- winding**

Re- winding machine is similar to winding machine and production capacity is double than of winding machine. This is because during winding the faults present in silk yarn are removed and hence the productivity suffers but in case of re- winding, only conversion of smaller package to bigger package or hank is performed. For twisted yarn produced from Two for One Twister (TFO), re- winding process is omitted. This machine is also double sided and bobbins produced from twisting machine are placed on top of the machine. The thread is re- wound on to the double flanged bobbins or cheeses which are driven by surface contact.

The four operations i.e. winding, doubling, twisting and re-winding are commonly termed as silk throwing. This is mainly followed for mulberry yarn reeling unit where production is very high by using multi- end/automatic reeling machine. For tasar sector, the twisting is carried out during reeling process using Motorized Reeling cum Twisting Machine (MRTM). In some tasar reeling sectors, untwisted yarns produced from Motorized Tasar Reeling Charkha (MTRC)/Buniyaad machine are twisted by same Motorized Reeling cum Twisting Machine (MRTM). Similarly, the bobbin winding for weft yarn and pirn winding for weft yarn are performed following conventional manual process.

**Warping**

In silk weaving, generally sectional warping is followed due to comparatively finer yarn as well as consequently higher number of ends required. Warping machine consists of two parts i.e. (i) warping creel and (ii) warping drum (Figure 29). In handloom sector, the warping operation is carried out manually whereas in case of power loom high capacity motor driven warping and beaming...
equipments are utilized. For manual driven warping creel, the no. of bobbins’ holders varies from 100 to 400 depending upon according to fabric production and type of loom. The creel is placed on two sides with working space in between for the worker to attend the breaks as well as replacement of empty bobbins. Double flanged wound bobbins are used for this purpose. The yarns from all the bobbins are passed through guides as well as thread stop motion (motor driven warping machine). Later the threads are collected through a reed before making a section to be wound on the warping drum. After a required length of the section is wound, a number of such sections are repeated on the drum depending upon the total no of ends required in fabric. For example if the creel capacity is 400 bobbins, so each section has 400 ends. Taking fabric width as 120 cm and ends/cm as 60, then the total no of ends in fabric is 7200 and 18 sections have to make during warping/beaming operation. In case of handloom weaving, smaller warping device is required because bigger warping machine is not economically viable. Sometimes, warp is prepared by hand process, combining a number of threads and making into a section or ball and finally preparing the warp sheet for weaving.

The wooden frame loom is shown in Figure 31. After innovation of fly shuttle frame handloom, different accessories have been developed for secondary motion i.e. positive 3/5 wheel take up motion. In conventional handlooms, the let off motion is controlled by the weaver i.e. after producing about a meter of fabric, the person stop the loom operation and by lowering the take up tension and wind the cloth on weavers (cloth) beam. The 3/5 wheel take up motion facilitates winding of silk fabric for each pick insertion. In any weaving process there are three primary motion i.e. shedding, picking and beat up. Shedding enables the bifurcation of warp threads from parallel position into two segments and the space available due to this operation; shuttle is moving from one end to another end through the entire width of during picking operation. After shedding and picking operation, the warp threads lower to previous position and the weft thread lay throughout the width of fabric imposed to cloth fell position by comb type steel wires assemble called dent. Like this the process is repeating and by interlacement of warp and weft, the fabric is woven. These three primary motions are carried out manually in handloom.

Figure 29: Tasar silk warping (Handloom weaving)

Silk weaving

Majority of silk fabrics are produced in India from handlooms. The total no of handlooms in India is about 24 lakhs and about 10 to 15% are engaged for silk weaving. Most of the handlooms are fly shuttle type and each place has its own tradition of looms. Two types of handlooms are popular in silk weaving clusters i.e. pit loom and frame loom. Pit loom is made of wood (Figure 30) whereas the both wood and iron made frame loom is available.

Figure 30: Pit handloom for silk

Developed techniques for weaving process to produce tasar silk fabrics in future

Figure 31: Fly shuttle frame loom for silk

Courtesy: CSTRI, Bangalore

Improved silk handloom developed by Central Silk Technological Research Institute (CSTRI), Central silk Board,
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

Bangalore is shown in Figure 32. In this loom, the take up motion is controlled by 5 wheel take up motion and so the weavers need not to stop the loom frequently for winding the woven fabric on cloth roller. The other advantages are reduction of drudgery, better productivity, fabric with very minimum fault etc. Also as like pit loom and wooden frame loom; jacquard as well as dobby can be incorporated for producing designed fabric. In silk handloom, two types of dobbay are used i.e. county dobbay and English dobbay. Country dobbay is made of wood and consisted of some levers actuated by tappets fixed on barrel. As the tappets are fixed, only one kind of design with slight variation is possible for each dobbay. For complicated designs with order; English dobbay is preferable. In this dobbay the hooks are responsible for lifting of warp threads according to design pattern instead of peg lattice in country dobbay. For, many improved handloom and shuttle power loom English dobbay is used for manufacturing designed fabrics.

Figure 32: Jacquard for silk loom

The limitation of dobbay is that floral designs (small or big) particularly elaborate designs cannot be made due to restriction for control on no of warp yarns. For this purpose, Jacquard is used which was invented in the year 1800 BC by one French Mr. Jacquard. This can be fitted in any pit loom; frame loom (wooden/iron) as well as power loom provided the height of loom frame is at least 7.5 feet. The capacity of jacquard is denoted by the no of hooks like 120, 240, 360, 480, 600 etc. In silk weaving using handloom, maximum 600 hooks are popular. The advantage of jacquard is that more no of warp threads can be controlled as per design. The jacquard also classified as single lift single cylinder, double lift single cylinder and double lift double cylinder. Single lift single cylinder is the simplest jacquard and has one hook for every end in the repeat. Common sizes have 200, 400, or 600 needles. The double lift single cylinder jacquard has two sets of knives, each mounted in a griffe. The two griffe move up and down in opposition over a trolls two pick cycle. A 600 needle machine has 1200 hooks. This type of jacquard is used when a harness cord is required to remain up for two or more consecutive picks. The double lift double cylinder jacquard is further development as compared to earlier version. In this machine, each harness cord and each end in the repeat are controlled by two needles and two hooks. So a 600 machine has 1200 needles and 1200 hooks to control 600 ends in the repeat. By these development control for the movement of warp threads can be achieved and more decorative designed fabric can be produced during weaving. The photograph for a jacquard machine commonly used for silk weaving is shown in Figure 32.

Before producing designed fabric, at first, the design is drawn on graph paper by expert person. After design preparation, punch cards are prepared manually or machine according to repeat of the design. One card is used for lifting of corresponding threads in each pick of loom operation. After preparation of cards, the paper board punch card. The hooks are placed over knives inside the griffe which lift by the movement of the punch cards due to rotation of cylinder. At the positions of holes on cards, the hook is lifted which also make upward movement of neck cord assembled in grate. Through neck cord and neck band the harness cords are tied which lift the corresponding warp yarns in each pick. For proper distributions of harness cords, the same is passed through the holes of comber card. Each warp end passes through a mail eye which has two small holes at each end with a bigger diameter hole at the middle. Through the two small holes at the ends of each mail eye; couplings termed as top coupling. The bottom coupling is connected through cord and weighing device at the end known as lingoes. The leveling of lingoes is most important factor to maintain proper positions after lifting of the warp threads in each pick. So, the set operations are very cumbersome to make ready of the loom/weaving machine equipped with jacquard to produce the designed fabric. Also in addition, the weaver has to foot press the liver for rotating of cylinder and thereby punch cards in each pick in addition to perform the three primary motions i.e. shedding, picking and beat up.

To reduce the operational drudgery during weaving, Central Silk Technological Research Institute, Bangalore, CSB has developed a pneumatic lifting mechanism for jacquard in which the weaver has to press a soft pneumatic pedal lever instead of very heavy mechanical lever (Figure 33). Now-a-days, Computer Aided Textile design (CATD) can be used for preparation of designs which are to be reproduced on fabric. The software for making design can be installed in any computer Desktop or Laptop. The manual processes for paper cardboard punching and lacing of the same also can be carried card punching machine and card lacing machine connected through interface with the desktop or laptop. The designer can prepare the design on screen of the computer and send the instruction to card punching device through computer interface. The paper board cards are stored in rack of card punching device. After receiving of signal, one card is placed at the punching position and holes are made as per design. According to the repeat of the design pattern, this device will take the required no of paper board card.
and punching of holes will be carried out. After punching process, the cards are placed in the rack of lacing machine which will the cards sequentially as per design by nylon thread. After lacing, the garland form of punch cards can be fitted over cylinder to produce required design in the fabric. The photographs for pneumatic lifting mechanism for jacquard fitted in improved handloom and computer aided textile design (CATD) unit are shown in Figure 33 and 34 respectively.

For higher production of designed silk fabric, the lengthy procedures for preparation of loom equipped with jacquard can be overcome by development of electronic jacquard (Figure 35). The design can be prepared on computer by software and then the instructions need to be passed directly to the jacquard through interface. So, the total manual operations like card punching, lacing and setting up the accessories along with components for jacquard can be eliminated except warp preparations procedures. The total no warp threads can be controlled from 400 to 10,000 by electronic jacquard. This type of jacquard can be incorporated in shuttle power loom as well as shuttle less loom like rapier.

Power loom for silk weaving

The productivity of weaving is enhanced by introducing power driving system for the primary and secondary motions in loom. The picks per minute denote the loom speed. In case of handloom, the maximum picks per minute can be achieved is 25 but in case of power loom the same ranges from 120 to 300. For silk weaving, the picks per minute are kept between 150 to 200. The photograph for silk power loom is shown in Figure 36.

Other than mechanized primary and secondary motions, auxiliary motions like warp control, weft stop motion and temple motion are incorporated in power loom. Warp control mechanism helps to instant stop of loom during breaks of warp yarns and weft stop motion for pick failure and thread breakages. The temple motion controls the proper width of the silk fabric by passing the same through screw type of spiral rollers kept at both side of the
fabric width driven by the movement of fabric during winding on cloth roller. Instead of over pick mechanism, at present under pick technique is incorporated which avoids the failure of weft insertion due to higher alacrity/force exerted by picking mechanism. For handloom, maximum 5 meter silk fabric can be woven in a day of 8 hours whereas 50 to 100 m can be woven by power loom.

**Shuttle less loom for silk weaving**

There are three types of sheds which separate the warp threads during weaving i.e. open shed, centre closed shed and bottom closed shed. Open shed is required for insertion of weft in case of shuttle loom and this motion consumes much duration during weaving. Instead of weft insertion by bigger carrier like shuttle; attempts have been made to insert the weft by means of small carrier i.e. projectile, by guides i.e. rapier or by air. Bottom closed shed is maintained for projectile and rapier techniques of weft insertion whereas centre closed shed is followed in case of air jet process of weft insertion. So, there are three types of shuttle less loom used for fabric production known as projectile, rapier and air jet. Projectile loom cannot use for silk filament as the slippage occurred at the grip point of small carrier (projectile) causes weft failure. Similarly, due to slippage of between pressurized air and silk filament; air jet method of weft insertion is avoided. The guiding technique of weft insertion i.e. rapier is very useful for producing fabric where silk filament can also be used as weft. The speed of the rapier loom ranges between 350 to 700 picks per minute and for silk weaving about 450 picks per minute can be maintained. In addition, jacquard and dobby for incorporating decorative designs in silk fabric can be fitted in this shuttle less loom. The productivity is about 2 to 3 times more as compared to power shuttle loom. The picture of rapier loom used for silk weaving is illustrated in Figure 37. Very minor defects are hardly observed in fabric produced by shuttle less looms due to different control mechanism.

**Dyeing of tasar silk yarn/fabric**

**Dyeing using acid /metal complex dyes**

For dyeing of tasar silk yarn/fabric, the following dyes are used.

1. Leveling Acid Dyes
2. Milling Acid Dyes
3. 1:1 Metal Complex Dyes
4. 1:2 Metal Complex Dyes

Acid dyes form electrovalent bond with silk fibre whereas metal complex dyes form co-valent bond. Hence the dyed material has fastness to washing, rubbing, perspiration and light. For light shade, 0.5 to 3% (on material weight) dyestuff being used for coloration whereas 3 to 6% and 6 to 10% being taken for medium and dark shade respectively as per requirement. Other than dyestuff, glacial acetic acid (CH₃COOH) and Glauber’s salt (Na₂SO₄) are used as auxiliaries which do not form bond either with fibre or with dyestuff but these facilitates for dye leveling and fixation. The dyeing procedures are described below (Trotman, 1975).

**Degumming and bleaching of silk yarn/fabric**

Due to presence of residual sericin in silk yarn/fabric, degumming followed by bleaching being performed before dyeing. For dark shade, degumming is required but bleaching may be omitted. But for light and medium shade as well as for natural colour; both degumming and bleaching are necessary.

**Degumming**

Through degumming, the silk gets free of sericin and fatty matters which remain as a superficial cover to the real silk. Degumming was carried out by two baths process both of which has washing soda and soap in them for boiling the silk. Thus facilitates removal of residual sericin from tasar yarn or fabric and hence dye can be imparted to silk fiber only.

**Recipe of the baths**

1. **1st bath** (of wt. of silk) 2. **2nd bath**
   - Soap – 15% 15% Soap -15%
   - Soda – 5% 5% Soda – 5%
   - Water ratio 1:40 Water ratio 1:40
   - Boiling time 45-60 minutes Boiling time 45-60 minutes

Boiling of tasar silk material was carried out at first in the 1st bath and after washing by plain water, it was boiled in the 2nd bath and then washed again by plain water. The combined boiling effect removed the sericin almost completely from the silk material.

**Bleaching**

Besides the sericin and fatty matters; silk with its original colour disturbs the perception of the proper colour. The bleaching operation can remove the inherent colour.

**Recipe**

- H₂O₂ (30%) – 12 ml /litre
- Sodium Silicate – 2 gm/ litre
- Sodium Perborate – 1 gm/ litre
- Liquor ratio – 1:40
- Boiling time- 20 to 30 min.

The bath was prepared with the aforesaid recipe and the degummed silk was put in the bath and boiled for 20 minutes to 30 minutes and...
then allowed to cool. Later the silk was washed by plain water and dried. While using hydrogen peroxide, bleaching is performed by oxidation process only.

Dyeing

The dye is pasted using leucowarm water. Hot water is then added while stirring and the solution is boiled till the dye dissolves completely. The dye –bath is set at 40°C with required quantity of pre – dissolved dyes, 5 – 10% Glauber’s salt, and 1-2% Glacial Acetic Acid. The pre- Wetted goods are then entered and worked for 15 minutes. The temperature of the dye- bath is gradually raised to 90-95°C within 45 minutes and dyeing continued for a period of 45 to 60 minutes. If required an addition of 1 to 2% Glacial Acetic Acid is made and dyeing continued for another 10-15 minutes for full exhaustion. The material is then removed, washed and dried.

Precaution to be taken during Dyeing

- For dyeing light shades, it is advisable to start the bath at room temperature and run the goods for 20 minutes before raising the temperature.
- Common salt should not be used as it tenders the silk fibre.

Dyeing using lac/natural dyes

For natural colour as well lac dyeing, mordanting is carried for improvement of fastness characteristics of dyed material. More than 400 different types natural colours are available at present (Seri, 2000a & 2000b). Some of the natural colours and their sources are given in Table 10.

<table>
<thead>
<tr>
<th>Name of dye</th>
<th>Colour</th>
<th>Part used</th>
<th>Botanical name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madder</td>
<td>Orange</td>
<td>Root</td>
<td>Rubia tinctorum</td>
</tr>
<tr>
<td>Indigo</td>
<td>Blue</td>
<td>Leaves</td>
<td>Indigofera tinctoria</td>
</tr>
<tr>
<td>Kamala</td>
<td>Yellow</td>
<td>Flower</td>
<td>Mallotus philippensis</td>
</tr>
<tr>
<td>Turmeric</td>
<td>Yellow</td>
<td>Root (Rhizome)</td>
<td>Curcuma longa</td>
</tr>
<tr>
<td>Myrobalan (Harda)</td>
<td>Light grey</td>
<td>Seed</td>
<td>Terminalia chebula</td>
</tr>
<tr>
<td>Lac (Insect dye)</td>
<td>Purple/Scarlet</td>
<td>Insect</td>
<td>Laccifer lacca</td>
</tr>
<tr>
<td>Cutch</td>
<td>Brown</td>
<td>Wood (inside bark)</td>
<td>Acacia catechu</td>
</tr>
<tr>
<td>Gall nuts</td>
<td>Dark grey</td>
<td>Seed</td>
<td>Quercus infectoria</td>
</tr>
<tr>
<td>Annatto</td>
<td>Yellow</td>
<td>Seed</td>
<td>Bixa orellana</td>
</tr>
<tr>
<td>Henna</td>
<td>Green/Brownish</td>
<td>Leaves</td>
<td>Lawsonia alba</td>
</tr>
<tr>
<td>Onion</td>
<td>Brown</td>
<td>Peels</td>
<td>Allium cepa</td>
</tr>
<tr>
<td>Pomegranate</td>
<td>Greenish yellow</td>
<td>Peels</td>
<td>Punica granatum</td>
</tr>
<tr>
<td>Tea</td>
<td>Beige &amp; brown</td>
<td>Leaves</td>
<td>Camellia sinensis</td>
</tr>
</tbody>
</table>

Mordanting

Mordanting gives the different shades and colors and also ensures affinity between dye stuff and material

Recipe (Weight of material)

- Liquor ratio – 1:50
- Mordant agent – 1 to 2 g/l
- Glauber’s salt – 10g/l
- Boiling time – 30 minutes.

As per above recipe a bath is prepared and temperature is raised to 60°C. The bleached tasar silk is then immersed in the bath. During the boiling time silk is continuously stirred well by glass rod.

Dyeing:

- Liquor ratio – 1:75
- Dye stuff – 1-5 % ( on weight of silk fiber)
- Formic acid – 3-5 g/l
- Temperature – Boiling
- Time – 30 to 60 min.

After 30 min, the tasar silk material is taken out from the mordanting bath with the help of glass rod. The dye solution is mixed with the mordanting bath solution and stirred well. Then, the mordanted silk is immersed in dye liquor and stirred well. The temperature is raised to boil and the silk material is continuously stirred. After absorption of dye stuff by tasar silk material 3-4% formic acid is added in the dyeing solution. Boiling is further continued for 20 minutes. The material is then subjected to soaping, washed & dried.

Soaping

- Liquor ratio – 1:40
Soap – 2gm/litre
Boiling time – 15-20 minutes

Dyed tasar silk material is immersed in the above said solution and boiled in the solution for 15-20 minutes to remove the superficial/loosely adhered colour. After boiling silk is washed by plain water followed by drying. The different combinations for mordants and lac dye are mentioned in Table 11.

Table 11: Combinations for mordants and lac dyes

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Mordents (%)</th>
<th>Lac Dye (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Potash alum (2)</td>
<td>0.5</td>
</tr>
<tr>
<td>2.</td>
<td>Potash alum (2)</td>
<td>1.0</td>
</tr>
<tr>
<td>3.</td>
<td>Tin Chloride (2)</td>
<td>5.0</td>
</tr>
<tr>
<td>4.</td>
<td>Potassium dichromate (2) and Oxalic acid (0.5)</td>
<td>1.0</td>
</tr>
<tr>
<td>5.</td>
<td>Cupric Sulphate (2)</td>
<td>5.0</td>
</tr>
<tr>
<td>6.</td>
<td>Pot. Dichromate (2)</td>
<td>0.5</td>
</tr>
<tr>
<td>7.</td>
<td>Copper Sulphate (0.5)</td>
<td>0.5</td>
</tr>
<tr>
<td>8.</td>
<td>Tin Chloride (0.5), Potash alum (0.5) &amp; Oxalic acid (0.5)</td>
<td>0.5</td>
</tr>
<tr>
<td>9.</td>
<td>Pot. Dichromate (0.5)</td>
<td>5.0</td>
</tr>
<tr>
<td>10.</td>
<td>Potash alum (0.5)</td>
<td>0.5</td>
</tr>
<tr>
<td>11.</td>
<td>Pot. Dichromate (0.5)</td>
<td>0.5</td>
</tr>
<tr>
<td>12.</td>
<td>Tin Chloride (0.5)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

(%) on weight of material.

Printing of silk fabrics
Printing can be described as localized dyeing by which decorative colourful design can be imparted in silk fabric without following cumbersome dobby as well as jacquard technique during weaving. The production of fabric is reduced by usage of dobby and jacquard during weaving to make decorative coloured designs significantly as compared to make plain weave pattern (Basu, 1964). Hence the cost of printed fabric is less as compared to designed fabrics produced by jacquard as well as dobby. The printing process consists of four factors:
1) Method of printing.
2) Preparation of printing paste/print paste composition.
3) Fixation of prints.
4) Washing.

Methods of printing for silk fabrics
There are two methods for printing of silk fabrics i.e. block printing and screen printing.

Block printing
The insertion of colour to fabric is carried out by using a wooden block where required design is made bottom portion by carpenter. After preparation of printing paste, the block is impregnated on the paste and then placed on silk fabric to produce the colour effect. Before printing, it is required to bleach the fabric so that the required colour effect can be produced. The fabric is placed over a woollen felt cloth with tension so that proper pressure can be applied during colour insertion. To produce multi design effect with different colours, separate block is required. Block printing has popularity in India particularly for specialized jobs though it is very slow process. Machine block printing known as “Perrotine Press Machine” in which all the operations are automatically performed. Maximum three colours can be imparted using this machine. Although this machine yields quick production, but not more than three colours can be produced as well as the block made of wood is liable to be easily broken.

Screen printing
Screen printing is relatively simple method of printing which can be carried out without use of complicated and expensive equipment. The process sequences for screen printing are methods of preparation of screens, screen printing table, squeegees, methods of fixing the material to be printed to the table and printing operation (Clarke, 1980). The fabric used for preparation of screens consists of silk, nylon or polyester but silk fabric mostly used for this purpose and the frame of screen is made of wood or stainless steel.

Printing process
The dyes used for printing of silk fabrics are ‘Procion’, ‘Procilan’, Acid, Direct and Basic. But with respect to fastness properties, acid based dyes are commonly used for printing as it is formed electrovalent bond between silk fibre and dye molecules. Later acid dyes are modified by incorporation of non-carcinogenic metal like chromium, zinc, etc. These are known as metal complex dyes which are subdivided into 1:1 and 1:2 based on presence of one or two metal molecule.

The general printing recipe for tasar silk fabrics is mentioned in Table 12:
**Table- 12: Printing recipe for tasar silk fabrics**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Quantity (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyestuff (Acid /1:1 Metal Complex/1:2 Metal Complex)</td>
<td>X</td>
</tr>
<tr>
<td>Di-Ethylene Glycol</td>
<td>40.0</td>
</tr>
<tr>
<td>Glycerin</td>
<td>20.0</td>
</tr>
<tr>
<td>Acetic acid (Glacial)</td>
<td>20.0</td>
</tr>
<tr>
<td>Perminal KBI</td>
<td>20.0</td>
</tr>
<tr>
<td>Gum Thickening (8%)</td>
<td>600.0</td>
</tr>
<tr>
<td>Hot water</td>
<td>230.0</td>
</tr>
</tbody>
</table>

**X-Based on the shade percentage**

The di-ethylene glycol and glycerin are used as hygroscopic agent to avoid drying because less quantum of water is used in printing paste. Perminal KBI is used as dye fixing agent. The gum is used for maintaining the adequate viscosity of the printing paste. For acid and metal complex dyes it is better to use sodium alginate, gum Senegal or gum Tragacanth instead of gum Arabic. This is because gum Arabic reacts with dyestuff and form bond for which the intensity of printing is reduced.

**Finishing of silk fabrics- future strategies**

Finishing of fabrics can be broadly divided into two categories i.e. (a) Mechanical finishing and (b) Chemical finishing. The objective of mechanical finishing is to impart or improve certain desirable qualities like drape, fall, handle, feel, stiffness, weight etc. and most of these finishing being temporary. The purpose of chemical finishing is to impart some desirable characteristics like anti-crease, flame retardant, soil resistance, waterproof etc. Chemical finishing is renowned for cotton, polyester etc fabrics as well as their blends.

**Mechanical finishing**

The machines which are used for mechanical finishing of silk fabrics are chemical padders/padding mangle, stentering machine cum curing chamber, calendars, and shrinking machines, decatizing machine and tamponing machine.

**Chemical padders/padding mangle**

This machine consists of combination for series of top and bottom rollers. The machine is popular as padding mangle and the capacity is expressed as no of bowls/rollers which are immersed inside the dye or finishing solution. For example in case of two bowls padding mangle; two rollers are dipped inside the solution. These rollers are made of stainless steel. Similarly for two bowls/rollers; another three pair of rollers are present in upward positions which are made of rubber coated stainless steel (one) and stainless steel (two). These are called squeezing rollers whereas others which are immersed in the solution are known as dipping rollers. The reason for using rubber coated stainless steel rollers for better elimination of excess solution from the fabric by squeezing action. The silk fabric is inserted to this machine by feed roller which is later subjected to pass through the dipping rollers as well as squeezing rollers.
Calendaring machine

Calendaring machine facilitates handle and appearance of the fabric. Three and five bowls (rollers) calendaring machines are available. Generally three bowls machine is used for finishing of silk fabrics. Out of three rollers; two rollers are made of stainless steel covered with cotton fabrics as composite and one roller consists only stainless steel which provides ironing action on fabric surface to impart smoothness (Figure 40). Electrical heater coil is incorporated throughout full width of this roller by which the temperature of the roller surface can be maintained between 100 to 120°C. Thermostat temperature control system is present to maintain the temperature within the range. Silk fabric is inserted to this machine by passing over a feed roller and then process through the nips of heated stainless steel roller as well as two cotton covered steel rollers. Pressing the fabric with heat facilitates ironing of the fabric and smoothness gets better. For lower thread density silk fabrics; felt calendar or palmer machine is used. In this machine, silk fabric is passed along with woolen felt which protects the silk fabric from damage due to nip pressure between rollers. This is used for taffeta and serge qualities.

Decatizing machine

Dimensional stability is improved and the fabric is smoothened by removing the creases. Heat treatment is provided with support of woolen felt.

Breaking machine

The breaking machine is used to impart a soft handle to the fabric when calendaring is not sufficient. Button type and knife type of machines are available.

Tamponing machine

The tamponing machine is used for treating fabrics which will have developed roughened surface during the earlier processing operations before finishing.

Chemical finishing

Chemical finishing of silk fabrics includes weighting, scrooping, crease recovery, flame retardancy and oil/dirt repellency. For chemical finishing process; the machines used are padding mangle, stenter cum curing/hot air dryer and calendar.

Weighting

The purpose of weighting to compensate the loss of weight due to degumming/softening. The original weight can be restored by treatment with chemicals such as iron compounds, tin compounds and tannin. This imparts a further handle and better drapability.

Scrooping

Scrooping terminology related to silk defined as peculiar cracking sound produced when fabric is rubbed or squeezed by hand. It is imparted by the treatment using dilute acetic acid or tartaric acid. Also lactic acid at 10 g/l for 5 to 10 min is also recommended.

Crease recovery finishes

Suitable resin pre condensates are used to achieve crease resistant finish. These products are such that they either react with one another or cross link with the fibroin back bone to form water insoluble products under the action of heat and catalyst. Many different types of N- methyl derivatives of nitrogenous compounds are used for this purpose.

Flame retardant

It is generally carried out using borax compound, poly halogenated acids having a cyclic nucleus such as chlorendic acid and urea which having self extinguishing properties.

Oil/dirt repellent finishes

Water and oil repellent finishes are applied in conjugation with each other and the conventional auxiliaries needed for this effect are waxes, metal acid salt and oxides.

Softening

Due to coarser denier of tasar filament; the fabric does not provide comfort to wearer similar to mulberry and eri silk fabric. To impart smoothness; tasar silk fabrics are treated with proteins/nitrogenous compounds (enzymes), silicon compound (sodium silicate) etc.

Developments in tasar silk fabric finishing

Bio-polishing of tasar silk fabrics

Studies revealed that bio- polishing using proteases viz. degummase and protease ‘A’ Amano 2 enhances luster as well as smoothness of tasar silk fabrics (Gulrajani, Agarwal, S. & Agarwal, R, 1999). Three varieties of tasar silk fabrics were used for the bio- polishing treatment i.e. A- unbleached of 75g/m² (warp 86 and weft 82 denier), B- semi bleached 75 g/m² (warp 74 and weft 56
Enzymatic treatment of tasar silk fabrics were carried out using enzyme Protease ‘A’ (Amano 2) of different concentrations (5, 10, 15, 20, 50 & 100 IU/g) and Degummase (5, 10, 15 & 20 IU/g) with material to liquor ratio 1:50 at temperature below 50°C for 90 min duration. In case Degummase, sodium bicarbonate buffer was used to maintain pH at about 9 whereas in case of Protease ‘A’ Amano 2, phosphate buffer was utilized to maintain pH about 7. The treated tasar samples were assessed for weight loss as well as luster with comparison of control samples; the results are depicted in Tables 13 and 14 respectively. It was revealed that the weight loss of unbleached tasar fabrics is more and minimum for fully bleached fabrics due to removal of sericin (gum) from silk filaments. In case of bleached and semi-bleached samples, the weight loss increase in enzyme concentration but no specific trend is noticed for unbleached samples. A marked improvement in the luster of the fabrics after the enzyme treatment was observed in case of both enzymes which indicates the improvement of fabric aesthetic characteristics (Table 13).

### Table- 13: Weight loss of tasar silk fabrics by different enzymatic treatment

<table>
<thead>
<tr>
<th>Name of enzyme</th>
<th>Concentration (IU/g)</th>
<th>Weight loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tasar silk A</td>
</tr>
<tr>
<td>Protease ‘A’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amano 2</td>
<td>Control</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6.72</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>7.31</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>6.33</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>6.35</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>5.70</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>6.61</td>
</tr>
<tr>
<td>Degummase</td>
<td>Control</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>5.91</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>6.60</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>8.31</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>7.13</td>
</tr>
</tbody>
</table>

Courtesy: Gulrajani et al, 1999

### Table- 14: Effect of enzymatic treatment on luster of tasar silk fabrics

<table>
<thead>
<tr>
<th>Fabric sample</th>
<th>Area under the curve (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Degummase 1000L</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
</tr>
<tr>
<td>Tasar silk ‘A’</td>
<td>221</td>
</tr>
<tr>
<td>Tasar silk ‘B’</td>
<td>259</td>
</tr>
<tr>
<td>Tasar silk ‘C’</td>
<td>284</td>
</tr>
</tbody>
</table>

Courtesy: Gulrajani et al, 1999

### Ozone treatment of tasar silk fabrics

Wet pick up characteristics is improved of tasar silk fabric by ozone treatment (Sargunamani & Selvakumar, 2011). Tasar silk fabric of untwisted warp (40 denier) and weft (60 denier), 45 g/m² areal density and 80 ends/cm along with 65 picks/cm was used for the experimental study. 60 g/m³ concentration of ozone with a flow rate of 0.5 liter/min was used for treatment followed by cold washing, soaking (2 g/L neutral soap), cold washing drying, and conditioning (Sargunamani & Selvakumar, 2007). The percentage change for different quality characteristics for tasar silk fabric is given in Table 15.
Table- 15: Percentage change for different quality characteristics for tasar silk fabric

<table>
<thead>
<tr>
<th>Fabric quality characteristics</th>
<th>Percentage change</th>
<th>Type of tasar silk fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow Index</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Breaking strength</td>
<td>6.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Breaking elongation</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Water content</td>
<td>3.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Flexural rigidity</td>
<td>4.4</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Courtesy: Sargunamani & Selvakumar, 2011

Although no significant change of different quality characteristics was noticed but the fabric smoothness is enhanced in case of undegummed and degummed tasar silk fabrics.

Summary

Post cocoon sector of tasar silk industry with the help of CTR&Ti, Ranchi has taken various inventive leads, leading to multi-dimensional approaches by covering cocoon stifling, cocoon cooking (softening), reeling, spinning, weaving, dyeing and product diversification. Now our prospective vision is to enhance the productivity of post cocoon sector by utilization of various effective technologies in integrated manner for sustainable growth of Indian tasar silk industry stakeholders. Though many new technologies have been developed in tasar post cocoon sector, still many developed technologies are yet to percolate in the field and for this, effective plan and strategies have to be chalked out and policy interventions required both at state and central government levels for sustainable growth of Indian tasar silk industry.

Appendix I: Technical features of reeling machines

<table>
<thead>
<tr>
<th>Features</th>
<th>Reeling Machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving arrangement</td>
<td>Motor-pulley, belts, worm wheel &amp; chain</td>
</tr>
<tr>
<td>Motor capacity in HP/Watt</td>
<td>0.25 HP</td>
</tr>
<tr>
<td>No. of ends</td>
<td>4</td>
</tr>
<tr>
<td>Yarn withdrawal system</td>
<td>Horizontal rotational movement of 0.32 m circumference takes up roller followed by twisting by ring and traveler mechanism before winding on bobbin.</td>
</tr>
<tr>
<td>Surface Speed in m/ min</td>
<td>30- 50</td>
</tr>
</tbody>
</table>
### Features

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td>4000</td>
<td>2500</td>
<td>2500</td>
<td>350- 400</td>
<td>150- 180</td>
<td>300- 350</td>
</tr>
</tbody>
</table>

| No. of operators    | 1                                             | 1                   | 1                                             | 1                           | 1                       | 1                     |

| Production (g) for 8 hours (50/70 denier) | 120- 150 | 100- 120 | 250- 300 | 350- 400 | 150- 180 | 300- 350 |

### Appendix II: Technical features of spinning machines

<table>
<thead>
<tr>
<th>Features</th>
<th>Motorized Spinning Machine (MSM)- Ring</th>
<th>Motorized Spinning Machine (MSM)- Flyer</th>
<th>Amber Charkha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving arrangement</td>
<td>Motor-pulley, belts and worm wheel</td>
<td>Motor-pulley, belts and worm wheel</td>
<td>Motor-pulley and belts</td>
</tr>
<tr>
<td>Motor capacity in HP/ Watt</td>
<td>0.25 HP</td>
<td>0.25 HP</td>
<td>Hand Driven</td>
</tr>
<tr>
<td>No. of ends</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Yarn withdrawal system</td>
<td>Horizontal rotational movement of bobbin along with twisting by ring and traveler mechanism before winding.</td>
<td>Horizontal rotational movement of bobbin along with twisting by flyer mechanism before winding.</td>
<td>Vertical rotational movement of bobbin along with twisting by ring and traveler mechanism before winding.</td>
</tr>
<tr>
<td>Spindle speed (RPM)</td>
<td>3500</td>
<td>3000</td>
<td>2500</td>
</tr>
<tr>
<td>No. of operators</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Production (g) for 8 hours (20 Nm*)</td>
<td>150- 200</td>
<td>150- 200</td>
<td>250- 300</td>
</tr>
</tbody>
</table>

*Metric Count

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CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE


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**Tasar Industry By-Product Utilization: An Emerging Field**

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**Introduction**

Silk is considered as the queen of textiles, and in India over thousands of years, it has become an inseparable part of Indian culture and tradition. India is blessed with all varieties of silk (Mulberry, Eri, Tropical Tasar, Temperate Tasar & Muga). Tasar cocoons are the largest among all the silk producing insects in the world (Akai, 2000). Tasar Silk is basically agro-forest practices associated with silkworm insect rearing. During the practice of sericulture, wastes and byproducts are produced, which are not completely utilized. Since tasar silk is associated with a high cost, even the by-products and wastes could have exploited commercially to generate extra income.

Tropical tasar silk is produced only in India. Tasar silk industry provides livelihood to nearly 3.5 lakhs families and having socio-economic relevance along with favour to ecology and environment. It harbours high potential for gainful rural employment and remunerative income to the tribal populace. Some of the key advantages for this industry are availability of the abundant nature grown plants, high market demand of tasar silk: domestic as well as global, profitable traditional occupation that requires least investment to get good return. Rural work-forces can be utilized gainfully etc. In this chapter, by-products such as silkworm litter, pupae, chitin, fiber waste, fibroin and sericin protein are covered with view to their economics, characteristics, and processing for product development and diversification are discussed.

**Tasar host plant and Silk by-products:**

Tasar silk industry spreads over various States of India which provides huge rural employment and livelihood particularly to women and tribes resides in remote area. Tasar culture is an eco-friendly, and promotes as well protects forest plantation. Less investment is required to perform tasar culture. This practices or the production of silk involves the rearing of silkworms to produce cocoons, and then processing those cocoons to make yarn and fabric. During various process of sericulture, various waste/by-products i.e host plant dead bark, litter, flimsy/cut cocoons, cuticle, wings, egg shell, pupae, cooking water and fibre waste were generated.

![Fig-1: Schematic steps for production tasar waste/ by-products during sericulture practices.](image)

- **Host plant materials:** The major constituents of *T. arjuna* in stem bark, root bark, fruits, leaves and seeds. As bark was considered to be the most important constituent from the medicinal point of view, initially reported that the bark contains several phenolic compounds (Amarraj and Gopi, 2017).

- **Litter** is the excreta of silkworm (Fig-2). It has been estimated that about 55% of the ingested leaf is digested and the rest is rejected as waste litter. It has been reported that generally, silkworm excreta contains carbohydrates (4%), protein (57.5%), lipids (30.5) and others (8%) (Patil et al., 2013).
- **Pupa** is the non-feeding, typically inactive life stage between the larva and the adult in holometabolous insects (Fig-2). The biochemical composition of tasar pupae is protein (62-65%), fats (20-25%), carbohydrate (7-8%), crude fiber (6-7%) (CTR&TI, Annual Report, 1989-90).

- **Waste cuticle** was generated during molting and metamorphosis in silkworm, and chitinous in nature (Fig-2).

- In **flimsy cocoons** the shell is loosely spun in layers and has a low silk content (Fig-2). It is due to several factors such diseases, poor nutrition and etc. However, a cut cocoon happens through natural vagaries. Flimsy and cut coons are unfit for reeling and can be used only for hand spinning or as raw material of machine spun silk yarn.

- An adult tasar silkworm has a wingspan of 50 to 90 mm and has a thick bristly body (the adult female is larger than the adult male). The wings are brown/grey-colored and have dark veins extending out to the margins (Fig-2). Major chemical composition is chitin in nature.

- **Tasar Coon cooking water**: In the processing of silk reeling (removal of threads from cocoon), cocoon is cooked in boiling water with other ingredients to dissolve the sericin gum and to locate the loose end of the silk thread (Fig-2). This process huge amount of boiling water has been generated, which contains silk protein sericin.

- **Fibre waste** are generated during reeling process, includes all kinds of unwindable raw silk (Fig-2).
Application of tasar host plant and silk by products

- **Host plant products**: Even though numerous medicinal plants have been explained in the Indian traditional therapeutic system for treatment of several diseases, very few plant products are now a days utilized in the modern medical system to treat most of the diseases, particularly; cardiovascular diseases (CVD), ulcers, diabetes, cough, excessive perspiration, asthma, tumor, inflammation and skin disorders. Among different plants, one of the medicinal plants indigenous to India is *Terminalia arjuna* commonly known as ‘Arjuna’, is being use as a cardiotropic in heart failure, ischemic, cardiomyopathy, atherosclerosis, myocardium necrosis (Amalraj and Gopi. 2017 references are there in). It has been reported that Polyphenols, flavonoids, tannins, triterpenoids, saponins, sterols and minerals are the major constituents of *T. arjuna*. Further, amino acids like tryptophan, tyrosine, histidine and cysteine are also the main ingredients in *T. arjuna* (Amalraj and Gopi. 2017 references are there in).

- **Litter**: On an average a tasar silkworm consumed 137gm of leaf throughout the entire life span (CTR&TI, Annual Report, 1995-96; Das et al., 2016). Further, 55% of the ingested leaf is digested and the rest is rejected as waste silkworm litter (Madan & Basudevan, 1989). In India total Tasar silk production was 2988MT in 2018-19. On an average of 1.85 x 10^3 MT litter has been generated during 2018-19. Such by-products which are presently discarded as waste can be put to better use for financial gains, generation of value-based products and the pollution of the environment can be minimized (Sharma and Madan, 1992).

Sericulture waste (silkworm litter), which is rich in nitrogen, could serve as a good source of organic waste for the growth of various varieties of edible mushrooms was also reported by Madan & Basudevan (1989). Further, utilisation of silkworm litter is an excellent growth medium for mass production of *Bacillus thurengiensis*. It has been observed that the organic treatments (Leaf litter, tasar silkworm excreta or both combined) always gave the improved quality of paddy crop and also increase soil fertility status (Mevada et al., 2018). So, if we can utilize leaf litter and tasar excreta as a source of organic matter for paddy cultivation; one can reduce the considerable amount of chemical fertilizers. It has been observed that tasar silkworm litter contains 0.73% Nitrogen, 0.15% Phosphate and 0.31% Potassium, which can be used as fertilizer for agriculture crops. Further, from silkworm excreta chlorophyll derivatives (CpD-A, -B, -C, and -D) is being extracted, among them CpD-A was extensively studied to clarify its role as a “photosensitizer” for photodynamic therapy (PDT) of tumors in vitro (Lee et al., 1990). Use of such substrates represents a better alternative for disposal and/or recycling wastes and minimizes pollution. The study promises to introduce such raw-materials with added advantages of improving economy by adding value to waste.

- **Pupa**: Pupa is the stage in the life cycle of silkworm in which maximum storage nutrients are available. Approximately 60 thousand tonnes of pupae after reeling are available in India. These protein rich pupae are simply discarded as waste after reeling and low amount is being used as animal feed. Generally, the feed stuffs of animal origins are considered better alternative protein source if fish diets because of their higher content and other superior indispensable amino acids than the plant origins. Several animal protein sources were evaluated to formulate the diets for fish such as poultry by-product meal, meat and bone meal, snail and other invertebrate meal. Main tendency is to partial replacement of fish meal with alternative protein source.

**Nutritional Value of tasar Silkworm Pupae**

Non-conventional sources such as tasar silkworm may constitute a significant biomass. Despite of better biochemical composition pupae comprising proteins (62.65%), fat (20-25%), minerals (7-8%), carbohydrates (7-8%), fats (6-8%) and crude fiber (6-7%). In addition to these, pupae also contain oil (Specific gravity-0.936; Saponification value-169; acid value-48.5, ester value 120.5), which can be utilized in cosmeceutical industry. Silkworm pupae protein has been considered to be a new available source of high-quality protein that contains all the amino acids needed by the human body. In tasar silkworm among 16 amino acids, aspartic acid 15.40%, glycine-12.10%, Glutamic acid 11.00, alanine 10.49 were dominant among other amino acids. In India total production (2018-19) of tasar silk is about 2988 MT. On an average each MT fiber generates 2MT pupal waste. Thus, the surging production of silk worm pupae imposes an environmental concern for their safe disposal. There is
need to find out the ways and means by which these wastes could be transformed into wealth through their possible inclusion either as a fish feed or fish feed ingredient for replacement of basic feed ingredients, poultry feed as well as human consumptions. There is a huge future scope for utilization of tasar pupae in various sectors. For utilization of by-products CTR&TI has taken some initiatives for its exploitation.

**Application of silkworm pupae as animal feed**

- **Human consumption:** One piece of silkworm pupa contains 18 kinds of amino acids, and 8 of them are essential amino acids for human beings (Qian, 1997). The human body needs eight kinds of human essential amino acids absorbed from food which are Ile, Leu, Lys, Met, Phe, Thr, Val, Trp, their contents in silkworms are two times higher than those of pork and four times than those of egg and milk. Pupae protein is a complete protein and the amino acids compositions are with appropriate proportions in line with FAO/WHO standards (Xia and Zhao, 2003; Chen et al., 2002a,b). The silkworms eating habit is very popular in China, thiland, Northeast region of India and etc. Further, silkworm pupae as a source of protein for astronauts also reported by Yang et al., (2009).

- **As fish feed:** Fishmeal (FM) is one of the major feed ingredients used in the preparation of fish feed due its balanced amino acid composition, high digestibility and palatability, which is enhances the uptake, digestion and absorption of nutrients in fish. However, the steady decline in catches of wild fish and the increased demand for quality aquaculture feed resulted in a rapid decrease in the availability of fishmeal. Indian major carp fingerlings fed with SWP, showed significant growth than control animals fed with mustard oil cake and rice bran was also reported by Bose and Majumdar, (1990). Common carp (Cyprinus carpio) fingerlings fed with pupal meal, showed significant growth difference than fishes fed with mustard oil cake and rice bran [Chakrabarthy et al., 1973]. Raw SWP incorporated at 60% in feed improved growth rate in Deccan Mahseer. Sawhney [Shakoori et al., 2015] observed that feed prepared with SWP for masheer (Tor putitora) fingerlings showed a significant growth, it was suggested that silkworm pupae was cheaper and could improve the economic returns of the fish farmers by partial replacement of fishmeal in rearing of masheer fingerlings. Tropical catfish (Clarias batrachus) revealed that dried SWP are a better source of protein in the diet providing satisfactory growth (Watanabe et al., 1991). A diet containing 100% SWP meal yielded better growth rate, feed conversion and protein utilization in catfish (Clarias batrachus) fingerlings [Harib et al., 1994] and African catfish (Clarias gariepinus) fingerlings [Oso et al., 2014]. Lee et al [1983] assessed the response of dietary substitution of fishmeal with SWP meal, promote meal, meat and bone meal and/or their combination on the performance of juvenile Olive flounder Paralichthys olivaceus. They observed that dietary substitution of fishmeal with 10% SWP and 10% SWP + 20% promote meal (PM) had no detrimental effect on growth and feed utilization of Olive flounder. The ornamental fish Silver barb (Barbomyrus gonionotus) fingerlings performed better than control, when fed with a diet replacing fish meal with 38% SWP. Thus, it could be concluded that ornamental fish species can be successfully reared with SWP, replacing fish meal upto 30-40%, without affecting the growth performance. 

  - As poultry feed: Poultry meat contributes about 37% to the total animal protein consumption in India (Ahmed and Islam, 1990) and so broiler industry is gaining importance due to increasing demand of animal protein. The conventional source of protein used in poultry diet is fishmeal and Soyabean which costly. Hence, the producers are facing difficulty on account of availability and prices of feed ingredients. Silkworm pupae meal is a valuable cheaper alternate protein source that can be used in poultry feeding. Tasar silkworm pupae meal feed enhance the growth of poultry chicks reported by Dutta et al., (2012).

<table>
<thead>
<tr>
<th>Silkworm species</th>
<th>Application</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. mori</td>
<td>Silkworm protein 30Kc6 is one of the members of the 30K family proteins that transport lipids and inhibit cell apoptosis in the insect and mammalian cells</td>
<td>Kim et al., 2003</td>
</tr>
<tr>
<td>A. mylitta</td>
<td>Free radical scavenging potential</td>
<td>Jena et al., 2014</td>
</tr>
<tr>
<td>B. mori</td>
<td>As a bioreactor</td>
<td>Jian et al., 2006</td>
</tr>
<tr>
<td>B. mori</td>
<td>Effectively reduce triglycerides, prevent and treat fatty livers , protect the liver after consumption of alcohols, improve the blood quality and the environment within the blood vessel, effectively soften the blood vessels, lower blood pressure, and prevent arteriosclerosis and thrombosis.</td>
<td>Harris et al., 1997</td>
</tr>
</tbody>
</table>
Silkworm species | Application | References
--- | --- | ---
*B. mori* | Pupal oil prevents prostate diseases, improving the functions of insulin-producing beta cells, restoring the fatty acid desaturase activity of cells in diabetic patients and has marked hypoglycaemic effect free from reoccurrence | Gavia et al., 2003

*B. mori* | Silkworm pupae intake and/or swimming exercise training activates fat metabolism to reduce the concentration of serum lipids. Thus, the silkworm pupae intake leads to a reduction in fat storage, this is considered to be effective in the inhibition of the metabolic syndrome. | Ryu 2014

Silkworm Pupae as an ideal source for growth medium

Dead pupa and larva of silkworms as nutrition medium for the growing of different fungi including *Cordyceps*, which produces cordycepin. Cordycepin is a nucleic acid metabolic substance, it functions to inhibit DNA and RNA biosynthesis, and is thought to induce positive cell death in abnormal cells (malignant tumors). Further, cordycepin has been consistently shown to inhibit cancer cells such as Ehrlich ascite tumors, melanoma, lung cancer, acute lymphatic leukemia (Ogawa et al., 2018 *references are therein*). Regarding the use cordycepin as a new drug for acute leukemia and HIV, clinical experiments in the final certification stage are still underway (Ogawa et al., 2018 *references are therein*).

Silkworm cuticle and wings are cheap sources of Chitin:

Insect silk is considered to be a cuticular substance (Richards, 1953), and the adult wing is described as largely cuticular. Insect cuticles form an exoskeleton that exhibits only a limited capacity to keep pace with body growth because it is a more or less rigid structure due to the presence of chitin and sclerotized proteins. Chitin, a polymer of N-acetyl-β-D-glucosamine is a major component of the insect cuticle. Solids NMR and gravimetric analysis revealed that the chitin content constitutes up to 40% of the exuvial dry mass depending on the insect species and varies considerably with the different cuticle types even in a single organism (Kramer et al., 1995). Chitin and chitosan have immense applications in various fields such as food industry, cosmetics, agriculture, water treatment, biomedicine, textile, biotechnology, paper industry; wound healing agents, etc., (Shahidi, 1994; Xu et al., 1996; Chen et al., 2002). Chitin and chitosan as an ideal material for wound dressing, and...
waste water treatment (Sridhari et al. 2000). Chitin and chitosan have potential applications in hair care, skin care, shampoos, hair colorants, styling lotions, hair sprays and hair tonics (Rinaudo 2006). Chitin and chitosan are used in toothpaste, mouthwashes and chewing gum. Chitin is also used as dental filler (Dutta et al. 2004). Chitosan act as chelating agent and heavy metals trapper (Khor & Lim 2003). Chitosan N-benzyl sulphonate derivatives are used as sorbents for the removal of metal ions in acidic medium and chitosan can also be used to remove the color from dye house effluents as reported by Weltrowski et al. (1996). Chitin and chitosan are also found to be used effectively to remove arsenic from contaminated drinking water as well as to remove petroleum products from waste water (Saha & Sarkar 2013). Chitosan is non-toxic therefore it is used in food industry. Microcrystalline chitin (MCC) is used as flavouring and colouring agent, shelf life as well as dietary fibre in baked food (Jianglian & Shaoying 2013). Chitin treated seeds (wheat) have shown the growth accelerating and growth enhancing effects. The addition of chitin to the soil reduces the root knot worm infestations and supression of fungal pathogens (Dutta et al. 2004). Tissue engineering is the development and manipulation of laboratory-grown cells, tissues or organs that would replace or support the function of defective or injured parts of the body (Khor & Lim 2003, Vankatesam & Kim 2010).

**Cocoonase**

Cocoonase is an enzyme which is secreted during pupal-adult emergence of tasar silkworm to soften the cocoon shell. It is documented that cocoonase is a trypsin-like serine protease and it removes the sericin by proteolytic cleavage. Studies have shown that cocoonase specifically cleaves sericin without affecting the fibroin. Thus, the degumming with natural sericin enhances the luster and softens the texture of tasar silk. Cocoonase enzyme is one of the un-utilized by-product of silk industry. Cocoonase of various commercially exploited *A. mylitta* ecoraces such as Modal, Sukinda, Laria and Raily have not been characterized so far. To obtain the silk from cocoon shell through softening of cocoons and silk degumming, several methodologies have been developed by different investigators. But still as a ruling practice, softening of tasar cocoon is being performed in highly alkaline solution using soap, soda, H2O2, alkali materials etc. which adversely affects the natural color and softness as well as organic nature of tasar silk. Hence, there is an urgent need to develop enzyme based method for cocoon softening. To proceed in this direction, it is needed to identify most active cocoonase/analogue from sericigenous insects. It is known that the silk produced by *A. mylitta* is a complex fabric formed by fibroin protein surrounded by sericin protein. Fibroin (core of filament) and sericin (outer coating) account for about 75% and 25%, respectively. The specific target of cocoonase is cocoon-shell-glue-protein sericin. It clearly indicates that active cocoonase can be utilized potentially for cocoon softening and in biomedical field due to its proteolytic activity.
Presently, CTR&TI has developed a simple method for collection of cocoonase that is suitable for large-scale cocoonase collection easily and effectively. In addition, preliminary studies on efficacy of cocoonase in cocoon softening have been carried out, which indicates silk surface modifications. Keeping aforesaid view in mind, it is needed to identify the most active cocoonase through molecular characterisation in order to see the enzyme activity pattern and use the most active cocoonase in future studies. In addition, cocoonase obtained from different sources such as natural and recombinant methods need to be characterized and compared with native cocoonase and its analogues. Therefore, rationale of the project will lead to identify the most active cocoonase among available cocoonase for its future application in silk processing such as degumming, surface modification and retention of natural color, soft texture, luster and organic nature of tasar silk. Such technologies will have immense use in post cocoon sector of tasar silk industry. It will lead to give value addition to tasar silk in the benefit of silk producers. More importantly, un-utilized cocoonase will be utilized productively.

Cocoonase enzyme was purified by using size exclusion chromatography and the MW around 25-26 kDa. Further, RNA isolation, cDNA preparation and PCR amplification and characterizations (SEM, Element analysis, FTIR, TGA/TDA, CHNS, DSC is being performed for further applications.

Silk protein sericin
Silk sericin and fibroin are natural macromolecular proteins derived from the cocoon of silkworm and are synthesized in the silkworm’s posterior and middle silk gland, respectively (Tomita et al., 2007). Sericin envelops the fibroin fiber with successive adhesive layers and ensures the cohesion of the cocoons by gluing the silk threads together. Fibroin accounts for about 75-80% of the total cocoon shell weight, with the sericin and non-sericin components contributing 15-16% and 5-8%, respectively. The carbohydrate, salt and wax making up the non-sericin component act as a water repellent for the cocoon. In silk industry, the sericin layer is removed fully from the silk fiber and discarded in the wastewater, since low cost and high efficiency methods for its recovery and utilization are lacking.

Therefore, most research is focused on purification, structure and function analysis of the sericin proteins in the sericin layer of the cocoon. At present, it was found sericin have various properties such as moisture absorption, antioxidant, anti-elastase and anti-tyrosinase activity (Fabiani et al., 1996; Shen et al., 1998; Wu et al., 2007, Chlapanidas et al., 2013). Because of these properties, sericin is being used many fields such as cosmetic biomaterials and textiles. The commercial value of sericin is high depending upon the purity of proteins.

The tasar yarn production in India is 2988 MT, and processing of the raw silk produces approximately about 300 tons of sericin. Therefore, the recovery of sericin from cocoon cooking waste waters would provide economical benefits. It would also significantly reduce the environmental impact of silk production processes and help sustainable development. Further, the extraction process is important which will determine the economic value of the sericin extraction method and its properties. Sericin has been extracted by various methods, such as high pressure and high temperature
techniques, acid or alkaline solutions, or enzyme extraction process. It has been observed that extraction method significantly affects the biochemical activities of silk proteins (Kurioka et al. 2004). Isolation and purification of a protein is a challenging task, taking into account both economical and technical aspects. The most used protein purification techniques are based on chromatographic processes that are very specific and allow obtaining very pure fractions. However, these processes present low yields, and are difficult to scale-up, increasing final product costs (Golunski et al., 2011). Therefore, economic and effective downstream processing methods are required for cost minimization. In this regard, there is need to optimize the overall process scheme towards the simplest and cheapest one. Considering the high market value of sericin and the severe environmental pollution caused by these silk effluents, it is clear that sericin recovery from silk effluents will provide significant economical and environmental benefits. Silk sericin, which is known to have moisturizing properties (Padamwar et al., 2005), protect against UV exposure and oxidation (Dash et al., 2008), aid in the wound-healing process (Aramwit & Sangcacul, 2007), and protect against cell death (Takahashi et al., 2003). Many products use this protein for various applications in the textile industry cosmeceutical products and food supplements (Zhang, 2002).

**Sericin Properties and Biomedical Applications**

The physicochemical properties and molecular heterogeneity of sericin influence on their functionality and these characteristics are directly influenced by extraction methods. Studies of biocompatibility and antioxidant potential, both in vitro and in vivo, have demonstrated that sericin is immunologically inert and have proven the safety and open wide possibility of applications of sericin in biomedicine, such as the food and cosmetic industries, supplement in the culture media, cryopreservation, wound healing, anti-tumour effect, various metabolic effects in organic systems, and indicate your use in tissue engineering and as a vehicle for drug delivery.

**Immunological Response**

Silk proteins have been used in the biomedical application due to its inert immunological responses. Panilaitis et al. (2003) reported silk fibres and soluble sericin are immunologically inert in culture of murine macrophage cells. Similarly, Sapru et al., (2017) reported *A. mylitta* sericin used for preparation of matrices causes no significant immune response of inflammatory cytokines and hemolysis of human blood. The sericin can be considered as a biocompatible protein, since it presents very low immunogenicity (Lamboni, 2015), and it can be utilized in various biomedical areas, as listed in sequence.

**Antioxidant.**

Dietary antioxidants have been of great interest, especially due to the findings on the effect of free radicals in the body, which can have serious consequences if their products are not neutralized by an efficient antioxidant system (Sorg, 2004). In vitro study by Jena et al., (2018ab) showed, that sericin having DPPH scavenging potential, inhibits lipid peroxidation and tyrosinase activity. Aramwit et al. (2010) demonstrated that the antityrosinase activity of sericin was greater when obtained from cocoons with pigments. Similarly, Dash et al. (2008) analysed the antioxidant and photo protector potential of sericin from *Antheraea mylitta*, against ultraviolet light B (UVB) in irradiated human keratinocytes. The antioxidant properties of sericin could be related to your high serine and threonine content, whose hydroxylgroups’ act chelating trace elements such as copper and iron (Kato et al., 1998). Further, Devi et al. (2011), in their study about sericin from *Antheraea assamensis*, and Prasong that compared the silk of *Samia ricini* with *B. mori*, concluded that the presence of polyphenols and flavonoids in sericin is responsible for its antioxidant role.

**Cosmetic application:**

The use of sericin in cosmetic formulation, such as creams and shampoos, leads to an increase in hydration, elasticity, cleaning with less irritation, and anti-aging and anti-wrinkle effects (2011) and also prevents nails from chapping and brittleness (Yamada et al., 2001).
Substrate for Culture Media and Cryopreservation:
Cell cultures are often the first way to test new discoveries or technologies, particularly in research on cell therapy and regenerative medicine (Terada et al. 2005). Many cell lines BSA (bovine serum albumin) was used as medium supplementation. Sericin with higher molecular weight, 50 to 200 kDa, also stimulates cell proliferation (Terada et al. 2005). Morikawa et al. (2009) used sercin or FBS (fetal bovine serum) as medium for rat islets culture and there were no observed significant differences in survival and insulin secretion for 14 days. Considering its antioxidant potential and the ability to eliminate free radicals, Kumar et al. (2015) used different sericin concentrations (0.25, 0.5, 1.5, and 2%) as a cryoprotectant. The supplementation of sercin in 0.25, 0.5, and 1% increased the spermatic motility of buffalo spermatozoa.

Wound Healing:
Sericin, operates in stimulating the migration, proliferation, and production of collagen (Aramwit and Sangcakul, 2007; Aramwit et al., 2009). In a clinical study, Aramwit et al. (2013) used the standard antibiotic cream (silver sulfadiazine) with 8% sercin for the treatment of open wounds and showed that sercin accelerated wounds closure. Similarly low molecular weight (30kDa) of sericin accelerated the healing process on corneal damage (Nagai et al. 2009).

Metabolic Effects:
Considering its antioxidant potential and its hydrophilic characteristic, the use of sercin in the gastrointestinal tract has been investigated by Sasaki et al. (2000). The rats fed with the diet supplemented with 3% of sercin increases absorption of zinc (41%), iron (41%), magnesium (21%), and calcium ions (17%), improving the bioavailability of these elements.

Anti-obesity:
Obesity, a worldwide epidemic, is characterized by an excessive body fat increase, accompanied by a number of comorbidities (Wilding, 2006). Okazaki et al. (2010) examined the effect of sercin on lipid and carbohydrate metabolism in mice fed with a high-fat diet. The addition of 4% of sercin on the diet for 5 weeks didn’t alter body weight, food consumption, and fat weight but reduced serum concentrations of cholesterol, triglycerides, free fatty acids, phospholipids, very low-density lipoproteins (VLDL), and low-density lipoprotein (LDL).

Tissue Engineering:
The tissue engineering normally uses biomaterials that are a suitable scaffold that possesses the specific structure of the tissue it replaces and must be capable in turn of being replaced in time via the ingress of new cells (Hunag and Fu, 2010; Mikos and Temenoff, 2000). Mandal et al. (2009) fabricated a sericin/gelatin blended 2D films and 3D scaffolds using sercin from A. mylitta cocoon and glutaraldehyde as crosslinking agent. The sericin/gelatin combination structure possessed uniform pore distribution and homogeneous morphology, improved mechanical strength, and have high swellability. Nayak et al. (2012) constructed 3D porous sericin matrices using genipin as cross linked and used chitosan matrices as control, with the objective of developing an effective tissue engineered skin replacement.

Drug Delivery:
An optimal effect of the drug is achieved when its release profile is both reliable and controlled and, eventually, a delivery system that is compatible and presents an adjustable morphology is necessary for that to occur, as the silk proteins (Hardy et al., 2008). Sericin can be used for drug delivery due to its chemical reactivity that enable the easy binding of other molecules and pH responsiveness, allowing the fabrication of small materials (Lamboni et al., 2015).

Silk protein fibroin
Silk is obtained from silkworm, comprising two proteins sericin and fibroin. In Sanskrit, silk is popularly known as “Kitta-Sutram.” The word “kitta” means worm, and “sutram” means thread. About 1 million tons of fresh weight cocoons produced worldwide and approximately 40,000 tons of dry cocoons are generated, that produce around 80,000 tons of fiber waste. India produced 2988 MT of tasar silk during 2017-18, leaving behind approximately 600-900MT (as reported silk waste contributes nearly 20-30%) of waste fibroin. The fiber protein secreted from the posterior-region of the silk gland, functions as a core filament of the fiber. Presently, fibroin is underutilized and mostly discarded as a fiber waste. It has been reported that fibroin if utilized properly has wide range of functions varying from useful food element, applications in cosmetic industry and in medical field. The most significant feature of the amino acid composition of silk fibroins is the high concentrations of glycine, alanine, and serine.
• **Electrospun fibers**: Electrospinning silk solution is a favoured processing methodology for producing nanometer- to micron-scale fibers that result in a high degree of available surface area for use in creating scaffolds for tissue engineering and regenerative medicine purposes (Jin et al., 2002). In brief, electrospun materials are produced by applying a strong electric field between a polymer solution and a collection device (Soffer et al., 2008). In the case of silk fibroin this has been readily accomplished using both organic solvents and aqueous based processes (Jin et al., 2002; Sukigara et al., 2003). The electrospun silk fibers have found utility in producing scaffolds for a variety of biological applications such as growing cardiac, bone, nerve, and skin tissue (Jin et al., 2004a; Schneider et al., 2009; Soffer et al., 2008; Wharram et al., 2010; Zhang et al., 2012b). Human endothelial and smooth muscle cells were successfully grown on these scaffolds, and mechanical testing demonstrated the ability of the constructs to withstand arterial pressures and tensile properties comparable to native vessels (Soffer, 2006).

• **Silk fibroin films**: Silk films offer the most immediate potential utility for a variety of biomedical applications. Silk film material properties like biodegradation, mechanical properties, chemistry, and optical properties may be readily modulated for a desired application (Arai et al., 2004; Horan et al., 2005; Karageorgiou and Meinel, 2004; Lawrence et al., 2008a; Li et al., 2003; Motta et al., 2002). In addition, fibroin films have been shown to support a multitude of cell types including a variety of cell lines from epithelium, endothelium, and fibroblasts, which allows for the adaptation to a variety of tissue systems (Arai et al., 2004; Meinel et al., 2005; Panilaitis et al., 2003).

• **Sponge scaffolds**: Regenerated silk fibroin solution may also be processed to produce three dimensional sponge scaffolds for use in tissue engineering (Mandal et al., 2012; Nazarov et al., 2004). Sponge scaffolds provide a framework of interconnected pores with a high amount of surface area within a defined three dimensional volume, which allows for cell attachment and tissue in growth scaffolds were highly biocompatible and encouraged tissue ingrowth to varying extents depending on porosity and solvent processing conditions (i.e., aqueous or organic solvent) (Wang et al., 2008b).

• **Hydrogels**: Hydrogels offer a tissue culture system where interconnected filaments aggregate and stabilize water within a confined volume to produce a gel. Gelation of the silk fibroin solution can be controlled by temperature, calcium ion concentration, pH, and polymer blending with materials like Polyethylene Oxide (PEO) to produce a hydrogel (Kim et al., 2004). Results indicated that gelation time decreased with an increase in protein concentration, decrease in pH, increase in temperature, addition of calcium, and addition of PEO. Gelation was linked to beta-sheet secondary structure formation throughout the hydrogel structure (Kim et al., 2004; Matsumoto et al., 2006).

• **Microspheres**: Microspheres describe a general class of particulates that have diameters in the high nanometer to micron range and assume a spherical shape, which can be used for a variety of biomedical purposes such as controlled drug release applications. Silk microspheres can be readily produced by mixing regenerated fibroin solution with lipid vesicles that act as templates to efficiently load biological molecules in an active form for sustained release (Wang et al., 2007b).

**Utilization of Cut cocoons in Art Craft:**

The eye catching art of cocoon craft is one of the interesting utility of cocoon and silk waste in generating self employment and additional revenue. The garlands, flower vases, pen stands, dolls, wall hangings, clocks, bouquets, lamp stands and greeting cards are being prepared using the waste cocoons and silk. The silk leather, a paint containing silk powder is used to decorate wood, plastics, steel and fabrics are also used in different parts of world.

![Fig-10: Various art and crafts prepared from tasar waste cocoons](image-url)
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Fundamentals of Seri-Extension Education
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Introduction

Extension is a programme and a process of helping village people to help themselves, increase their production and to raise their general standard of living. Extension is a two-way channel; it brings scientific information to the village people, and also takes the problems of the village people to the scientific institutions for solution. Extension education is a non-formal education to bring desirable changes in knowledge, skills, attitudes and understanding of the rural people to improve their social, economic and psychological status. Sericulture Extension may be defined as a special branch of Extension Education which deals with the economic and social aspects of people engaged in or associated with Sericulture. Seri-extension workers who act like catalyst translate the latest research developments to the farmers in easy language for their better understanding and adoption.

Scope of Seri-Extension: The following nine areas of programme emphasis indicate the scope of Sericultural Extension work:

1. Efficiency in sericultural production.
2. Efficiency in marketing, distribution and utilization.
3. Conservation, development and use of natural resources.
4. Management on the farm and in the home.
5. Family living.
6. Youth development.
7. Leadership development.
8. Community development.

CONCEPTS OF SERI-EXTENSION

There are three main concepts in Extension. They are 1. Education 2. Extension Education Process 3. Salesmanship

1. Education: Aim of education is to bring desirable changes in human behavior.
   a. Change in knowledge Eg: Extension worker can improve knowledge of seri farmers through trainings.
   b. Change in skills (Mental and physical) Eg: Calculation of fertilizer dosages, pesticide dosages etc., Skills of women farmers on reeling can be improved by demonstrations etc.
   c. Change in attitude. Eg: Attitude of farmers can be changed through exposure visits.

2. Extension Educational Process The concept of Extension Education Process was developed by Dr. J. Paul Leagans (Fig 1). The Education starts with study of present situation and identification of problems. Based on the problems identified, solutions are found out and objectives are formulated. In the third phase, plan of work is taught on how to attain the objectives, then the entire process is evaluated and tested whether formulated objectives are attained or not and in the final stage reconsideration about the unattained objectives and unaddressed problems is done. Any Extension work undertaken in villages follows the same path.

Fig 1: Extension Education Process

2. Salesmanship Extension worker is primarily engaged in the “selling” of ideas like salesman selling products.

Principles of Seri-Extension Education

1. Cater the interests and needs of the people. Eg: Extension work is successful if it is according to people’s needs-Demonstration on improved technologies of tasar sericulture instead of old technologies which already farmers are aware of.

2. Grass-roots principle: Extension agent should start with basics and then the advanced topics.

3. Principle of cultural differences: Cultural differences exist between Extension worker and farmers. Among farmers they vary from region to region. Eg: A demonstration on tasar insect pupal recipes should not be conducted in a village where insects are not eaten.

4. Principle of cooperation and participation: Farmers participation and co-operation is of fundamental importance for the success. Eg: Success stories of sericulture farmers should be shared to encourage new farmers.

5. Principle of learning by doing: Eg: Demonstration on reeling machines is very effective than lecture method.

6. Adaptability principle in the use of extension teaching methods: An extension agent should carry different teaching aids based on the demand and use them as and when required. Eg:
Power point presentations, posters, charts, live samples etc.

7. Principle of leadership: Farmers gets easily convinced about latest technology if it is adopted by a local leader than taught by an extension worker. Extension worker should first convince him by his teachings and with help of local leader he should disseminate the technologies to the rest for better results.

8. Whole family principle: The family is the basic unit of any society. All the members of the family have to be developed equally by involving all of them. Tasar sericulture is a family farming.

9. Principle of satisfaction: Take feedback and response of the trainees of the training for assessment and improvement. Farmer’s satisfaction is of prime importance.

EXTENSION PROGRAMME PLANNING

Extension Programme Planning is the process of analysing existing situation, problems critically finding out solutions to these problems, prioritizing and selecting the relevant solutions based on local needs and resources and finally preparing a written statement indicating the situation, objectives, problems and solutions with cooperation from all the stakeholders. The function of extension programme planning is to provide a clear guide – a blue print or a plan useful to extension workers in conducting an ongoing educational programme.

Programme Development Process

The first 4 -steps constitute the Extension Programme and the next 5 steps, the Annual plan of work (See the figure)

1. Collection and analysis of data: All extension workers must possess the basic farm and family information for preparing sound family, village and block plans.

2. Determination of objectives in consultation with farmers.

3. Definition of problems:
   a. Problems solved by the villagers with their own resources like improving the yields by adopting improved practices, digging compost pits, vermicompost etc.
   b. Problems that need community cooperation without involving much outside assistance like construction of village roads or deepening of irrigation tank etc. by volunteering efforts.
   c. Problems that require outside assistance on account of high cost involved and the technical knowledge needed like purchase of plant protection equipment, construction of school building etc.

4. Finding solutions to problems: The extension workers should advise the villagers and guide them in finding the solutions to the problems. The solutions offered should be practicable, economical and should result in satisfaction and learning.

5. Selecting problems and determining priorities: All the problems cannot be tackled simultaneously even though solutions are known for them. Extension workers have to play a great role in prioritizing the problems.

6. Preparing a plan of action or Annual plan of work: A plan of work is listing of activities by which objectives already decided upon are to be achieved.

7. Carrying out the plan strictly.

8. Continuous checking and evaluation of results: Record each activity for future reference and evaluation. Frequent monitoring and assessment have to be done. Each future programme should be based on results of the previous one. Systematic evaluation provide information about the effectiveness of various methods used and various steps taken for executing the programme.

9. Review of progress and projection of plans: At the end of each cycle of programme planning process as a periodical review of situation and reconsideration of plan for setting up revised objectives should be done in view of the changes in social and economic levels of people. Acceptable programmes may be expanded to the neighbouring areas. Research should be conducted to find out the reasons of failure of the programmes. All developmental programmes are tools for doing more work that is effective.

PARTICIPATORY RURAL APPRAISAL (PRA)

Through this method, extension agent collects the village information for effective planning and implementation of various programmes.

Characteristics of PRA:
1. Carried out in the field and has an informal character.
3. Continuous interaction of research team with villagers to develop methods and procedures together.
4. Short, intensive periods of field work alternated with analytical workshops/discussions by the team.
5. Carefully selected methods/ techniques used by the team.
6. Flexible use of the methods.
7. Learning from & listening too, people is utmost important.
8. PRA can usefully supplement the long survey methods.
9. PRA has purpose and is a means to an end.
10. Optical ignorance and diversity of analysis.

**Some PRA techniques employed in sericulture**

1. **Handing over the stick**: Encourage local people to share their experiences that helps in planning. Do not try to impose your interests, opinions, values or common sense during the process.

2. **Do-it-yourself**: Farmers should be encouraged to participate in the practical sessions or live demonstrations of techniques eg. Preparation of Jeevan Sudha or use of dupratex etc. Do-it-yourself prompts changes in attitude of farmers.

3. **Participatory Mapping / Modelling**: Village or block map can be drawn using colours or Rangoli powder to visualize the resources in the village like forests, lands, rivers, pastures, watersheds etc. on the ground or a cement floor.

4. **Transact walk**: A transact walk is a kind of exploratory walk which is under taken by team along with the villagers to observe and record every send in minute detail of a particular area.

5. **Time line**: Historical events in the village are discussed with elderly people and a time line is constructed to understand the village past record and future course of action can be designed. Eg. Disease and pest incidence, severity and management options followed.

6. **Matrix Ranking**: Assigning value to different criteria and ranking them. Eg. Preferential use of egg washing methods by various stalk-holders can be identified.

7. **Seasonality/ Seasonal Analysis/ Seasonal calendars**: These helps to understand the month wise/ season wise incidences of various abiotic and biotic abnormalities in particular area. This helps us to understand pest, disease problems in a particular season, employment availability, labour migration, rainfall patterns, labour wages, labour availability, water availability, market prices, crops, food consumption, diseases to crops, livestock, human beings etc.

8. **Venn diagram**: Various inside and outside agencies or institutions help for the upliftment of the rural people. The Venn diagram shows the diagram of a village and its institutions. The institutions are depicted in different size circles, the bigger the size, the more is its importance to village, and the institutions are depicted at various distances. It is also called Chapathii diagram.Eg. Role of various agencies in upliftment of tasar like CTR&TI, DoS, PPC’s, PRADHAN etc.

**Strengths of PRA**

- Community forum
- Local solutions
- Adequate data
- Systematized participation
- Accelerated changes already in motion.
- Builds self-confidence.

**Limitations**:

- PRA did not provide final absolute answers.
- PRA had a relatively small sample size and it could not provide statistically accurate data.
- PRA should be seen as complementing these more conventional approaches.
- The best possibility for the people may not be necessarily the absolute best.

**TRANSFER OF TECHNOLOGY**

ToT is defined as a process by which the recommended practices produced by the research and development agencies are transmitted through extension agents to producers. Effective ToT takes place when the maximum number of potential adopters understand, accept and actually put into practice the major part of an item of a technology with the minimum time lag and with the maximum possible material and financial benefits.

**Problems faced in ToT**
Service Delivery mechanism still fragmented, it must be organized and coordinated to deliver common message to the client system. This will make the delivery system effective and credible rather than confusing to the receiving client system.

The delivery channel like local government unit or councils should be responsive and supportive rather than as perceived to be difficult to work with, it being a political authority.

The receiving client system should be organized and coordinated are rather than disorganized having too many proliferated organization.

The capability extension workers to integrate the usable technology for the total farm system should be obtained through continuous training on farming system.

The low educational levels of farmers have to be matched with simple understandable project message printed in the local dialect. More method and result demonstration have to be undertaken in the farmers field.

COMMUNITY DEVELOPMENT PROGRAMME (CDP)
Community Development is a movement designed to promote better living for the whole community with the active participation of people and on the initiative of the community.

Objectives of Community Development Programme
1. To increase the sericulture production
2. Community and integrated development
3. The extension of the new scientific knowledge
4. Development of co-operative organizations
5. Construction of roads.
6. To increase the adult education and primary education
7. Facility for entertainment.
9. To inspire the youth for the development programme.

Some examples
1. Reutilization of virgin and waste lands, repairing of old wells, digging new wells and provision of major/minor irrigation facilities, watershed etc
2. Repair of old roads, construction of new roads and arrangement for transportation and communication facilities.
3. Attempting to provide safe drinking water by repairing old wells or constructing new ones.
4. Social welfare activities include rehabilitation of old, disabled and destitute, provision for better housing, organisation of sports, promotion of cultural activities etc.

RURAL DEVELOPMENT
Rural Development is an improvement in the living standards of the masses of low income population residing in rural areas and making the process self-sustaining. It is carried out through various schemes and programmes by involving various agencies and organizations, and above all, the local people themselves.

Objectives of Rural Development
- Providing goods and services in terms of social and economic infrastructure
- Increasing the income of every rural family on a self-sustaining basis
- Creation of additional employment opportunities in rural areas.

Problems in Rural Development
1. Inadequate communication channels especially Mass Media in rural areas
2. Limitation of funds and staff for training the farmers
3. As a traditional society with old ways and practices does not want to take risk unless they see the results.
4. In an illiterate traditional society real leadership could not come forward.
5. Preaching to rural people and educating them in new techniques require specialized skilled workers. It is very expensive to produce such workers
6. Communities and individuals differ in their needs as their circumstances change.
7. Organizational constraints
8. Vaguely framed objectives of Organization.

Some important schemes for Rural Development launched by Government of India are

<table>
<thead>
<tr>
<th>S. No</th>
<th>Scheme</th>
<th>Salient Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pradhan Mantri Gram SadakYojana</td>
<td>Launched on 25 December 2000 by then Prime Minister Atal Bihari Vajpayee, the scheme aims at enhancing rural road connectivity.</td>
</tr>
<tr>
<td>2</td>
<td>Deen Dayal Upadhaya Grameen Kaushalya Yojana:</td>
<td>Launched on 25th September 2014, a part of National Livelihood Mission, has the objectives of catering to the career aspirations of the rural youth and adding diversity to the income of rural families.</td>
</tr>
<tr>
<td>3</td>
<td>Swarnjayanti Gram Swarozgar Yojana (SGSY)/ National Rural Livelihood Mission</td>
<td>Launched in 2011. Also known as Ajeevika, this scheme aims at empowering women self-help model across the country. Under this scheme, the government provides a loan of 3 lakh rupees at an interest rate of 7% which can be reduced to 4% at the time of repayment. It also helped in increasing the household income by improving access to financial services.</td>
</tr>
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</table>
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

<table>
<thead>
<tr>
<th>S. No</th>
<th>Scheme</th>
<th>Salient Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Prime Minister Rural Development Fellowship Scheme:</td>
<td>It has dual goals of providing short-term support to the district administration in the underdeveloped and remote areas of the country and develop competent and committed leaders and facilitators who can serve as a resource for a long-term.</td>
</tr>
<tr>
<td>5</td>
<td>Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA):</td>
<td>As per the National Rural Employment Guarantee Act (NREGA) of 2005, 100 days of employment is guaranteed to any rural household adult who is willing to do unskilled manual work in a financial year. The Act addresses the working people and their fundamental right to live life with dignity. If a person does not get a job within 15 days, he is eligible for getting unemployment allowance. National Rural Employment Guarantee also highlights the importance of basic right to work. Amendments have been introduced to this act to minimize corruption in the scheme.</td>
</tr>
<tr>
<td>6</td>
<td>Sampoorna Gramin Rozgar Yojana (SGRY):</td>
<td>Launched in 2001 to provide employment to the poor. It also aimed at providing food to people in areas who live below the poverty line and improving their nutritional levels. Other objectives of this Yojana were to provide social and economic assets to the people living in rural areas. The scheme did not include the employment of contractors or middlemen.</td>
</tr>
<tr>
<td>7</td>
<td>Sarv Siksha Abhiyan</td>
<td>Launched in 2000. It is an attempt to provide an opportunity to all children between 6 and 14 years of age to get free education which is also a basic fundamental right. The state and the central government share the expenses of this project.</td>
</tr>
<tr>
<td>8</td>
<td>Samsad Adarsh Gram Yojana (SAGY):</td>
<td>Launched in 2014 by the Government of India in which each Member of Parliament will take the responsibility of three villages and look after the personal, human, social, environmental and economic development of the villages. This would substantially improve the standard of living as well as the quality of life in the villages.</td>
</tr>
<tr>
<td>9</td>
<td>Pradhan Mantri Awaas Yojana (Gramin)/ Indira Awas Yojana:</td>
<td>To provide housing to rural poor people in India. The goal of this scheme is to provide home to all citizens till 2022. The cost of constructing the houses will be shared by the centre and the state. The scheme has been implemented in rural areas throughout India, except in Delhi and Chandigarh. Houses developed under this scheme will have basic amenities such as toilet, electricity connection, drinking water connection, LPG connection etc. The allotted houses will be jointly under the name of husband and wife.</td>
</tr>
<tr>
<td>10</td>
<td>Antyodaya Anna Yojana (AAY):</td>
<td>Launched in 2000, the Antyodaya Anna Yojana aimed at providing food grains to around 2 crore people at subsidised rates. As per the scheme Below Poverty Line (BPL) families were provided 35 kgs of food grains. Rice was provided at the rate of Rs 3/kg and wheat at the rate of Rs 2/kg. The scheme was first launched in Rajasthan but has now been implemented in all Indian states.</td>
</tr>
<tr>
<td>11</td>
<td>Provision of Urban Amenities In Rural Areas (PURA)</td>
<td>PURA is a strategy for Rural Development in India which was proposed by former President APJ Abdul Kalam in his book Target 3 billion. PURA proposes that urban infrastructure and services should be provided in rural areas to create opportunities outside the cities. This will also prevent the migration of youth from the rural areas to urban areas. The Central Government has been running PURA programs in various states since its launch in 2004.</td>
</tr>
</tbody>
</table>

SELF-HELP CONCEPT

A self-help group (SHG) is a village-based financial intermediary usually composed of 10–20 local women. SHG are small and economically homogenous affinity groups of rural poor, they are voluntarily coming together for achieving the following.

- To save small amount of money regularly.
- To mutually agree to contribute a common fund.
- To meet their emergency needs.
- To have collective decision making.
- To solve conflicts through collective leadership mutual discussion.
- To provide collateral free loan with terms decided by the group at the market driven rates.

Distinguishing features of SHG

- An SHG normally consists of not less than five persons (with a maximum of twenty) of similar economic outlook and social status.
- It promotes objectives like economic improvement and raising...
resources for development and freedom from exploitation.

- It has its own by-laws for the proper functioning of the group as well as for the observance of certain rules by the group members and regulations concerning membership.
- The form of such a group could be mostly on an informal basis (unregistered).
- Periodical meetings of members are held for solving their problems (economic and social) and they collect fixed savings of the members.
- The savings of members are kept with a bank in the name of group and authorized representative of the group operates the bank account.

**Functions of SHG**

- Enabling members to become self-reliant and self-dependent.
- Providing a forum for members for discussing their social and economic problems.
- Providing a platform for members for exchange of idea.
- Developing and encouraging the decision-making capacity of members.
- Fostering a spirit of mutual help and cooperation among members.
- Providing organizational strength to members.
- Providing literacy and increasing general awareness among members, and
- Promoting numerically and equipping the poor with basic skills required for understanding monetary transactions.

**COMMUNICATION**

It is the process of transferring/sharing an idea, skill or attitude from one person to another accurately and satisfactorily. Communication is meant to influence the behavior of people exposed. A good extension worker should be a good communicator. It is the flow of information from communicator to receiver.

**Types of Communication**

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<tr>
<th>Sl.No</th>
<th>Type</th>
<th>Feature</th>
<th>Example</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>According to Organizational Structure</td>
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<td></td>
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<tr>
<td>1</td>
<td>Formal Communication</td>
<td>It is a two-way communication. Flows through official route.</td>
<td>Director instructs his subordinates</td>
</tr>
<tr>
<td>2</td>
<td>Informal or Grapevine Communication</td>
<td>It is a quick vehicle for message. No official route/hierarchy.</td>
<td>Simple gesture, smile, rumors etc.</td>
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<tr>
<td></td>
<td>According to direction of flow</td>
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<td></td>
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<tr>
<td>1</td>
<td>Downward communication:</td>
<td>From higher authority to lower information flows.</td>
<td>Written orders, reports, manuals, booklets etc.</td>
</tr>
<tr>
<td>2</td>
<td>Upward communication</td>
<td>Information flows from lower to higher level. Helps to understand the ground reality.</td>
<td>Feedback, assessment report etc.</td>
</tr>
<tr>
<td>3</td>
<td>Horizontal communication</td>
<td>Information flows between the two persons of same level.</td>
<td>Personal discussion</td>
</tr>
<tr>
<td></td>
<td>According to the way of expression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Verbal or oral communication</td>
<td>Communication through words uttered from mouth</td>
<td>Speeches</td>
</tr>
<tr>
<td>2</td>
<td>Written Communication</td>
<td>Communication through written words</td>
<td>Text book, bulletins etc.</td>
</tr>
<tr>
<td>3</td>
<td>Non – Verbal communication</td>
<td>Communication through symbols, colors, signs etc.</td>
<td>Traffic signals, smile, anger etc</td>
</tr>
</tbody>
</table>

**Classification of Extension Methods**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Individual contacts</td>
<td>Farm and home visits, Office calls, Telephone calls, Personal letters etc.</td>
</tr>
<tr>
<td>2</td>
<td>Group contacts</td>
<td>Meetings, conferences, workshops, demonstrations etc.</td>
</tr>
<tr>
<td>3</td>
<td>Mass contacts</td>
<td>Bulletins, pamphlets, mass media (TV, Radio etc), social media (Facebook, Whatsapp, etc) etc.</td>
</tr>
</tbody>
</table>

Some extension methods used in Tasar Culture.

1. **FIELD TRIAL**: It is a method by which the new technique
developed at the research institute is evaluated/trialed at local conditions for its suitability. It is done to build confidence between extension worker and stake holders/farmers for its applicability and feasibility. Eg. use of Pebrine Visualization Technology (PVT) instead of traditional methods during mother moth examination.

Advantages:
- Shortfalls of the technology can be improved to suit the local conditions.
- Confidence building among the stakeholders.
- Spread of the new technology quickly.
- Feasibility studies can be done.

Limitations:
- Selection of farmers/stakeholders can be biased for getting the positive results.
- Difficult to suit the technology to all the situations.
- Conclusions are may be biased.
- Failure of the technology may incur the financial losses to farmer.

2. RESULT DEMONSTRATION: It is a method of disseminating an already established technology or a fact at the research station among the farmers, followed by district trials and observation plots.

Principles of Result Demonstrations:
- Seeing is believing.
- Uniform advantage under similar conditions.

Objectives:
- Determination of feasibility and utility of a recommended practice under rural conditions.
- Establishment of confidence between both the farmer and the extension worker.

Procedure or Technique:
1. Analyze situation and determine need
2. Decide upon specific purpose
3. Plan the result demonstration
4. Select demonstrators
5. Select the plot
6. Start the demonstration
7. Supervise the demonstration
8. Complete the demonstration
9. Follow-up

Advantages:
1. Practicality of recommendation is entrusted in the extension worker.
2. Local proof of benefits is available.
3. Farmers establish confidence in extension worker and his recommendations.
5. Helps to discover local leaders.

Limitations:
1. Tedious process and time taking on the part of extension worker.
2. Expensive.
3. Good demonstrators are difficult to find.
4. Teachings value frequently may be rendered ineffective due to abiotic and biotic factors.
5. Most convincing stage of demonstration is observed by only few people.

3. Method Demonstration: Method demonstration is a short time demonstration given by the extension worker himself or a trained leader for the purpose of teaching a skill to a group. The members of the group repeat the demonstration in the presence of the others. (eg. Demonstration of Nursery Techniques for raising Tasar Food Plants, Prunning and Pollarding, Mother Moth Examination, reeling etc.). This helps to fix the process in the minds of the audience and increases confidence in their ability to master the technique. The method demonstration is the oldest form of teaching long before language was developed, men taught their children how to hunt, how to cultivate etc., through method demonstration.
4. **Field Trips / Conducted Tours / Study Tours/Exposure Visits:** It is a method in which a group of interested farmers accompanied and guided by an extension worker, goes on a tour to see and gain first-hand knowledge of improved practices in their natural setting. This method satisfies and motivates the farmers who are not convinced and believe in the said concept.

**Purpose:**
1. To stimulate interest, conviction and action in respect of a specific practice, e.g., preparation of vermicompost.
2. To impress the group about the feasibility and utility of a series of related practices, e.g., proper preservation of farm yard manure, rural composting, urban composting and green manuring which are all included under the item “development of local manurial resources”.
3. To encourage the farmers by showing the accomplishments in other villages.
4. In short, to help people to recognize problems, to develop interest, generate discussion and to promote action.

5. **FARMER FIELD SCHOOL (FFS)** Farmers Field School (FFS) is a participatory extension group method a form of adult education, which evolved from the concept that farmers learn optimally from field observation and experimentation. Simple experimentation helps farmers further improve their understanding of functional relationships (e.g. pest-natural enemy population dynamics and crop damage-yield relationships). In this cyclical learning process, farmers develop the expertise that enables them to make their own crop management decisions. FFS is a place where farmers undergo a field oriented, discovery based training that enable them to become field experts and be able to grow a healthy crop. FFS is an effective extension tool, which can be used for empowering the farming community, developing self-confidence, increase in social and human capital and promote better living through awareness of Health Environmental concerns (issues on sustainable sericulture).

**Concept of FFS**
- FFS consists of group of people with a common interests who get together on a regular basis to study the “how and why” of a particular topic. The topic covered can vary considerably from IPM, organic sericulture, to income generating activities such as reeling and weaving.
- FFS is participatory extension methodology recognizes the need to involve farmers in technology development and transfer.
- FFS emphasizes building on the farmers’ ability to experiment and draw conclusions and it empowers farmers to improve their socio-economic conditions.
- FFS is basically “School without walls”
- It operates with the principle of non-formal education (non-formal learner centred educational process) and most of the session and contents are based on the adult learning principle.
- In FFS, farmers learn about sustainable agricultural practices on the field. The fields belong to an experiment station or to a community. There, farmers meet regularly for the duration of an entire cropping season. They learn by observing what is happening on the field, by considering what they have observed in small groups, and by hands-on management of the field from pre-planting to harvest.

**Objectives of FFS**
- Empowering farmers on decision-making
- Educate farmers with science based learning
- To make farmers the experts and evaluators instead of passive acceptors of technology
- Confidence building with field interaction and discovery based learning
- Encourage experimentation with skill orientation
6. **CAMPAIGNS:** It is an intensive teaching activity undertaken at an opportune time for a brief period; focusing attention in a concerted manner on a particular problem, with a view to stimulate the widest possible interest in a community, block or other geographical area. Campaigns are launched only after a recommended practice has been found acceptable to the people as a result of other extension methods like method or result demonstrations etc. Co-ordinated communication and educational efforts are often called as campaigns.

7. **EXHIBITIONS:** Exhibitions are the mass communication media. These inform, educate and entertain the masses. They are of educational value but the maintenance of the exhibition is relatively a costly and difficult venture. However, careful planning and execution can achieve the objectives of educating the viewers who learn a lot from these exhibitions. Exhibition is a planned display of models, specimens, charts, posters etc. presented to public view for instruction, judging in a competition, advertising or entertainment. Exhibition method is suitable for reaching all types of people. Exhibitions may be held in the village, block, sub-division, district, and state, national and international levels. Though an exhibition is organized around a major theme, other related themes and unrelated items like entertainment may also be included. Field days, farmers’ fairs, kisan melas, Institutions and other various organizations in which field visit, training programmes etc are combined with exhibition are effective and popular. Exhibitions may also be organised by taking advantage of local fairs and festivals. In fixing dates for exhibition, the weather condition and farm operations may be kept in view.

8. **KISAN MELAS:**

Kisan Mela is an organized educational activity for involving and educating farmers by bringing together the farmers, scientists, extension workers, input agencies, developmental departments and non-governmental agencies on agriculture or allied aspects at a Research Station or an important educational centre, where the farmers can see, interact and gain firsthand knowledge about the latest technologies and developments in sericulture and allied aspects.

9. **RADIO:** It is a medium for mass communication, a tool for giving information and entertainment. This medium is cosmopolite in approach and is suitable for communication to millions of people widely dispersed and situated in remote areas. Radio is suitable for creating general awareness amongst the people, help change their attitude and reinforce learning. People with no education or very little education and those who are not in a position to attend extension programmes personally, can take advantage of this medium and can build up knowledge and skill. It reaches very large number of people at very low cost (cheapest medium). AIR broadcasts various programmes on tasar culture in Jharkhand, Odisha etc.

10. **TELEVISION:** Television is an electronic audio-visual medium which provides pictures with synchronized sound. Television is one of the most important mass media for dissemination of information in rural areas. This medium is cosmopolite in approach and can be used to create instant mass awareness. Television has unique advantages over other mass media. While it provides words with pictures and sound effects like...
the movies, it scores over the latter by its high intimacy and reaches the largest number of people at the shortest possible time. The visual in it has the advantage over the radio.

Doordarshan, eTV Jharkhand etc telecast the tasar activities and conduct the live sessions with the Scientists.

Table: Calendar of extension activities at various centres of CTR&TI

<table>
<thead>
<tr>
<th>Activities</th>
<th>Monthly distribution of extension programmes</th>
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<tbody>
<tr>
<td></td>
<td>May</td>
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<tr>
<td>Unit RSRS Bhimtal</td>
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<tr>
<td>Awareness programme</td>
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<tr>
<td>Farmer’s day/ Field day</td>
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<tr>
<td>Kisan Mela</td>
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<tr>
<td>Unit REC Palampur</td>
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<td>Awareness programme</td>
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<td>Farmer’s day/ Field day</td>
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<td>Kisan Mela</td>
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<td>Unit RSRS Dumka</td>
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<td>Farmer’s day/ Field day</td>
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<td>Unit RSRS Baripada</td>
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<td>Unit RSRS Bhandara</td>
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<td>RSRS Warangal</td>
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<td>REC Kapistha</td>
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<td>REC Seoni- Champa</td>
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<td>REC Chakradharpur</td>
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<td>Kisan Mela</td>
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</table>

**INFORMATION SOURCES**

1. **Internet**: The internet is an electronic infrastructure and it is the window to the information superhighway. The internet offers access to data, graphics, sound, software, text and people through a variety of services and tools for communication and data exchange. Internet in India was available for some time through ERNET which was made available for commercial use by VSNL (VIDESHI SANCHAR NIGAM LIMITED) since 1995. Internet is a network of networks connected through different types of communication channel to communicate.
irrespective of distance and time.

**Limitations of internet**
1. Requirement of continuous power supply
2. Failure in Network
3. Lack of knowledge for the people on use of internet
4. Selecting the required information in the net is difficult from the volumes of information
5. Sometimes it misleads the individual for wrong selection of information
6. Internet services are not available in rural areas hence farmers needs to travel to the urban areas to utilize the facility

2. **Regional Units:** Regional units of CTR&TI, Ranchi viz. Regional Sericultural Research Station (RSRS) and Research Extension Centre (REC) have been established in all the major Tasar growing states of India. These units serve as the site for providing help and information to the farmers to cater their region specific needs.

3. **Cyber Extension:** Information is an important resource in modern sericulture. The development of computers and improvements in telecommunication offers farmers and extension workers, many new opportunities to obtain technical and economic information quickly and use it effectively for their decision making.

4. **Libraries:** The Library facilities at CTR&TI, Ranchi and BTSSO, Bilaspur are repositories of Journals and Books covering all the aspects of Tasar Sericulture.

5. Information bulletins from CSB, Bengaluru.

**I.T. INITIATIVES BY CSB**

- **CSB** concentrated on software development using contemporary technologies and networking of various Research Institutes under its control for smooth exchange of information such as availability of raw material, market trends etc.

- ‘SMS service’ through mobile phone on day-to-day market rates of Silk and Cocoons for the use by the farmers and other stakeholders of the industry. Both PUSH and PULL SMS services are in operation. All the registered 3615 farmers are receiving SMS messages on daily basis.

- SERI-5K database has been designed and developed to maintain and manage Bivoltine cluster farmers throughout the country.

- SILKS Portal: Sericulture Information Linkages and Knowledge System portal has been developed in association with North Eastern Space Application Centre, Dept. of Space by capturing geographical images through satellite and used for analysis and selection of potential areas for promoting Sericulture activities in those areas. Multi lingual, multi district data is being updated regularly.

- **AEBAS:** Aadhaar enabled bio-metric attendance system is being implemented at Central Silk Board. Over 4,550 employees including farm workers have registered into the attendance portal. 179 units where 5 or more officials are working are in the Process of procuring and implementing AEBAS devices.

- **Video Conference:** CSB has fully fledged Video Conference facility at CSB Complex, Bangalore, CSR&TI, Mysore & Berhampore, CTR&TI, Ranchi, CMER&TI, Lahdoigarh and RO, New Delhi. Linking CSR&TI, Pampore, through Video Conference is in advanced stage of implementation.

**Application of ICT in sericulture & knowledge management**

- Accessing databases and journals will be easy.
- Sericulture extension and technology transfer
- Creating new business opportunities for sericulture farmers
- Developing appropriate sericultural planning, coordination and implementation
- Sericulture knowledge management:
  1. Building of national level sericultural database
  2. Developing database of traditional knowledge
  3. Mapping of potential sericulture areas through satellite based GIS

**DIFFUSION AND ADOPTION OF INNOVATIONS**

An extension worker’s job does not end with merely informing the farmers about improved practices, he should ensure practical application (by the farmers) of the result of research and field trials.

**Adoption:** It is a decision to make full use of an innovation as a best course of action available.

**Adoption Process:** According to Rogers, “Adoption Process is the mental process through which an individual pass from hearing about an innovation to final adoption”. Adoption process occurs at individual level

**Diffusion:** It is a process by which an innovation is communicated through certain channels over time among the members of the social system. It is special type of communication in that the messages are concerned with new ideas.

**Diffusion Process:** Diffusion process is the spread of a new idea from its source of invention or creation to its ultimate users or adopters’.

**Innovation:** An innovation is an idea, practice or object that is
perceived as new by an individual or other unit of adoption.

**Perception:** Perception is an activity through which an individual becomes aware of objects around oneself and of events taking place.

5 stages of the adoption process, which received worldwide attention. They are 1) Awareness 2) Interest 3) Evaluation 4) Trial and 5) Adoption.

**Innovation Decision Process**

Rogers & Shoemaker have used the term Innovation – Decision Process in preference to Adoption process.

**Definition:** According to Rogers (1983, 1995) the innovation – decision process is the process through which an individual passes from first knowledge of an innovation, to forming an attitude towards the innovation, to a decision to adopt or reject, to implementation and use of the new idea, and to confirmation of this decision. This process consists of a series of actions and choices over time through which an individual or an organization evaluates a new idea and decides whether or not to incorporate the new idea into the ongoing system. This behaviour consists essentially of dealing with the uncertainty that is inherently involved in deciding about a new alternative to those previously in existence. Innovation – decision is a process that occurs over time and is conceptualized to have five stages.

1. **Knowledge stage:** It occurs when an individual or other decision making unit is exposed to an innovation’s existence and gains some understanding of how it functions. Knowledge function is mainly cognitive or knowing. A need can motivate an individual to seek information about an innovation and the knowledge of an innovation may develop the need.

   Questions such as ‘what is the innovation?’ ‘How does it work?’ and ‘Why does it work?’ are the main concerns of an individual about an innovation. The first of these three types of knowledge, awareness-knowledge, is information that an innovation exists. Awareness-knowledge then motivates an individual to seek ‘how-to-knowledge’ and ‘principles’ knowledge. This type of information-seeking is concentrated at the knowledge stage, but it may also occur at the persuasion and decision stages.

   How-to knowledge consists of information necessary to use an innovation properly. The adopter must understand what quantity of an innovation to secure, how to use it correctly, and so on. When an adequate level of how-to-knowledge is not obtained prior to the trial and adoption of an innovation, rejection and discontinuance are likely to result. Principles-knowledge consists of information dealing with the functioning principles underlying how the innovation works. Examples of principles-knowledge are: The notion of germ theory, which underlies the functioning of vaccinations and the biology of plant growth, which underlies fertilizer innovations. It is usually possible to adopt an innovation without principle knowledge, but the danger of misusing the new idea is greater, and discontinuance may result.

2. **Persuasion stage:** Persuasion occurs when an individual or some other decision making unit forms a favorable or unfavorable attitude towards the innovation. Persuasion function is mainly affective or related to feeling. At this stage, the individual becomes more psychologically involved with the innovation and actively seeks information about it. The individual perceives the attributes of innovation, which is conditioned by one’s personality and social system norms, and develops a general idea about the innovation.

   In developing a favorable attitude towards the innovation, an individual may mentally apply the new idea to the present or anticipated future situation before deciding whether or not to try it. There may be two levels of attitudes, a specific attitude towards the innovation, and a general attitude towards change. A previous positive experience helps the process and a previous negative experience i.e. a failure develops resistance to future new ideas.

3. **Decision stage:** Decision occurs when an individual engages in activities that lead to a choice to adopt or reject the innovation. The individual puts the innovation to a small-scale trial in own situation. Considering its relative advantage, risk involved and many other related factors like availability of market, need for the family etc., the individual decides whether to adopt or reject the innovation. For some individuals and for some innovations, the trial of a new idea by a peer like themselves can substitute at least in part., for their own trial of an innovation. This ‘trial by others’ provides a kind of vicarious (realized through other’s experience) trial for an individual. Extension agents often seek to speed up the innovation-process for individuals by organizing demonstrations and field days of a new idea in a social system. These are quite effective in influencing adoption by individuals.

4. **Implementation stage.** Implementation occurs when an individual or other decision making unit puts an innovation into use. At this stage the individual is generally concerned with where to get the innovation, how to use it and what operational problems will be faced and how these could be solved. Implementation may involve changes in management of the enterprise and/or modification in the innovation, to suit more closely to the specific needs of the particular person who adopts it.

   Re-invention often occurs at the implementation stage. Re-invention is defined as the degree to which an innovation is changed or modified by a user in the process of its adoption and implementation. Recognition of the existence of Re-invention brings into focus a different view of adoption behavior – instead of simply accepting or rejecting an innovation as a fixed idea, potential adopters on many occasions are active participants in the adoption and diffusion process, to give their own unique meaning to the innovation as it
is applied in their local context. Adoption of an innovation is thus a process of social construction.

5. **Confirmation stage**: Confirmation occurs when an individual seeks reinforcement of an innovation decision already been made, or reverses a previous decision to adopt or reject the innovation if exposed to conflicting messages about the innovation. The decision to adopt or reject an innovation is not a terminal act. Human mind is in a dynamic state and an individual constantly evaluates situation. If the individual perceives that the innovation is giving satisfactory results he will continue otherwise may reject it. Reversal of the decision after adoption or rejection of an innovation may, take place at a later state. At the confirmation stage, extension agents have the additional responsibility of providing supporting messages to individuals who have previously adopted. Extension agents often assume that once adoption is secured, it will continue. But there is no assurance against discontinuance, because negative messages about an innovation circulate via interpersonal networks in most client systems.

**Adopter Categories and their Characteristics:**

1. **Innovators (Venturesome)**: They are venturesome and first people to adopt a new idea, much ahead of other members in the community. They are generally very few in number and not more than one or two in a community. They may deviate from the social norm and may be viewed as deviants by others.
   - **Characteristics:**
     - Have larger farms
     - High net worth and risk capital.
     - Willing to take risks.
     - Usually not past middle age.
     - Generally well educated.
     - Have respect and prestige in progressive communities but not in conservative type of communities
     - Mentally alert and actively seeking new ideas.
     - Their sphere of influence and activity often goes beyond the community boundaries.
     - They have many formal and informal contacts outside the immediate locality.
     - They often bypass the local extension worker in getting information from the originating sources and may learn about new things even before he does. They sometimes manage to get samples of seeds or chemicals even before they are released for public use.
     - They subscribe to many farm magazines and specialised publications
     - Other farmers may watch the innovators and know what they are doing but the innovators are not generally named by other farmers as “neighbours and friends” to whom they go for information.

2. **Early adopters (Respectful)**: They are localite and are a more integrated part of the community. Because early adopters are not too far ahead, the average members of the community can comprehend their activities relating to adoption of the innovation. They have more opinion leadership and potential adopters look to them for advice and information about the innovation. They try to maintain adoption leadership to keep up their prestige in the community. (1) Younger than who have a slower adoption rate, but not necessarily younger than the innovators (2) They are not the persons who test the untried ideas but they are quickest to use tried ideas in their own situations (3) Have large farms. (4) Higher education than those who adopt more slowly,( 5) High income (6) They participate more in the formal activities of the community. (7) They also participate more in government programmes. (8) This group usually furnishes a disproportionate amount of the formal leadership (elected positions) in the community. (7) They read papers and farm journals and receive more bulletins than people who adopt later. (10) They may be regarded as “community adoption leaders.”

3. **Early Majority (Deliberate and local adoption leaders)**: They adopt new ideas just before the average members of the community. They are neither very early not relatively late to adopt an innovation. They are deliberate and take longer time to make the decision to adopt, in comparison to the innovators and early adopters. 1. Slightly above average in age, education and farming experience. 2. They take a few more farm Journals and bulletins than the average. 3. They have medium high social and economic status. 4. Less active in formal groups than early adopters, but more active than those adopting later. 5. In many cases, they are not formal leaders in the associations in the community, but they are active in those associations. 6. They actively participate in extension programmes like training, demonstration, kisanmela, study tour etc. 7. They are most likely to be informal leaders, but not holders of elected positions. 8. Have more limited resources than early adopters and innovators, and so cannot afford to make hasty or poor decisions. 9. They associate mainly with people of their own community. 10. They value highly the opinions their neighbours and friends hold about them for, this is their main source of status and prestige. 11. They are mostly mentioned as “neighbours and friends” from whom the majority of farmers seek information.

4. **Late Majority (skeptical and later adopters)**: They are cautious and skeptical, and adopt new ideas just after the average members of the community. They adopt mainly because people have already adopted the innovation and are getting the benefit out of it.
   1. Those in this group have less education and are older than the early majority.
   2. They form the major part of formal organisational membership, although they participate less in such formal groups.
Factors Influencing Adoption Process:

I. Social factors: Community standards and social relationships provide the general framework wherein the process of change occurs, and they account for the differences between one community (or group) and another.

- **Social values**: In some groups and communities, people place a higher value upon material gains and money than they do in others. In some other groups, changes in farming are encouraged and expected; prestige is attached to the adoption of new ideas and techniques. In others, more value is placed upon tradition and little freedom is allowed for the individual to deviate from the group's pattern in adopting innovations. The extent to which changes are adopted depends on the values and expectations of the group and upon the extent to which the individual is expected to conform. Where there is great emphasis on maintaining traditions and values rooted in the past, change occurs more slowly. On the other hand, where emphasis is upon individualism and personal success, change occurs more rapidly.

- **Local Leadership**: The acceptance of change is also influenced by the nature of leadership and control in the group or community. In some communities, none would accept a new idea, unless and until one man (the leader) in the community is sold on the idea. Once sold, he would influence all farmers in the community to accept it. In such situations, it is important to identify and use such influential leaders. The influence of informal leaders is likely to be greater where neighbor, kinship and community ties are the strongest.

- **Social contacts**: The nature and extent of social contact within, and outside the community is important in the diffusion of new ideas and techniques, as indicated below:

  - **Nature of Social contacts**: The presence of organizations whose objectives include the promotion of changes will aid directly and indirectly in the diffusion process. On the other hand, where social contacts are primarily through kinship, visiting and informal activities, there may be greater resistance to change.

  - **Extent of Social contacts**: The extent to which social contacts are confined to the immediate locality is a factor. The broader the social orientation of the people, the more likely they are to accept new ideas. Only a few individuals may have such outside contacts, but they may be in a position to influence their neighbours. Local orientation on the part of the majority is not necessarily a limiting factor on the diffusion of new ideas, so long as a few leaders have outside contacts.

  - **Social distances**: The social distances associated with wide status differences are also a factor in the diffusion of farm information through inter-personal channels. For example, tenant farmers in some areas may not get ideas from the large farm owners because of their lack of contact. Also small-scale farmers may fail to communicate with large-scale farmers. Rigid class structure impairs inter-class communication of ideas.

II. Personal Factors: Why some people adopt new ideas and practices more quickly than others relates in part to the individual himself.

- **Age**: Elderly farmers seem to be somewhat less inclined to adopt new practices than younger ones. (However, the findings of several Indian studies do not support the existence of a negative relationship between age and adoption).

- **Education**: More than eight years schooling is almost always associated with higher adoption rates than lesser amounts.

- **Psychological characteristics**: Exposure to reliable sources of farm information may create a state of rationality which in turn predisposes. A mentally flexible person has higher adoption rates than one with mental rigidity. Some people are found to be more prone to change than others.

- **Values and attitudes (cultural characteristics)**: Values found to be positively related to farm practice adoption rates are: a desire by farmers and their wives for a high school or college education for their children, a high emphasis on science and material comfort, and also wide contacts within and beyond the community. A high emphasis on traditionalism, isolationism and security e.g., owning farm free of debt has been found to be negatively associated with adoption of improved practices.

III. Situational Factors: Reasons why farmers adopt farm practices more quickly at one time than another relate to the situation in which they find themselves when alternative courses of action become known.

- **The Nature of the Practice**: The speed with which adoption will take place is partly dependent on the nature of practice
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

Divisibility (Trialability):

- Those practices which cost little seem to be adopted more rapidly than those which are more expensive.

Innovation: Change involving new technique or operation

Change in total enterprise: e. g., from agriculture crop to tasar farming.

Cost: Those practices which cost little seem to be adopted more rapidly than those which are more expensive.

Net returns: Those practices which yield, the greatest marginal returns per rupee invested, and in the shortest time seem to be adopted most readily. The above two characteristics viz., cost and net returns are also referred to as “relative advantage” or “Profitability”.

Compatibility: Is the degree to which an innovation is consistent with existing values and past experiences of the adopters. An idea that is not compatible with the cultural norms of a social system will not be adopted so rapidly as an idea that is compatible e. g., the lack of compatibility of beef norms of a social system will not be adopted so rapidly as an innovation that is compatible e. g., the lack of compatibility of beef production with cultural values in India.

Divisibility (Trialability): Is the degree to which an innovation may be tried on a limited basis. New ideas that can be tried on a small scale or on the installment plan will generally be adopted more rapidly than innovations that are not divisible. e. g., new seeds or fertilizers can be tried on a small scale, but new machinery or a thing like cow dung gas plant cannot be so tried.

Communicability (Observability): Is the degree to which the results of an innovation may be diffused to others. The results of some practices are easily observed (e. g., application of nitrogenous fertilizer to plants), while the results of some innovations are not easily observed (e. g., pre-treatment of seeds, or soil conservation measures).

- Farm Income: High farm income nearly always is associated with high adoption levels.
- Size of Farm: Size of farm is nearly always positively related to the adoption of new farm practices.
- Tenure Status: Adoption scores are usually higher for owner cultivators than for tenant cultivators.
- Sources of Farm Information Used: The number of sources used or the number of contacts with information sources is positively related to adoption rates. A high positive correlation is particularly evident with the use of such sources as Government agencies. High dependence on relatives and friends as sources of information is usually negatively associated with the adoption of new farm practices.

Level of Living: Since successful farm practice adoption is instrumental in providing the means for supporting a higher level of living, a positive correlation between the two would be expected and is generally found.

SERICULTURE EXTENSION SYSTEM

Organizational extension streams of CSB and DoS

Regional Sericulture Research Stations (RSRS) and Research Extension Centers established in different Tasar growing states are organizations of Central Silk Board through which Extension programmes are organized for tasar farmers of respective states to enhance their knowledge and skill in Nursery raising, host plant maintenance, tasar rearing, grainage and Post Cocoon activities. Pilot Project Centers are the units of Directorate of Sericulture (DoS) which are involved in all the activities of Tasar culture at the field level. Tasar farmers are identified in the operational area of PPCs and are trained in all the activities of tasar culture under technical guidance of RSRSs and RECs of CSB working in the area. Pilot Project Officer (PPO) is head/in charge of the Pilot Project Center (PPC).

Training

The R&D institutions of CSB, spread across the country, covering all activities on the silk value-chain pertaining to all the four silk sub-sectors, are intensively involved in training, skill seeding and skill enhancement on a sustainable basis. From the year 2015-16 onwards, CSB’s capacity building and training initiatives have been restructured under the following five heads to be implemented and monitored by the Capacity Building & Training Division:

A. Skill Training & Enterprise Development Programmes (STEP): Under this category a variety of short-term training modules focusing on Entrepreneurship development, In-house and industry Resource Development, Specialized Overseas Training, popularization of sericulture technologies, lab to land technology demonstration programmes, training impact assessment surveys etc have been planned to be taken up. Some of the popular programmes under this component are:

B. Establishment of Sericulture Resource Centre (SRC): These training cum facilitation centres are established in select Mulberry Bivoltine & Vanya clusters with a unit cost of Rs.3.50 lakhs to act as an important link between Extension Centres of R&D labs and the beneficiaries. The purpose of these SRCs is: technology demonstration, skill enhancement, one-stop shop for Seri-inputs, doubt clarification and problem resolution at cluster level itself.

Guidelines for Implementation of SRC

- The SRC will act as important link between extension centers of R&D labs and beneficiaries, for technology demonstration, skill enhancement, one-stop shop for seri-inputs, doubt
clarification and problem resolution.

- SRC should be established in Vanya cluster and its owner can be a progressive farmer/NGO/Society with at least five years of sericulture experience.
- Each SRC is expected to conduct at least 10 batches of training and exposure programmes with a minimum of 10 to 15 farmers in a year.
- The allocated budget for each SRC is Rs.3.50 lakh towards CAPEX and Rs. 0.50 lakh towards operational cost for two years i.e. 2015-16 and 2016-17 (Rs. 25000 for each year@ Rs. 2500 for each of 10 batches mandated in a year).
- The distribution of CAPEX is: Rs. 1.50 lakh for construction of training shed (150 Sq.ft.) and Rs. 1.50 lakh towards procurement of training materials - TV, projector, white board, basic furniture etc. The construction amount will be released in installment looking into the progress of construction.
- The training equipment needed for SRC for which an amount of Rs. 1.50 lakh is allocated can be procured by the institute following laid down procedures.
- The training/demonstration under SRC should be for one day and the SRC owner himself can conduct the programme or he can take support of CSB/DOS technical personnel for the same.
- The progress report of the functioning of SRC should be reported on monthly report format and Director of the institute will monitor it regularly.

C. **Capacity Building & Training by R&D Institutes of CSB:**

In addition to conducting structured long-term training programme (Post Graduate Diploma in Sericulture) the R&D institutes of CSB will also conduct technology-based training both for farmers and other stakeholders besides organizing Krishi Melas, Farmer’s day, farmer’s interaction workshops etc. for empowering the framers and other industry stakeholders.

D. **Capacity Building in Seed Sector:** Silkworm seed is the most critical sector that drives the entire silk value chain. The quality of seed determines the quality of industry output. Therefore addressing the capacity building and training needs of this sector is of paramount importance. It is proposed to conduct a variety of training programmes to cover industry stakeholders like – Pvt. Silkworm Seed Producers, Adopted Seed Rearers, Managers and work force attached to Govt. owned grainages.

E. **Information, Education and Communication (IEC):** IEC is meant for supporting Capacity Building and Training initiatives by popularizing recommended technologies through Brochures, pamphlets, handouts, booklets etc. This component also propose to produce technology based instructional videos, study materials and documentary films to show case the industry.

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<table>
<thead>
<tr>
<th>Program</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab to Land Program</td>
<td>The Lab to Land Programme was launched by the ICAR in 1979.</td>
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<tr>
<td></td>
<td>The overall objective of the programme is to improve the economic condition of the small and marginal farmers and landless agricultural labourers particularly scheduled castes and scheduled tribes, by transfer of improved technology developed by agricultural universities, research institutes, etc.</td>
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<td></td>
<td>The lab to land programme would enable the participating organizations to intensify their own extension efforts.</td>
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<td></td>
<td>This would also provide opportunity to the scientists to come in close contact with the farming communities, which would enable them to understand their problems and uncover the barriers to rapid transfer of technology.</td>
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<td></td>
<td>During this process, suitable package of technology practices would also be evolved or modified so that they are best suited to the local farming condition.</td>
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<td>Major thrust in the programme is to introduce the most appropriate technologies that would help in diversification of labour use and introduction of supplementary sources of income.</td>
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</table>

**Implications in Sericulture.**

- In sericulture, after completion of research projects at research institutes, outcome of the research is inducted in the field through Extension units (RSRS and REC) of Central Silk Board.
- New technology developed at Institute level is introduced to farmers in the field through ‘Field trial’ and ‘Demonstration of Technology’ under lab to land programme.
Program Features

Institute-Village Linkage Programme (IVLP)

- The Indian Council of Agricultural Research launched an innovative technology assessment and refinement programme, called Institute-Village Linkage Programme (IVLP) during 1995.
- The concept is based on participatory mode, ensuring greater linkage between scientist and farmer in a bottom up approach.
- IVLP is a participatory approach of scientists, extension staff and stakeholders (farmers) of the target area and mainly aimed at assessing the problems hindering productivity of the area and developing a technology package which is acceptable to local community, low cost and effective in solving problems, thereby increasing the productivity and income in a sustained manner.

Implications in Sericulture.

- In Vanya sector, the scheme is proposed to be implemented with the support of DOS and RSRS.
- This Institute will provide input which includes low cost technologies, training on technical knowhow, cost of dfls, training programmes and technology demonstrations. The Programme has been discontinued in Tasar Sericulture sector.

Methodology:

- Identification of potential cluster/area and concerned units for implementation of the programme in consultation with concerned DOSs.
- Selection of 2-3 nearby villages as cluster in each unit and selection of 25-30 progressive farmers ready to associate with the programme.
- Conducting reconnaissance survey to understand the status of sericulture, technology status, adoption level.
- Preparation of the technology module in consultation with scientists, extension workers and farmers.
- To facilitate adoption of appropriate technologies for removal of drudgery increased efficiency and higher income of farmer.
- To introduce technological interventions with emphasis on stability and sustainability along with productivity of small farm production system.

RSRSs involved under IVLP:

<table>
<thead>
<tr>
<th>Tropical Tasar</th>
<th>Temperate Tasar</th>
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</thead>
<tbody>
<tr>
<td>RSRS Dumka (Jharkhand)</td>
<td>RSRS Imphal (Manipur)</td>
</tr>
<tr>
<td>RSRS Jagdalpur (Chhattisgarh)</td>
<td>RSRS Bhimtal (Uttarakhand)</td>
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<tr>
<td>RSRS Baripada (Odisha)</td>
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</tbody>
</table>

Package of practices/technologies to be adopted under IVLP

1. Rain water harvesting through plot bunding/compartmental bunding for in-situ moisture conservation.
2. Control for gall infestation.
3. Rearing field disinfection measures.
4. Maintenance of chawki garden.
5. Maintenance of economic plantation.
6. Increase in leaf yield through secondary nutrients.
7. Integrated farming system for augmenting income of farmer.
8. Use of Jeevan Sudha for control of silkworm disease.
## RE-STRUCTURED CENTRAL SECTOR SCHEMES (CSS) OF VANYA SEED SECTOR

### Vanya Cluster Promotion Programme (VCPP)

- The VCPP programme is implemented jointly by CSB and state units.
- While CSB units shall be responsible for capacity building and transfer of improved technologies to the farmers identified for the said purpose, States shall implement remaining components to the farmers and jointly take up the supervision, monitoring and disease monitoring activities, etc.

### Details of Institute-wise & Cluster wise CDFs nominated for Vanya Clusters (Tasar Sector).

<table>
<thead>
<tr>
<th>#</th>
<th>Institutes linked</th>
<th>State</th>
<th>Name of the cluster</th>
<th>Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CTRTI, Ranchi</td>
<td>Jharkhand</td>
<td>Mohanpur, Deoghar</td>
<td>Pre Cocoon Sector</td>
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<td>2</td>
<td></td>
<td></td>
<td>Jarmundi, Dumka</td>
<td>Pre Cocoon Sector</td>
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<td>3</td>
<td></td>
<td></td>
<td>Ramgarh, Dumka</td>
<td>Pre Cocoon Sector</td>
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<td>4</td>
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<td>Boarijore, Godda</td>
<td>Pre Cocoon Sector</td>
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<td>5</td>
<td></td>
<td></td>
<td>Bandgaon, West Singhbhum</td>
<td>Pre Cocoon Sector</td>
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<tr>
<td>6</td>
<td></td>
<td></td>
<td>Majhgaon, West Singhbhum</td>
<td>Pre Cocoon Sector</td>
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<td>7</td>
<td></td>
<td>Odisha</td>
<td>Thakurumnda-Mahuldiha, Mayurbhanj</td>
<td>Pre Cocoon Sector</td>
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<td>8</td>
<td></td>
<td></td>
<td>Baincha-Jalghati, Mayurbhanj</td>
<td>Pre Cocoon Sector</td>
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<td>9</td>
<td></td>
<td>Telangana</td>
<td>Mahadevpur, Karimnag</td>
<td>Pre Cocoon Sector</td>
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<tr>
<td>10</td>
<td>Andhra Pradesh</td>
<td></td>
<td>Kunavaram, Khammam</td>
<td>Pre Cocoon Sector</td>
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<tr>
<td>11</td>
<td>Maharashtra</td>
<td></td>
<td>Awalgaon-Mendki, Chandrapur</td>
<td>Pre Cocoon Sector</td>
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<tr>
<td>12</td>
<td>West Bengal</td>
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<td>Kashipur, Purulia</td>
<td>Pre Cocoon Sector</td>
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<tr>
<td>13</td>
<td>Uttar Pradesh</td>
<td></td>
<td>Bundelkhand, Jhansi</td>
<td>Pre Cocoon Sector</td>
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<tr>
<td>14</td>
<td>BTSSO, Bilaspur</td>
<td>Jharkhand</td>
<td>Barhet, Sahibganj</td>
<td>Pre Cocoon Sector</td>
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<td>15</td>
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<td>Jhinkpani, Chaibasa</td>
<td>Pre Cocoon Sector</td>
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<td>16</td>
<td></td>
<td></td>
<td>Jagdishpur, Deoghar</td>
<td>Pre Cocoon Sector</td>
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<td>17</td>
<td></td>
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<td>Rajnagar, Saraikela-Kharsawan</td>
<td>Pre Cocoon Sector</td>
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<td>18</td>
<td>Odisha</td>
<td></td>
<td>Telkoi-Benhamunda, Keonjhar</td>
<td>Pre Cocoon Sector</td>
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<td>19</td>
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<td></td>
<td>Jeenari-Pardapada, Keonjhar</td>
<td>Pre Cocoon Sector</td>
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<td>20</td>
<td>Madhya Pradesh</td>
<td></td>
<td>Narsinghpur</td>
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<tr>
<td>21</td>
<td>Uttar Pradesh</td>
<td></td>
<td>Mungadih, Sonbhadra</td>
<td>Pre Cocoon Sector</td>
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<tr>
<td>22</td>
<td>Chhattisgarh</td>
<td></td>
<td>Ambikapur</td>
<td>Pre Cocoon Sector</td>
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</tbody>
</table>

### Components of support under VCPP (CSS):

1. Support to Adopted Seed Rearers (ASR) for productivity improvement
   - i) Assistance to ASRs for development of chawki garden
   - ii) Assistance to ASRs for maintenance of existing plantations
   - iii) Assistance to ASRs for equipments
   - iv) Disinfectants support to ASRs
2. Assistance to Private Tasar Graineurs
3. Assistance for strengthening of tasar seed multiplication infrastructure
4. Assistance for Door to Door service for disinfection
5. Assistance for mobile seed testing facilities for disease monitoring
6. Support Services
<table>
<thead>
<tr>
<th>Program</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) Capacity building</td>
<td></td>
</tr>
<tr>
<td>ii) Exposure visit</td>
<td></td>
</tr>
<tr>
<td>iii) Awareness programmes/group discussions @ 2 such programmes/cluster</td>
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</tr>
<tr>
<td>iv) Resham Krishi Mela</td>
<td></td>
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<tr>
<td></td>
<td>(GOI share for beneficiary oriented components- 90% for SC/ST, Special status States- 90% and for others- 80%. In group activities, Capacity building, exposure visits, Krishi mela/ Govt facilities/activities-100%)</td>
</tr>
<tr>
<td></td>
<td>The components shall be implemented directly by the CSB’s Institutes/ nested units. The CSB/ its nested units are the implementing agencies.</td>
</tr>
</tbody>
</table>

**TRIBAL SUB-PLAN (TSP)**

- The Project namely “Empowerment of Scheduled Tribe families through Sericulture under Tribal Sub-Plan (TSP) is approved by Ministry of Textiles covering the States of Andhra Pradesh, Jharkhand, Chhattisgarh, Odisha, Maharashtra, Telangana, Bihar, Uttarakhand.

- In Jharkhand State, the project is being implemented in Bengtangar village under Bandgaon Block of West Singhbhum District and Hutar village under Bero Block of Ranchi District by Project Implementing Agency, CTR&TI, Ranchi.

**Project Objectives**

- Promoting functional activity groups of Tasar silkworm rearers,
- Promoting Cluster Block level aggregations (formal or informal) of the primary groups to enable the producers to sustain their initiatives,
- Demonstrating the technologies evolved by the CTR&TI,
- Implementing various activities across tasar value chain to build capacity of producers, equipping them with implements and accessories, create assets such as seed production units, reeling units, sorting–grading centres,
- Building capacities of all participating families in adopting skills to effectively and profitably engage in livelihood activities based on tasar sericulture,
- Promoting a cadre of community based service providers to provide hand holding assistance, implementation and linkages for credit and market for the participating families,
- Promoting and nurturing suitable producer organizations to provide sustainable systems for services to the project participants besides dovetailing with other developmental schemes,
- Introduction of improved technologies and practices to push the productivity frontiers for accelerated growth in Tasar Sector,
- Strengthening seed sector to eliminate the key supply constraint in Tasar Sericulture and
- Undertaking activities pertaining to documentation of processes, impacts and for wider dissemination of experience.

Some of the critical areas of intervention for enhancing the quality and productivity of the activities in tasar culture are identified as:-

- Raising and maintenance of block plantation of host plants of tasar silkworm in forest and government wastelands,
- Soil and water conservation practices and integrated nutrient management for rejuvenation of the natural flora and existing block plantations,
- Adoption of chawki garden concept,
- Augmenting tasar basic seed requirement,
- Private participation in silkworm seed production,
- Creation of marketing avenues for tasar cocoons and silk,
- Value addition locally by creating stifling, storage, reeling and spinning facilities,
<table>
<thead>
<tr>
<th>Program</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Timely input support facilities,</td>
<td></td>
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<tr>
<td>• Forward and backward linkages across the value chain</td>
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<tr>
<td>• Other support services</td>
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</tbody>
</table>

**Principles of the Project:**

Various activities across the tasar silk value chain will be planned, operated and managed by the community at a scale, with organizing Community Based Organizations at various levels viz., village and cluster level to ensure sustainability; empowerment process at each stage in the project, with participatory bottom-up approach in planning and monitoring; appropriate use of technology in production, as applicable; convergence and leveraging existing resources and infrastructure across value chain, resuming in a set of micro-enterprises to ensure higher incomes; environmental sustainability, promoting regeneration and non-exploitative practices.

**Expected Outcomes of the Project:**

- Increasing skill levels of the tribal households in various activities of tasar sector,
- Building backward and forward linkages across the tasar silk value chain and self-sustaining community institutions,
- Creation of large pool of technical and entrepreneurial capacity for the Tasar sub-sector to increase the bargaining power of tribal people,
- Drudgery reduction for tribal women in various tasar activities specially in cocoon conversion through use of tools/technologies,
- Many ‘passive’ rearers would become ‘active’ due to better linkages and market support,
- Youth would be attracted to the sub-sector through improved opportunities for employment and business environment to take up entrepreneurial activities in tribal areas,
- Production and availability of Basic and Commercial seed locally,
- Significant improvement in poverty indicators of health and food security.
- Efforts would be made to cover about 300 tribal families under the Project. The Project would promote, from among the participants, a group of rearers who would be involved in seed stock multiplication in isolated plantations under aseptic conditions.
- The seed stock would be processed to prepare Disease Free Layings (DFLs) or high quality Tasar seeds. Isolated plantations would thus be a feature of the project that would create capacities for large scale seed production.
- Required nucleus seed and basic seed will be procured from BSM&TCs of BTSSO or BSPUs created under special projects, against specific Memorandum of Understanding entered with the said unit for detailed indent will be placed well in advance.
- The Nucleus seed rearers (NSRs) shall be from the progressive tasarrearers with a capacity to rear about 200 dfls per crop. While this activity is planned in the isolated patches where block plantation or well-maintained natural flora are either available or to be raised during the project period.
- The PIA shall establish backward and forward linkages for the supply of nucleus seed dfls to ASRs and procurement of seed cocoons for production of basic seed dfls by the designated BSM&TC or BSPU in private sector. The rejected cocoons can only be given to the reelers/spinners for yarn production.
- The Basic Seed Rearers (BSRs) will also be selected from the progressive tasarrearers with a capacity to rear 200 dfls per crop. It is the PIA who shall establish backward and forward linkages for the supply of basic seed dfls to SRs and sale of seed cocoons to the entrepreneurial and rejected cocoons to spinners and play the role of facilitator.
- The PIA shall carefully select the entrepreneurial and their location taking into consideration of the requirement of Commercial Rearers (CRs). The PIA shall closely monitor the functioning of these Private grainages.
- The Backward and forward linkages with SRs and CRs are very important for the success of the grainages and shall assist in establishing these linkages, among the project beneficiaries.
Program | Features
---|---
Community Resource Persons would help to build rural institutions which will address the sustenance issues. Skill upgradation would be undertaken by imparting training to the beneficiaries/entrepreneurs on proven technologies. Project personnel would also be trained on different technical and managerial aspects, project implementation, monitoring, reporting, etc.

Implementation:
The project is currently implemented in West Singhbhum and Ranchi Districts of Jharkhand State at an outlay of Rs. 264.678 lakh for a period of three years starting 2017-20. Of this, people’s own contribution/DOS share is Rs. 6.352 lakh. Project also envisages dovetailing the grant support from any other developmental schemes from the line departments to scale up the project size and also to augment income and employment to the project participants.

Expected Outputs:
The major outputs by the end of the project period would be:
1. Annual production of 0.25 lakh each of basic seed and commercial seed, and Production of 12.5 lakh Tasar cocoons annually.
2. Besides, the project would help in regeneration of Tasar host plants in fringe forest areas to an extent of 140 ha, bring in about 50 ha, wasteland under green cover with Tasar host plants, engaging 9 CRPs, 2 Para-Professionals and one consultant.

The Central Silk Board, under Ministry of Textiles, GOI would undertake the role of Nodal agency to provide overall guidance in implementation and monitoring. Department of Sericulture would facilitate utilization of the available infrastructure in general and plantations in particular and other resources in the sector for front loading the project, besides extending support for capacity building.

Project Components:
1. Raising of Block Plantation,
2. Assistance to Nucleus Seed Rearers (NSRs)
3. Assistance to Basic Seed Rearer (BSRs)
4. Assistance to Commercial Rearer (CRs)
5. Assistance to Private Graineures (PGs)
6. Assistance to Basic Seed Production Unit (BSPU)
7. Disease Monitoring
8. Assistance to Reelers’ and Spinners’ Collectives
9. Support to Post-cocoon sector
10. Human Resource Development
   a) Beneficiary training programme
   b) Exposure visit
11. Information Education & Communication Strategy
12. Project Administration Expenses
   a) Community Resource Persons
   b) Para-professionals
   c) Project Consultants

Project Cost and Source of Funds:
The total outlay of the project for a period of three years from 2017–18 to 2019–2020 is estimated at Rs. 249.678 lakh of which project assistance amounts to Rs. 243.662 lakh.
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

<table>
<thead>
<tr>
<th>Program</th>
<th>Features</th>
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</thead>
<tbody>
<tr>
<td><strong>Program Features</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Funds</strong></td>
<td><strong>Beneficiary/ DOS share</strong></td>
</tr>
<tr>
<td>Share of funds</td>
<td>6.352</td>
</tr>
<tr>
<td>Percentage</td>
<td>2.41</td>
</tr>
<tr>
<td>While the beneficiary share is mostly his/her labour contribution to various activities besides locally available material, required credit would be mobilised from corpus fund available for groups etc., with the help of PIA.</td>
<td></td>
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<tr>
<td>Out of the total project cost, 98.0% would be the project assistance amounting to Rs. 264.678 lakh, which is met by Central Share of TSP from MoT and the balance would be the beneficiaries/ DOSs’ share. Besides, funds would be mobilised from other line departments viz., Department of Rural Development, Agriculture, Forests as the case may be to address the gaps.</td>
<td></td>
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<tr>
<td>In case of higher project assistance from other development agencies, project targets would be revised upwards.</td>
<td></td>
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<tr>
<td><strong>MAHILA KISAN SASHAHTIKARAN PARIYOJANA (MKSP)</strong></td>
<td></td>
</tr>
<tr>
<td>Building on the successful models developed under special SGSY projects in Bihar and Jharkhand for replication, CSB and MoRD came up with the idea of undertaking multi-state ventures involving Society for Elimination of Rural Poverty, Govt. of Andhra Pradesh/ Telangana (SERP), Bihar Rural Livelyhood Promotion Society (BRLPS), Govt. Of Bihar, PRADAN, BAIF and Kovel Foundation under the Mahila Kisan Sashaktikaran Pariyojana (MKSP) – Non- Timber Forest Produce (NTFP), a sub component of National Rural Livelihood Mission (NRLM).</td>
<td></td>
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<tr>
<td>The eight projects envisage to cover 36117 mahilakisans (26094 in tasar sector) from 23 districts in 8 states at an outlay of Rs. 71.60 crores shared by MoRD and CSB (75 : 25). The project envisages to raise 3503 ha of tasar host flora, rejuvenation of 9468 natural tasar flora, to establish capacities to produce 6.75 lakh dfls of basic seed, 59.35 lakh dfls commercial seed &amp; 16.09 crore reeling cocoons besides nurturing 478 CRPs for up scaling programmes.</td>
<td></td>
</tr>
<tr>
<td><strong>Project Objectives:</strong> Major objectives of the projects are –</td>
<td></td>
</tr>
</tbody>
</table>
1. to create sustainable livelihoods for marginalized households, in various activities of Tasar sericulture and farm based interventions |
2. to expand the scope of livelihoods through Tasar sericulture during and post-project period and |
3. to mobilize families in new clusters of the project districts through organizing women members in to Self-Help-Groups, building their capacities for self-management and supporting families to build their livelihood vision. This mobilization would act as the base for further expansion of the tasar based livelihood initiatives beyond the project period. |
| **MKSP has been discontinued in Telanagana & Andhra Pradesh.** |
| **Physical Progress (in 2016-17):** | |
| A total of 25076 farmers were covered (78.95% -ST, 5.81% -SC and 15.43% - minorities) in 828 hamlets, 692 revenue villages, 59 blocks and 26 districts of the project states. |
| Under the project, 937ha. of block plantations were raised by 1865 farmers. 1732 seed rearers brushed 5.55 lakh dfls of basic seed procured from BTSSO and BSPUs under special SGSY Projects, to produce 116.48 lakh seed cocoons @ 28.93 seed cocoons per dfl. 249 nucleus seed rearers brushed 63200 dfls of nucleus seed to produce 25.54 lakh seed cocoons @ 32.29 seed cocoons per dfl. 235 private graineurs processed 105.10 lakh seed cocoons and produced 23.37 lakh commercial dfls @ cocoon:dfl ratio of 5.1 ; 1 and 10199 commercial rearers brushed 26.98 lakh dfls procured from the private grainages of MKSP/special SGSY projects/DOSs, to produce 428.74 lakh reeling cocoons. |

CHALLENGES IN TASAR SERICULTURE

Broadly the challenges faced by Sericulture industry are mentioned below

- Fragmented nature of sericulture industry
- Scarcity of skilled /trained manpower
- Mostly poor, illiterate farmers/stakeholders
- Ineffective use of infrastructure facilities at State & Pvt. Sector
- Poor flow of credit to the sector
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

- Lack of revolving fund for reeling sector
- Frequent market distress situations due to policy changes
- Weak Extension mechanism

Challenges in Vanya Silk Sector

<table>
<thead>
<tr>
<th>S. No</th>
<th>Challenges</th>
<th>Suggestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mostly done as outdoor rearing in the forests</td>
<td>Develop man made systematic plantation for controlled rearing like mulberry</td>
</tr>
<tr>
<td>2</td>
<td>Only two commercial crops per year - Uneconomical</td>
<td>R&amp;D breakthrough for increasing the crop cycle</td>
</tr>
<tr>
<td>3</td>
<td>Tasar &amp; Muga – completely outdoor rearing – subjected to vagaries of nature</td>
<td>R&amp;D interventions for indoor rearing like mulberry</td>
</tr>
<tr>
<td>4</td>
<td>Less fecundity unlike mulberry</td>
<td>R&amp;D efforts to increase fecundity</td>
</tr>
<tr>
<td>5</td>
<td>Muga &amp; Tasar Cocoon – poor reelability</td>
<td>R&amp;D breakthrough for better silk recovery</td>
</tr>
<tr>
<td>6</td>
<td>Commercial use of Vanya Silks still in primitive stage</td>
<td>Vanya silk to be promoted as organic silk for commercial use through product development, diversification and marketing.</td>
</tr>
</tbody>
</table>

Challenges in Post-Cocoon Sector

<table>
<thead>
<tr>
<th>S. No</th>
<th>Challenges</th>
<th>Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Increasing production of superior grade raw silk (3A/4A)</td>
<td>Installation of more Automatic Reeling Units and Multi End Reeling Units</td>
</tr>
<tr>
<td>2</td>
<td>Improvement of productivity, quality and drudgery reduction in Vanya silk sector</td>
<td>Popularisation of new reeling machine and process parameters</td>
</tr>
<tr>
<td>3</td>
<td>Product development and diversification for higher value realisation</td>
<td>Development of wide range of new and diversified products as per market demand</td>
</tr>
<tr>
<td>4</td>
<td>Better finish to silk fabrics / products</td>
<td>Application of functional finishes like easy care, aroma, stain guard etc.</td>
</tr>
<tr>
<td>5</td>
<td>Energy conservation and water management in reeling sector</td>
<td>Adoption of new technology for the use of non conventional energy and reuse of water</td>
</tr>
<tr>
<td>6</td>
<td>Effective utilisation of by-products for increased income</td>
<td>Development of new products from silk waste, sericin and pupae</td>
</tr>
</tbody>
</table>

SWOT analysis of the in tasar sub-sector Jharkhand

**Strengths**
- Jharkhand is a traditional tasar habitat and home of the Daba ecorace.
- There are a large number of traditional and experienced rearers, generating livelihood and employment.
- There is self-sufficiency in high quality DFLs in selected clusters.
- Rearing generally provides good returns.
- The state has the largest network of Basic Seed Multiplication & Training Centres (BSM&TCs), Pilot Project Centres (PPCs) and other centres along with experienced and dedicated NGOs.
- State initiatives like Jharcraft are integrating reellers, spinners and weavers into high-end markets.
- Highly experienced research and extension institutions exist such as Central Tasar Research & Training Institute, P4 unit and Regional Extension Centers.
- Jharkhand has the largest Raw Materials Bank in the country.

**Weaknesses**
- Forest cover is on the decline, leading to a scarcity of host plants, besides inaccessibility in Left Wing Extremism (LWE) affected pockets.
- Management of host trees is poor.
- Compliance with PoP and quality standards is limited.
- Contamination from unqualified DFLs is a problem.
- Monitoring and extension services are limited.
- Community-led organizations are limited.
- There’s a high dependence on Chinese yarn.
- The efficiency of reeling machines is limited.
- There is fluctuation in cocoon prices.
- There is no working capital for cocoon procurement.
- The supply of cocoon and yarn is inadequate to meet the demand.
- Cocoon storage facilities are limited.
- There’s a shortage of quality cocoons and yarn.
Tasar silk is unique and has niche value.
Tasar sericulture helps rejuvenate forests and in carbon sequestration.

**Opportunities**
- Initiation of newly-focused projects such as the Mahila Kisan Sashaktikaran pariyojana (MKSP) holds promise for the sector.
- Availability of a network of PPCs with basic infrastructure
- Jharcraft marketing and value addition initiatives and promotion of post cocoon, weaving, designing and apparel clusters.
- Possibilities of creating community-based enterprises led by women.
- Presence of sensitive resource institutions and experienced NGOs.
- Huge opportunities on the production of tasar-reeled yarn that can substitute Chinese yarn.
- Environmentally sound green products.
- Carbon sequestration.
- Large number of beneficiary schemes for weavers.
- Convergence through Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), Forest Department and CSR funds in establishing plantations in view of the availability of large tracts of private and forest wastelands and infrastructure.
- Demonstration and adoption of best practices and new technologies.

**Threats**
- Climate change is a big threat, as is the potential outbreak of diseases.
- Poor quality control.
- Mining and industrialization projects are eroding forest cover.
- Complementary and substitute products may take away the market for tasar.
- Migration and change of vocation among weavers is likely to affect the sub-sector.
- Young people do not have a strong incentive to practice tasar sericulture.
- Change in existing government policies or new ones that favor Chinese yarns (through customs duty), give impetus to tasar-lookalike synthetic fibers and spinning mills, and policies on forest rights, mining and land acquisition will impact tasar.

**Recommendations for pre-cocoon**
- Protect existing forest cover
- Discourage diversion of forest lands for industrial purposes
- Increase host plant plantations to fill the gaps in the forest cover.
- Create empowered community organizations.
- Develop user-friendly methods for pebrine detection.
- Produce quality DFLs in Pilot Project Centres (PPC).
- Maintain strict seed zones.
- Ensure compliance with rearing Package of Practices (PoP) through community institutions.
- Monitor private grainer’s through community institutions.
- Recruit of staff in the Directorate of Silk and other allied departments.
- Rationalize Minimum Support Price (MSP) on commercial cocoons based on market trends.
- Make working capital available for cocoon procurement.

**Recommendations for post-cocoon**
- Increase the outreach of raw material banks and cocoon banks.
- Develop improved machines for reeling and spinning based on market needs and competitive yarn.
- Provide training and skill development opportunities for youth in post-cocoon activities.
- Set up yarn banks.
- Incentivise tasar yarn production; ensure linkage with MGNREGA
- Develop a Hub-Spoke model on Loom-Ready tasar.
- Utilize process waste to increase the remuneration for reelers.
- Value addition and development of a range of designs
- Vegetable-dyeing and blending.
- Strengthen existing community institutions, especially self-help groups.
- Participatory Guarantee Systems for organic, handmade silk.
- Cocoon procurement based on shell weight.
- Infrastructure for cocoon storage; scale up cocoon banks.
- Supportive policies on habitat conservation.
- Convergence and collaboration with existing programs of Mahatma Gandhi National Rural Employee Guarantee Act (MGNREGA) and the Forest Department.
- Establish a strict conservation circle for wild Raba in Kolhan region.
- Revive Sarihan ecorace in the Santhal Parganas region.
- Put in place supportive policies and incentives for enterprises.
- Increase outreach and service delivery of welfare schemes.
- Upgrade skills so that youth are motivated.
- Demonstrate emerging new technology in post-cocoon activities.

**References**


Outlook of CTR&TI Ranchi and Outline of Key R&D Initiatives

J.P. Pandey*, K. Jena, Ravi Ranjan, Sushmita Das, Dinesh Kumar, G.P. Singh, Z.M.S. Khan and Alok Sahay

Central Tasar Research & Training Institute, (Central Silk Board, Ministry of Textiles Govt. of India)
Piska Nagari, Ranchi-835303, Jharkhand, India

* Corresponding author

Introduction

CTR&TI Ranchi is one of the premier Institute of Central Silk Board under Ministry of Textiles Govt. of India. This is the exclusive nodal Institute at National level which was established in 1964. CTR&TI Ranchi provides R&D support in all aspects of Tasar Culture throughout India. Institute is running many research projects of various funding agency like DBT, CSB, MNRE etc having research collaboration with various premier Institute/University of India i.e. IISER Pune, University of Hyderabad, NCL Pune, IIT Delhi, BIT Mesra, NIAB Hyderabad etc. The CTR&TI Ranchi also coordinates various National programmes like CDP, TSP, IVLP, MKSP etc. including R&D support in field of Tasar Culture in many states of India. (Annual Reports 1964-2019; CTR&TI Foundation Day-Chronicle 2019; Gargi, et al., 2015a.; Gargi, et al., 2014; Gargi, et al., 2015b. Giri, et al., 2015. Jena, et al., 2018b; Jolly, et al., 1976; Jolly, et al., 1968; Jolly, et al., 1969; Jolly, et al., 1979a; Kar, et al., 2005; Kumar et al., 2010; Kumar et al., 2009; Kumar et al., 2009a; Pandey et al., 2010; Reeta et al., 2016; Sahay et al., 2006; Sahay et al., 2006; Singh et al., 2011; Singh, et al., 2005; Sinha, et al., 2009; Sinha, et al., 2012; Sinha, et al., 2013; Sinha, et al., 2010; Srivastava et al., 2017. Sunita et al., 2016; Sunita et al., 2017; Suryanarayana and Srivastava 2005; Thangavelu and Singh 1991; Thangavelu, 2000).

CTR&TI Ranchi has initiated various special programmes for North West States of country which includes research activities pertaining to pre and post cocoon processing and value addition as well as conservation of Tasar Silkworm genetic resources.

Objective

- To use the state-of-the-art technologies developed by the Institute for enhancing the productivity, quantity and quality of tasar silk.
- To develop excellence, skill and entrepreneurship for strengthening the Tasar Silk Industry.
- To provide quality, relevance and equity to rural education about Tasar silk through training and skill up-gradation.
- To provide quality life in rural population by taking up Tasar Culture as a source of income generation Product diversification for catering the needs of the market.

Mission:

- To transfigure the R&D efforts of the Institute for increasing production of quality Tasar Silk thereby increasing income generation of rural poor, especially the tribal populace associated with Tasar Industry.

Vision:

- To see India emerge as the Global Silk Leader

Mandate:

The Institute mandate is to serve as the National Institute to organize and promote Tasar silk industry through basic & applied research, extension & technology transfer and generation of trained human resource in tasar industry. To fulfil its mandate, the Institute carries out following activities:

- Conduct basic and applied research on tasar host plants and silkworms for improvement and optimization of output, and on post-cocoon aspects for increasing the rate of production and refinement in the process for quality yarn and fabrics.
- Evolution, maintenance and supply of Breeders Stock.
- Development of innovations for improved silkworm rearing, cocoon preservation and seed production.
- Developing technologies for control of pests and diseases of host plants and silkworm.
- Demonstration, dissemination and popularization of the developed technologies through organizing various extension and motivational programmes and commercialization of products.
- Generation of trained and skilled human resource to fulfil the need of tasar industry.
- Coordination with the Department/Directorate of Sericulture of command States.
- Extending consultancy services to different agencies and organizations.

Distinctive features of tasar silk Industry:

- Tropical tasar silk is produced only in India.
- Tasar silk industry provides livelihood to nearly 3.5 lakhs families and having socio-economic relevance along with favour to ecology and environment.
- It harbours high potential for gainful rural employment and remunerative income to the tribal populace.
- Availability of the abundant nature grown tasar food plants.
- High market demand of tasar silk: locally as well as globally.
- It is a profitable traditional occupation that requires least investment to get good return.
- Rural work-forces can be utilized gainfully.

Specialised laboratories for research & development: The
entire gamut of Research & Development is being carried out by different Divisions/Sections/Laboratories of the Institute namely, Soil Science & Chemistry, Arboriculture Division related to Tasar Host Plant. Similarly, for Tasar Silkworm improvement and productivity, different laboratories involved are Silkworm Breeding & Genetics, Silkworm Physiology, Silkworm Pathology & Microbiology, Silkworm Seed Technology, Silkworm Rearing Technology and Entomology. The studies on Post-cocon (Reeling & Spinning) activities are carried out by the Post-Cocon Technology division. In addition, the Institute is having effectual infrastructure to conduct Molecular Biology and Biotechnology linked experiments. Institute also conducts research at nested units too.

**Highlights of infrastructure:** The Institute is spread over in a total area of 37.48 ha, of which 25.37 ha are under host plant cultivation (*Terminalia arjuna*: 13.53 ha; *T. Tomentosa*: 8.75 ha; Field Gene Bank: 0.74 ha; Nursery: 0.35ha; Natural Sal forest: 1.0 ha Mulberry plantation around 1 ha &Technology Park). Following are key highlights of infrastructure:

- The laboratories are well equipped to carry out research of advanced and molecular nature.
- To facilitate grainage operations for carrying out silkworm breeding studies and race maintenance programme, two tasar grainage buildings are available in the campus.
- To conduct research on silkworm diseases under control condition, a well equipped separate rearing house is available in the campus. Besides, two P4 Silkworm Breeding Stations located in Dumka and Chakradharpur in Jharkhand to undertake maintenance of the breeders stock.
- The Project Monitoring, Evaluation & Coordination (PMEC) section monitors and coordinates the entire R&D activities of the Institute and its nested Units.
- The Extension and Transfer of Technology (ETT) section of the Institute coordinates the activities of nested Units in methodical transfer of proven technologies developed/ findings emanated from the institute laboratories/sections for translating the benefits of the same to the tasar farmers and other stakeholders.
- The extension network of Institute in the form of Regional Sericulture Research Stations (Tropical & Temperate) and Research Extension Centres (Tropical & Temperate) situated in different tasar growing States extends the support in transfer of technology.
- The Training Division of the Institute is well equipped with modern infrastructure required to impart training to different target groups. It shoulders the responsibility of generating skilled and trained human resource in the field of tasar sector through various training programmes structured for different target groups-Officers/Officials from Departments of Sericulture of command states, stakeholders and entrepreneurs.
- Training Division provides need-based formal and informal training programmes, tailor made for specific situations and needs.
- In-house training programmes are also arranged for updating the knowledge of the field functionaries in latest developments. The courses cover all aspects of tasar culture from cultivation and management of host plants, silkworm seed production & rearing, pest & disease management and processing of yarn.
- The Institute also provides facilities to under-graduates /post-graduate students from different Institutions/Universities to carry out project works/dissertations in different aspects of tasar culture, including Molecular Biology & Biotechnology.
- The Institute houses an equipped library with all facilities and provides its readers the facilities like National & International Journals, inter-library loan, photocopying, etc.
- It has a good collection of over 3640 reference books/text books on different aspects, bound volumes of scientific journals and a number of scientific magazines/newsletters.
- Institute is having exclusive museum focused on various activities of tasar sericulture.

**Technologies developed by the Institute**

**A. Tropical Tasar - Host Plant**
- Nursery technique for raising *Terminalia arjuna* (Arjun) and *T. Tomentosa* (Asan) seedlings
- Vegetative propagation of *Terminalia* plants (Juvenile cutting method)
- Integrated package for raising / maintenance of tasar host plants & management
- Establishment of Chawki Garden for two crop system
- Integrated farming system for augmenting the income of farmers
- Application of secondary nutrient combination -SM5 for boosting the leaf yield
- Integrated management of leaf gall in *Terminalia* plants
- Neem based pesticide for management of bark eating caterpillar in *Terminalia* plants

**B. Tropical Tasar - Silkworm Ecoraces**
- Bivoltine & Trivoltine ecoraces
- Commercialization of tasar silkworm, *Antheraea mylitta* – Sukinda ec orace

**C. Tropical Tasar – Silkworm Rearing**
- Module for disinfection and hygiene in rearing field
- Egg incubation and larval brushing technique
- Chawki rearing of tasar silkworm under nylon net
- Integrated technology package for rearing of tasar silkworm
- Semi synthetic diet for young age rearing

**D. Tropical Tasar - Silkworm Protection**
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

- Foliar application of Sodium Hypochlorite to minimize Virosis and Bacteriosis in tasar silkworm.
- Leaf Surface Microbe (LSM) for silkworm disease management
- Silkworm disease management using 'Jeevan Sudha' formulation
- Management of silkworm pests and predators

E. Tropical Tasar - Silkworm Ecoraces

- Commercialization of tasar silkworm, *Antheraea mylitta* – Daba
- Commercialization of BDR-10 : An authorized race of tasar silkworm, *A. mylitta* 10
- Tasar silkworm egg cleaning and surface sterilization machine
- Integrated technology package for management of nematodes in tasar silkworm rearing

F. Tropical Tasar – Post-cocoon Activities

- Non-peroxide cooking method for tasar cocoons
- Motorised tasar reeling machine (MTRM)

G. Temperate (oak) Tasar – Host Plant

- Methods for raising and maintenance of block plantation of *Quercus serrata*

H. Temperate (oak) Tasar – Silkworm Species / Breeds

- Commercialization of Oak tasar silkworm, *Antheraea proylei*
- Commercialization of RTRS 1 : A cross breed of Oak tasar silkworm
- Commercialization of C27 : A cross breed of Oak tasar silkworm
- Temperate (oak) Tasar – Silkworm Rearing
- Technology for Oak tasar silkworm rearing

J. Temperate (Oak) Tasar – Silkworm Seed Production

- Quality silkworm seed production of Oak Tasar
- Cleaning and surface sterilization of tasar silkworm eggs using ‘Depuratex’ 20

E. Tropical Tasar - Silkworm Seed Production

- Preservation of cocoons for tasar silkworm seed production
- Moth mating and oviposition for higher production of tasar silkworm seeds
- Pebrine visualization solution for easy and quick identification of pebrine spores Machines for reeling & spinning of tasar silk yarn

Patents and commercialized products:

- LSM - A process of biological control of Tasar Silworm diseases. (patent)
- Nylon bag for oviposition and brushing of worms.
- A drug formulation for the control of pebrin in Tasar silkworm. (patent)
- Nylon net for silkworm rearing and pest control. (patent)
- Motorized tasar reeling cum twisting machine.
- Lac die for finised fibres. (patent)
- Jeevan Sudha (Commercialised).
- Depuratex (Commercialised)

**Strong R&D background of CTR&TI:** During five decades CTR&TI institute achieved diverse milestones in the field of tropical and temperate tasar culture which was possible due to team work. This event is organized to celebrate aforesaid glorious movement where basic and applied research innovation and key achievements would be deeply discussed for added-speedy development of tasar silk industry in future which would give elite motivational feeling forever. Therefore, the core rationale of present foundation day event is vast. CTR&TI, Ranchi was established in 1964 under the flagship of Central Silk Board (http://csb.gov.in) to conduct R & D to cater the needs of Tasar Silk Industry (both tropical and temperate), a tribal based rural enterprise in the country. With its network of Regional Stations (RSRS earlier known as RTRS), P4-TBS and Research Extension Centres (REC) and one Raw Material Bank at Chaibasa, the Institute provides the state-of-the-art Technological know-how to the command states, both under tropical and temperate tasar sector. CTR&TI engaged in generating useful technologies through Research & Development and its effective transfer in the field, with an ultimate aim to improve the socio-economic status of the stakeholders associated with tasar industry. Besides carrying out research on different aspects of tasar culture of direct field applicability, it also undertakes research on molecular level to unearth certain intricacies of tasar silkworm for achieving higher productivity and quality (Annual Reports 1964-2019; CTR&TI Foundation Day-Chronicle 2019; Gargi, et al., 2015a.; Gargi, et al., 2014; Gargi, et al., 2015b. Giri, et al., 2015. Jena, et al., 2018b; Jolly, et al., 1976; Jolly, et al., 1968; Jolly, et al., 1969; Jolly, et al., 1979; Kar, et al., 2005; Kumar et al., 2010; Kumar et al., 2009; Kumar et al., 2009a; Pandey et al., 2010; Reeta et al., 2016; Sahay et al., 2006; Sahay et al., 2006; Singh et al., 2011; Singh, et al., 2005; Sinha, et al., 2009; Sinha, et al., 2012; Sinha, et al., 2013; Sinha, et al., 2010; Srivastava et al., 2017. Sunita et al., 2016; Sunita et al., 2017; Suryanarayana and Srivastava 2005; Thangavelu and Singh 1991; Thangavelu, 2000).

**Facilities and decree area:** CTR&TI is having its research and administrative building, tasar host plantation as well as residential quarters spread over in an area of 86.31 acres of land. Besides, with its network of Regional Sericulture Research Stations (RSRS), Research Extension Centers (REC), P4 Silkworm Breeding Centers and Raw Material Bank (RMB), the Institute provides the state-of-the-art technological know-how to many states under its command area. The key set-up and Infrastructure at institute is as follows:

- Video conferencing facility. with NKN high speed internet.
- PGDS course with eight specialized Laboratory.
- Genomics and proteomics facility and By-product utilization laboratory.
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

- Unique grainage house and Technology park.
- Water conservation and Total 44 Ecoraces registered with NBAIR, Bangalore.
- Huge infrastructure of plantation. NBAIR, Bangalore.
- Facility to perform biotechnological work.
- Gene bank of Tasar food plants 344 registered accessions registered with NBPG, New Delhi.

**Skill development, Training and HRD programmes:** Tasar silk industry, Training Division of CTR&TI runs various Human Resource Development & Training programmes for the Scientists, Officers and technical/field staff of Central Silk Board (CSB), Department/ Directorate of Sericulture (DOS) and NGOs from different tasar silk producing States; and also farmers, silk reelers/spinners, unemployed youths and other stakeholders of tasar silk industry. These programmes are conducted by highly experienced and qualified scientists of CTR&TI. Most of the training programmes are fully sponsored by the CSB/funding agencies and the participants are provided boarding, lodging and transport facilities. The institute provides hostel facilities for students and trainees. To generate human resource by imparting training through fifteen month duration “Post-Graduate Diploma in Non-Mulberry Sericulture” course which is affiliated to Ranchi University, Ranchi. Institutes also conduct many short-term Certificate & Adhoc courses in Tasar Sericulture. The Institute also provides facilities to under-graduates /post graduate students from different Institutions / Universities to carry out project works / dissertations in different aspects of tasar culture, including biotechnology. Training Division is equipped with modern audio-visual and class room facilities, supported with professionally competent scientists-cum-faculty. It has well-equipped Laboratories, Computer facility with LAN and Internet, rearing fields and grainages for practical training. The library of the Institute houses a good collection of books / journals / magazines. This Institute has well furnished hostel facilities for trainees. Improved technologies & their transfer to the field, human resource development & training and formulation of societal development programmes. The Institute undertakes all sorts of R&D programmes, including molecular level to unearth the intricacies of tasar silkworm for breaking the barrier of productivity and quality. It has well equipped R&D sections with a wide range of modern equipments and a Library having good collection of scientific journals of national, international repute, books and technical reports. Skill development is one of the core focus for the institute.

**R&D Thurst Areas Identified & Vision 2030**

- Countering Global warming.
- Drudgery reduction.
- Mechanization.
- Development of eco-friendly technologies.
- Reduction of input cost.
- Early detection of pebrine disease in tasar silkworm.
- Conservation of endangered ecological population of *A. mylitta, A. frithii*.
- Production of quality seeds.
- Advance Proper cocoon cooking protocol.
- Utilization of by-products of tasar industry.
- Molecular characterization of germplasm accessions
- Isolation of marker genes for desired characters such as dwarf, resistant to disease and abiotic factors.
- Development of suitable plant geometry for mechanization of tasar farming.
- Establishment of Germplasm stations for tasar food plants and silkworm.
- Genetic and molecular characterization of eco-races for promoting their conservation and development of productive breeds.
- Development of robust lines to tolerate stress condition with improved productivity, recovery percent & denier.
- Molecular characterization of disease causing pathogens and development of transgenic silkworm
- Application of Nano-technology against viral disease.
- Improvement in Nano-technology against viral disease.
- Utilization of waste-products of tasar industry.
- Exploitation of sal flora and conservation of ecoraces.
- Development linkage of breed development in seed sector P4 to P1 system.
- Full proof technology for seed cocoon preservation in adverse condition.
- Introduction of seed zone concept & establishment of germplasm station for tasar food plants and silkworm or germplasm station for vanya sector.
- Development of high yielding disease tolerant races in term of fecundity and silk yield and low denier through biotechnological tools.
- Development of indoor rearing technique for tasar ecoraces.
- Development of chowki rearing concept (CRC) and its establishment.
- Studies on diapause mechanism and preservation of eggs.
- Studies on termination of diapause in bivoltine stock.

**Major focus for well-again outputs**

- Ultra safe seed zone.
- New Zone identification.
- Water conservation and harvesting.
- New plantation of jarul and waste land.
- Modern grainage house.
- Ideal condition for cocoon preservation.
- Re-scheduling of crop.
- Semi-synthetic diet popularization.
- Mechanization of disinfection module.
- Tasar motivator concept.
- Adoption of New Tasar zone.
- Awareness and motivation.
- Use of print and digital media.
- Conservation of tasar ecoraces.

Major R&D highlights of the Institute (1964-2020)

First decade (1964-1973)
- Establishment of Plantations
- Rearing performance on different food plants
- Observation of Chromosome number
- Inbreeding studies
- Effect of photoperiod and darkness on hatching
- Maintenance of ecorace germplasm
- New ecoraces survey
- Identification of pest and predators

Second decades (1974-1983)
- Acclimatization of the eco-races.
- Inbreeding Analysis of Various Ecoraces.
- Digestive enzymes in the alimentary canal of A. mylitta
- Chemical control of food plant pests and diseases
- Control of parasitoids and predators of tasar silkworm through chemo-sterilization
- Synchronization of hatching
- Morphological changes of embryo
- Chemical composition of secondary food plants & Oak tasar food plants

Third decades (1984-1993)
- Development of Tasar Keet Oushadh (T.K.O)
- Integrated pest management in tasar culture
- Chawki rearing under nylon net
- Improved Breeds of Oak Tasar Silkworm by Hybridization
- Ex-situ Conservation

- Establishment of Gene bank
- LSM for control of bacteriosis in tasar silkworm
- Drug formulation for control of Pebrine disease
- Neem derivatives against the control of major defoliators
- Studies on voltinism with reference to Latitude and Photo Period
- Hormonal regulation of diapause and voltinism
- Standardization of fertilization doses and micronutrients

Fifth decades (2005-2014)
- Improvement of Daba ecorace for higher fecundity.
- Molecular characterization of pathogens.
- Development of botanical formulation for virosis.
- Molecular marker for the identification of thermo-tolerant line.
- Standardization of rearing schedule of Laria ecorace on Sal plantation.
- Development of indoor rearing techniques.
- Development of culture method of stem borer.
- Forecasting and forewarning system for management of pests.
- Management of gall insect through plant-based pesticides.
- Characterization of tasar host plant germplasm.
- Ecogenetic analysis diapause and reproduction in A. mylitta
- Changes in enzyme profile of tasar silkworm under disease condition
- Development of SM5 for better foliar growth
- Temperature based management to minimize the loss in seed cocoons preservation.
- Modification in semi-synthetic Diet.

2015-2020 (Till Feb)
- Tasar silkworm egg cleaning and disinfection machine
- Development of techniques for collection of cocoonase from emerged moth
- New egg laying device for easy collection of egg.
- Further multiplication of L. Speciosa for rearing
- Identification/development of Terminalia varieties and hybrids.
- Development of methods for Isolation of sericin from cocoon cooking water.
- PVT for quick and easy detection of pebrine spores
- Molecular characterization of cocoonase and sericin
CORE FEATUERS OF CRT&TI

- Low investment & high return
- Rural woman and tribal employment
- Restore ecology and environment
- Congruence with traditional culture
- Unique features of tasar silk industry
- Diverse silk components
- 90% Rural employment
- Huge host plant availability
- Provides livelihoods to around 3.5 lakhs people

Unique features of Forest friendly tasar silk industry in India

- Huge Plantation
- Forest based tasar silk Industry activities.
- Other Activities
- Tasar food plant Gene Bank
- Technology Park
- Soil health card

Activities and initiatives of Forest friendly Tasar Industry

- Field level demonstration
- Massive Training
- Farmers based module for forestry
CURRENT STATUS AND RECENT ADVANCES IN TASAR SERICULTURE

Core focus of Tasar Silk Industry

1. Harmony with nature
2. Product diversification
3. Self-employment
4. Women empowerment
5. Employment generation
6. Production & Productivity enhancement
7. Zero-waste industry
8. Skill-development

Prospects of Tasar Silk Industry in India

Tasar Industry

- CDP
- Central Sector
- Other
- IVLP
- MKSP
- MNAREGA
- SHG
- Women empowerment

Various programs conducted support
**List of various by-products of Tasar Silk Industry and its prospective utilization in Bio-Prospecting**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Various areas for Bio-prospecting</th>
<th>Prospective Bio-prospecting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sericin isolation from Tasar Silk waste</td>
<td>Bio-active molecules, nano-particle, hydro-gels, cosmetics, anti-cancer, biomedical, textiles, etc.</td>
</tr>
<tr>
<td>2.</td>
<td>Cocoonase isolation from emerging moths</td>
<td>Proteolytic, bio-medical, organic silk, anti-inflammatory</td>
</tr>
<tr>
<td>3.</td>
<td>Protein powder isolation from waste pupae</td>
<td>Source of protein, nutrient, amino-acid, bio-polymer, immuno-adjuvant, anti-diabetic etc.</td>
</tr>
<tr>
<td>4.</td>
<td>Preparation of compost from silkworm Litters</td>
<td>Biomedical, microbial culture, edible natural colors, medicinal etc.</td>
</tr>
<tr>
<td>5.</td>
<td>Isolation of fibroin from silk waste</td>
<td>Biomaterials, pharma-industry</td>
</tr>
<tr>
<td>6.</td>
<td>Isolation of chitin and useful proteins from waste moths</td>
<td>Chitin, protein, sensory and endocrine</td>
</tr>
<tr>
<td>7.</td>
<td>Extraction of chitin and anti-ageing protein from waste puparium</td>
<td>Anti-ageing, chitin etc.</td>
</tr>
<tr>
<td>8.</td>
<td>Extraction of bio-molecules from Larval Exuvae</td>
<td>Need to be explored.</td>
</tr>
<tr>
<td>9.</td>
<td>Extraction of useful proteins from Eggs -of muconimm</td>
<td>Anti-septic, Anti-microbial, antifungal</td>
</tr>
<tr>
<td>10.</td>
<td>Extraction of Pigments</td>
<td>Metabolic enhancer</td>
</tr>
<tr>
<td>11.</td>
<td>Cementing material from calcium oxalate anal secretion</td>
<td>Anti-microbial, anti-fungal etc.</td>
</tr>
</tbody>
</table>
References


tomentosa - Primary food plant of Tasar silkworm *Antheraea mylitta* D. Indian Forester, 135(12):1677-1685.


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GLIPMES OF BOOK

SOIL TO SILK ACTIVITIES IN TASAR SILK INDUSTRY

TASAR FOOD PLANT GENE BANK

TASAR REELING MACHINE

GALL INSECTS

Egg laying boxes

Product diversification in tasar

Arjuna tablets

Cordyceps culture