

# sericologia

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BOMBYX MORI SESSION

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GENERAL PRESENTATION  
PRESENT SITUATION OF SERICULTURE IN THE WORLD

Dr. Satoru UEDA  
Chairman

The world production of cocoons was estimated at about 484,000 tons in 1985. This amount has been slowly increasing every year recently. Although there are about 50 countries in the world which produce silkworm cocoons, eight countries, i.e. China, India, U.S.S.R., Japan, Brazil, Thailand, Korea, and North Korea account for about 97% of the total world production of cocoons.

Among these countries, the changes in the cocoon production were most remarkable in Japan during the last 20 years. Japan which was the leading country for the production of cocoons in the world until 1968, was taken over by China after 1969 due to the gradual increase of the cocoon production in China. The labor productivity of sericulture in Japan has increased by about three times during this period due to the improvement of the methods of breeding and disease control of the silkworms, and the dissemination of the communal rearing system and of mechanized sericulture. However, the cocoon production in Japan which amounted to 121,000 tons in 1968 decreased to reach a value of about 40,000 tons. The main causes of the decrease are as follows :

- 1) Decrease in the importance of agriculture in the Japanese economy compared with the industrial sector and trade. In particular, the importance of sericulture, a non-food agricultural activity, decreased.
- 2) In Japan, due to the scarcity of plains, it is very difficult to enlarge the mulberry hectareage and to mechanize sericulture, hence the high cost of cocoon production.
- 3) The ageing of the sericultural farmers.
- 4) The main factor, I believe, is the decrease in the domestic consumption of silk associated with the drastic changes of the living conditions in Japan. Presently, the demand for classical Japanese style silkwear has been markedly reduced, and the technology for the treatment of silk for Western style clothes is insufficiently developed yet.

One may wonder what is the present situation of the silkworm rearing techniques in the world. We will obtain some information about this problem from the presentations of the delegates from Thailand, India, China and Vietnam who participate in this workshop and Korea and Japan. However, no information is available from other countries.

In 1979, Dr. OHMURA systematically described the silkworm rearing techniques in the world based on publications from each country as well as on the reports of Japanese researchers who visited cocoon-producing countries.

In each country, the main problem faced by the sericulture industry is how to stabilize the cocoon crop and increase the productivity of the cocoons. On the other hand, in Japan, emphasis is placed on the need for saving labor for rearing the cocoons.

It had been considered until approximately 1955 that the cocoon crop was essentially affected by the nutrition of the silkworm and the environmental conditions of silkworm rearing. Especially the effect of the former factor was thought to be very important. However, in 1951 and 1961 in Japan, midgut polyhedrosis and infectious flacherie respectively, were observed in silkworm with symptoms of flacherie, an important cause of poor cocoon crop. Subsequently it was found that these diseases are caused by viruses. Therefore it was deemed important to isolate the pathogens from the facilities where silkworms are being reared for the stabilization of the cocoon crop.

Sericulture in the world can be classified broadly into sericulture of the temperate zone and sericulture of the tropical zone. Sericulture was able to develop in the temperate zone for the following reasons :

- 1) Although in the temperate zone mulberry growth is limited to the period of the year from spring to autumn and the growth rate is slower than in the tropical zone, the quality of the mulberry leaves is superior to that in the tropical zone.
- 2) Suitable environmental conditions for silkworm rearing can be easily obtained in the temperate zone.

In Japan, the silkworm rearing system is characterized by the production of heavy cocoons and high raw silk percentage. Attempts were made to apply these systems to the tropical zone. In addition, in order to enhance the profitability of the sericulture industry and the efficiency of labor, the rearing frequency per year was raised 2 times to 5-8 times and the multiple rearing system was developed. However, problems arose, including the occurrence of silkworm diseases under high temperature conditions and the decrease of the cocoon quality in the summer season.

In the tropical areas, mulberry can be grown all the year round and the rearing of silkworms is possible throughout the year. The polyvoltine silkworm race has been used in the tropics except for recent progressed techniques. Although the cocoons of the polyvoltine race are small and the raw silk percentage is rather low, the polyvoltine race seems to be resistant to silkworm diseases.

Recently, the cocoon crop has become unstable in the summer season in the temperate zone due to the fact that the silkworms became susceptible to pathogenic agents or various stresses as a result of the emphasis placed on the increase of the cocoon weight and raw silk percentage of the cocoons. In this connection it will be important to observe the future development of tropical sericulture where the resis-

tant polyvoltine race is used. The progress of sericulture in India and China which is practised both in the tropical and temperate zones is of particular interest.

Finally, I would like to describe briefly the silkworm rearing system using artificial diet which is adopted in Japan. The practical use of an artificial diet for communal rearing of young silkworms which was initiated in 1977 has become increasingly popular, accounting for thirty percent of all the rearing methods.

The advantages of this system are as follows :

- 1) The composition of the diet is always constant regardless of the weather conditions in the year.
- 2) Pathogenic agents can be easily isolated from the rearing facilities to achieve sustained production of cocoons.
- 3) The labor required for the rearing can be markedly reduced.

On the other hand, there are also some disadvantages. The cost of the diet and of the construction of the communal rearing facilities for the use of the artificial diet is very high. In particular, the cost of the diet is about 3 times that of mulberry leaves. In addition, the feeding response of the silkworms may vary depending on the silkworm races used. However, this method can be easily applied in Japan because the saving of the labor cost far outweighs that of the ingredients composing the artificial diet.

## REPORT OF THE BOMBYX SECTION

I would like to summarize the reports presented in this section. Nine papers were presented : five from Thailand, two from India and one from China and Vietnam respectively. These presentations were also roughly classified into three groups according to the theme :

- 1) Silkworm breeding and heterosis, four presentations ;
- 2) Silkworm pathology and pest control, two presentations ;
- 3) Rearing conditions, two presentations.

First, I shall summarize the highlights of the presentations relating to breeding and heterosis. In the studies on the performance of F1-hybrids between a native polyvoltine race and the bivoltine race, it was shown that when a female belonging to a polyvoltine race was crossed with a male belonging to a bivoltine race the economic characters of the cocoons were remarkably improved. The second generation of F2-hybrids, however, was much inferior to the F1-hybrids in almost every character except the number of eggs laid.

To breed highly productive races in emphasizing vigour, the Japanese or Chinese bivoltine race was crossed with a polyvoltine race. Breeding of a new bivoltine race was attempted by back-crossing the bivoltine race to the hybrid between the semi-exotic bivoltine race and the polyvoltine one. Several quantitative characters of the cocoons produced using the new bivoltine race were examined both in Thailand and Vietnam.

I would like to make a few comments on the above reports. The health of the silkworms improved and the cocoon production increased by rearing F1-hybrids between the female of a polyvoltine race and the male of the bivoltine ones. But it is not advantageous to rear F1-hybrids by reciprocal crossing due to the very low level of heterosis. If reciprocal crossing cannot be used for rearing, I believe that the cost of egg production will be twice as high as that of the original egg production. I would like to propose, therefore, that further investigations on the crossing of this race with other races be promoted for example as three way hybrid or double crosses.

I shall now summarize the presentations dealing with silkworm pathology and pest control. Three novel drugs were found to be effective in suppressing or arresting the development of *Nosema bombycis* in the silkworm when administered less

than 36 hours after the infection. These findings are important for the control of the pebrine disease of *Bombyx mori*. The prophylaxis of the pebrine disease had been achieved by disinfection and pebrine inspection of the mother moths. This report, however, suggests the possibility of medical treatment for the pebrine disease. The infectivity of *Aspergillus tamarii* Kita to the silkworm larvae in different instars was examined. It was observed that the younger larvae were more susceptible than the older ones to the infection with this pathogenic agent. For the control of nuclear polyhedrosis, the solubility of the polyhedron in several alkaline solutions was examined, taking into account the fact that the free virus loses its pathogenicity in a comparatively short period of time. The data presented in these reports seemed for me to follow almost the same tendency as those in previous reports. For the establishment of effective disinfection methods for *Aspergillus tamarii*, it is important to study the distribution and the characteristics of this fungus in the silkworm rearing facilities.

Finally, there were presentations on the conditions of silkworm rearing. Reports on the appropriate time of bed cleaning for the 5th instar larvae of the silkworm and the proper size of the silkworm rearing bed were also presented. I would like to make a few comments on both reports. I believe that studies on the rearing methods and rearing conditions of silkworms should be further promoted. Indeed the role of factors such as the number of feedings, the amount of leaves supplied, the conditions of rearing facilities and methods for cleaning the beds in relation to the temperature and aeration conditions should be analysed in a comprehensive manner and not only as isolated factors.

HETEROSIS IN F1 HYBRID BETWEEN POLYVOLTINE AND BIVOLTINE SILKWORM  
(BOMBYX MORI LINN.)

S. KANTARATANAKUL\*, C. THARVORNANULKIT\*\*, S. WONGTHONG\*,  
S. CHAREONYING\*, A. CAMPIRANON\*\*\* and P. SAKSOONG\*\*\*

Seven native Thai strains, generally reared by local farmers were reciprocally interbred with a Japanese bivoltine strain. Heterosis as regarding yield and other economic characters e.g. filament length, whole cocoon weight, cocoon shell weight and cocoon shell ratio, was recorded in all crosses. Better yields were detected in the crosses in which the female Thai strains were used, namely 15 KY, Nang Lueng, PC21, Nang Noi, NK5, NK4 and BR9. 15 KY ranked first in three of the characters, indicators of yield, i.e. 40% heterosis in a single cocoon filament length, 42% heterosis in the cocoon shell weight and 12% heterosis in the cocoon shell percentage. The hybrid larvae were also reported to be easier in rearing and expressed high vitality in comparison with the introduced bivoltine strains. The prospect of introducing hybrids to farmers and problems relevant to bivoltine rearing were discussed.

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## INTROOUCTION

Raw silk production in Thailand is not only insufficient but also fluctuates in quantity and quality. Therefore imported raw silk and silk seeds always play more and more important roles in our silk industry. In order to cope with these problems, sericulture specialist should concentrate on the silkworm breeding programme for exploitation of good new breeds to replace the poor yield local multivoltine races. The bivoltine hybrids were introduced to rearers about 17 years ago. However, only 5-10% of rearers accepted these hybrids, the others still prefer the yellowish multivoltine cocoon to the introduced ones. Therefore, the hybrids between these two types should be a suitable breed for our rearers. This would present us with the yellow cocoons with better quality.

The application of heterosis or hybrids vigor in the breeding programme of both animal and plant production has been extensively carried out. In silkworm, a marked improvement in several characteristics of economical importance has been observed in F1 hybrids between breeds belonging to different regional races (FAO, 1973). Nevertheless, papers concerning heterosis of local multivoltine x bivoltine in our country are very few. Hence the present study attempts to reveal the heterotic effects when a Japanese race is crossed to the multivoltine strains in order to select desirable parents for future breeding programme.

## MATERIAL AND METHODS

Seven native Thai strains, generally reared by local farmers, namely NK4, NK5, PC21, 15 KY, BR9, NN and NL were reciprocally interbred with a Japanese bivoltine strain (K1). All the experimental crosses were reared under laboratory conditions (25-28°C and 70-90% R.H.), with four replications in a completely randomized block design. Heterosis as regarding yield and other economic characters, e.g. filament length, whole cocoon weight, cocoon shell weight, cocoon shell ratio and fullgrown larval weight, were recorded in all crosses.

## RESULTS AND DISCUSSION

The superiority of heterosis was found in all traits except for one cross of K1 x NL in the shell percentage character in which negative value resulted (Table I). Comparison of the mean values of each character is presented in Fig. 1-5. Local multivoltine female seemed to yield hybrids which were superior to hybrids obtained when bivoltine were used as female in all characters. Each character will be discussed individually.

### Fullgrown larval weight :

The PC 21 x K1 yielded the best heterosis value whereas NK5 x K1, NK4 x K1 and 15 KY x K1 yielded almost the same heterosis value and were ranked second. It is noted that marked superior heterosis was expressed by NL ♀ x K1 ♂ (22.57) in comparison with the direct cross K1 ♀ x NL ♂ (3.73).

### Filament length :

K1 x 15 KY and 15 KY x K1 crosses ranked first in both direct and reciprocal crosses and the value was remarkably high when comparing with other combinations. Interestingly, the cross between K1 and NL showed 2.29 time of heterosis value when using NL as a female parent (12.16 versus 27.93).

#### Cocoon weight :

NL x K1 cross yielded highest heterosis value comparing to all diallel crosses followed by 15 KY x K1, NK4 x K1, NK5 x K1 in respective order. It could be said that as regards this character, better results were obtained when the polyvoltines were used as females. Poor heterosis occurred in the cross of K1 x NL.

#### Cocoon shell weight :

Similar to other characters mentioned generally reciprocal crosses gave higher heterosis value, i.e. 15 KY x K1 ranked first, followed by NK5 x K1, PC 21 x K1 and NL x K1 respectively. 15 KY x K1 and K1 x 15 KY gave best heterosis both ways. In contrast, NL x K1 had poor performance.

#### Cocoon shell percentage :

15 KY x K1 and K1 x 15 KY crosses gave best heterosis comparing to all other diallel crosses. In contrast, NL had poor performance similar to the other four characters mentioned earlier.

Among the crosses, the performance of K1 with 15 KY are best both ways. This is followed by a cross to BR9. The incidence of maternal influence on every trait studied was prominent. Therefore if highest yield is expected, the female parent should be of Thai strain. Two points should also be mentioned that, first the eggs produced will be of non-diapause type and hence timing of rearing should be well planned in advance, and second, the number of eggs per female is lower.

#### ACKNOWLEDGEMENT

#### ACKNOWLEDGEMENT

This work was carried out under the Royal Initiated Project responsible by Kasetsart University. The strains used were provided by Department of Agriculture, Ministry of Agriculture and Cooperative.

#### REFERENCE

FAO (1973) Manual on Sericulture, vol. 11, Silkworm rearing. Food and Agriculture Organization of the United Nations, Rome. 131 p.

| Hybrids    | HETEROSIS                            |                              |                             |                                  |                     |
|------------|--------------------------------------|------------------------------|-----------------------------|----------------------------------|---------------------|
|            | Fullgrown *<br>larval weight<br>(gm) | Filament **<br>length<br>(m) | Cocoon **<br>weight<br>(cg) | Cocoon shell**<br>weight<br>(cg) | Shell<br>percentage |
| K1 x NK4   | 14.50                                | 8.12                         | 16.89                       | 20.83                            | 3.10                |
| K1 x NK5   | 13.03                                | 9.74                         | 15.04                       | 18.04                            | 2.29                |
| K1 x BR9   | 8.83                                 | 10.22                        | 17.52                       | 23.65                            | 5.21                |
| K1 x PC21  | 11.33                                | 14.27                        | 15.82                       | 21.90                            | 4.60                |
| K1 x 15 KY | 14.24                                | 23.60                        | 15.33                       | 23.60                            | 7.46                |
| K1 x NN    | 14.07                                | 15.29                        | 16.19                       | 22.06                            | 5.52                |
| K1 x NL    | 3.73                                 | 12.16                        | 12.64                       | 10.42                            | -0.27               |
| NK4 x K1   | 25.89                                | 21.97                        | 27.93                       | 27.36                            | 3.55                |
| NK5 x K1   | 25.90                                | 25.31                        | 27.11                       | 33.52                            | 6.61                |
| BR9 x K1   | 18.80                                | 16.95                        | 25.17                       | 29.05                            | 3.62                |
| PC21 x K1  | 26.85                                | 26.90                        | 24.93                       | 33.35                            | 6.81                |
| 15 KY x K1 | 25.27                                | 40.03                        | 28.44                       | 42.20                            | 12.10               |
| NN x K1    | 24.15                                | 25.81                        | 26.61                       | 32.07                            | 5.38                |
| NL x K1    | 22.57                                | 27.93                        | 30.79                       | 33.02                            | 6.80                |

\* ten larvae

\*\* single cocoon

Table 1. Heterosis value of selected characters of K1 versus seven local multivoltine silkworm races.

| Parents | Fullgrown *<br>larval weight<br>(gm) | Filament **<br>length<br>(m) | Cocoon **<br>weight<br>(cg) | Cocoon shell **<br>weight<br>(cg) | Shell<br>percentage |
|---------|--------------------------------------|------------------------------|-----------------------------|-----------------------------------|---------------------|
| K1      | 29.09±7.94                           | 1 035±161.03                 | 126.56±35.71                | 22.39±6.32                        | 18.64±0.97          |
| NK4     | 19.88±4.96                           | 466±20.72                    | 82.82±19.31                 | 10.07±2.30                        | 12.31±0.37          |
| NK5     | 20.33±6.41                           | 403±73.08                    | 83.13±23.10                 | 1.65±2.26                         | 11.91±0.78          |
| BR9     | 21.87±3.92                           | 393±56.29                    | 85.25±26.95                 | 10.93±3.68                        | 12.86±1.00          |
| PC21    | 21.05±3.97                           | 437±79.28                    | 89.01±24.88                 | 11.49±3.21                        | 13.09±0.11          |
| 15 KY   | 18.79±5.18                           | 388±37.55                    | 81.11±18.52                 | 9.65±2.76                         | 11.94±0.64          |
| NN      | 19.52±6.09                           | 391±41.38                    | 84.10±22.66                 | 9.78±2.63                         | 11.82±1.24          |
| NL      | 17.61±2.99                           | 347±86.28                    | 68.20±20.01                 | 7.16±2.55                         | 10.47±0.77          |

\* ten larvae

\*\* single cocoon

#### Appendix 1. Mean value of selected characters of parents.

| Hybrids    | Larval<br>days | duration<br>hours | Pupation rate<br>(%) | Eggs/Female | Hatching<br>percentage |
|------------|----------------|-------------------|----------------------|-------------|------------------------|
| K1 x NK4   | 21             | 23                | 97.00                | 477         | 97.07                  |
| K1 x NK5   | 21             | 26                | 94.00                | 505         | 97.24                  |
| K1 x BR9   | 22             | 07                | 98.50                | 479         | 96.95                  |
| K1 x PC21  | 22             | 03                | 96.67                | 433         | 97.39                  |
| K1 x 15 KY | 21             | 21                | 97.83                | 488         | 97.59                  |
| K1 x NN    | 22             | 14                | 96.83                | 495         | 97.90                  |
| K1 x NL    | 22             | 02                | 96.33                | 499         | 96.05                  |
| NK4 x K1   | 23             | 20                | 96.00                | 441         | 92.31                  |
| NK5 x K1   | 23             | 16                | 99.33                | 412         | 97.55                  |
| BR9 x K1   | 25             | 00                | 97.33                | 379         | 87.17                  |
| PC21 x K1  | 24             | 03                | 80.67                | 419         | 95.44                  |
| 15 KY x K1 | 23             | 22                | 96.67                | 434         | 94.63                  |
| NN x K1    | 23             | 21                | 97.00                | 419         | 95.91                  |
| NL x K1    | 24             | 00                | 97.50                | 370         | 94.50                  |

#### Appendix 2. Comparison of four selected characters of diallel crosses between K1 and seven Thai multivoltine silkworm races.

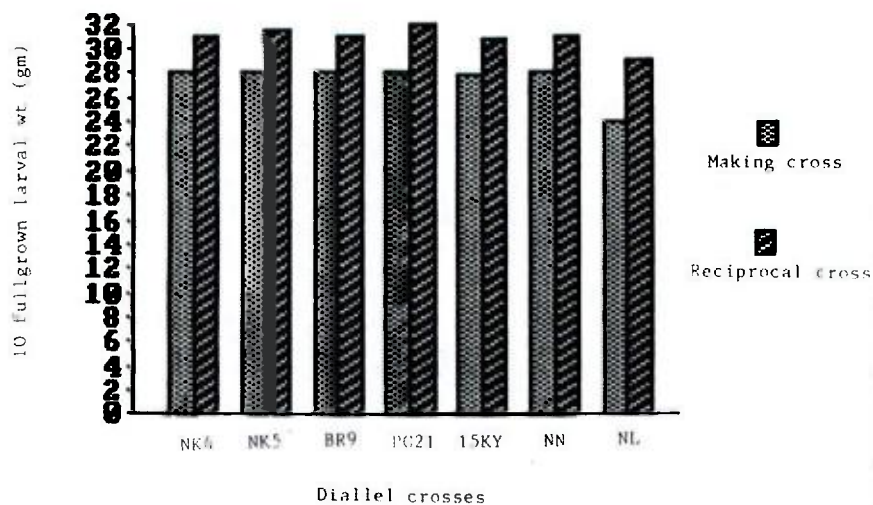


Fig. 1. Full grown larval weight of diallel crosses:  
K1 vs 7 Thai multivoltine races

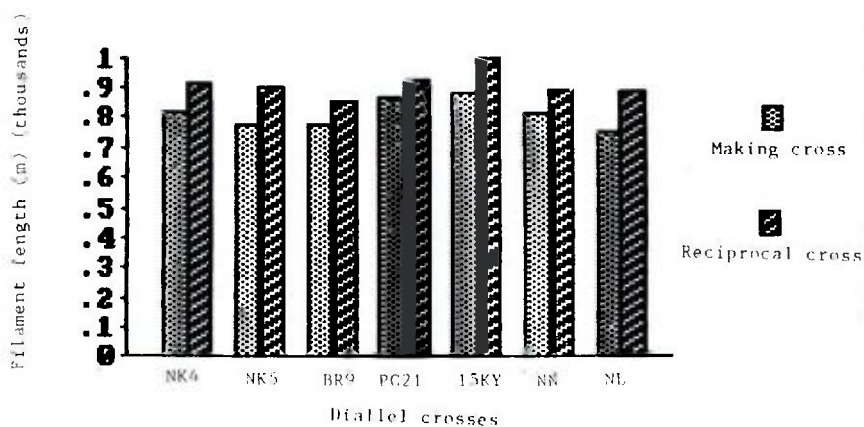


Fig. 2. Filament length of diallel crosses:  
K1 vs 7 Thai multivoltine races

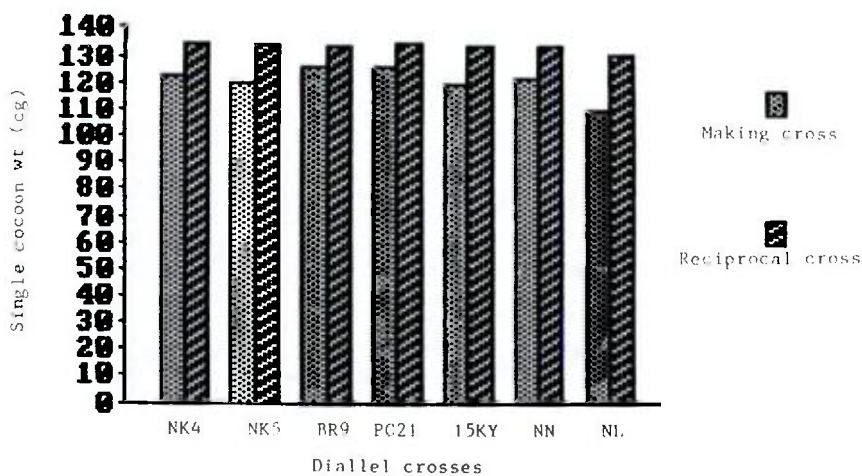


Fig. 3. Single cocoon weight of diallel crosses:  
KI vs 7 Thai multivoltine races

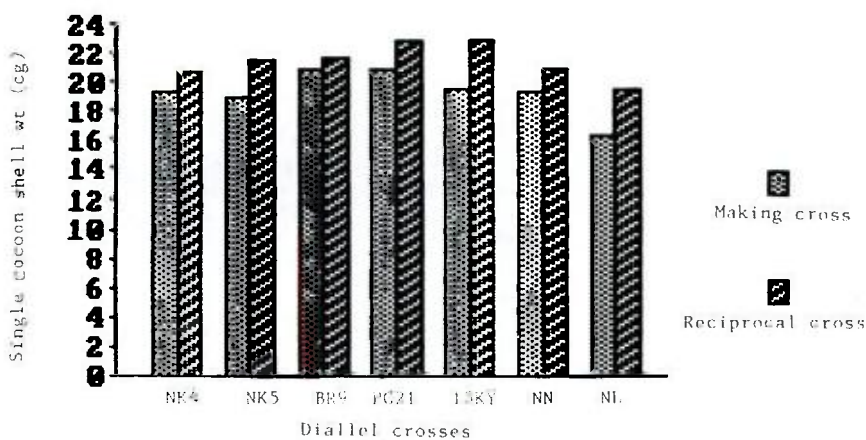


Fig. 4. Single cocoon shell weight of diallel crosses:  
KI vs 7 Thai multivoltine races

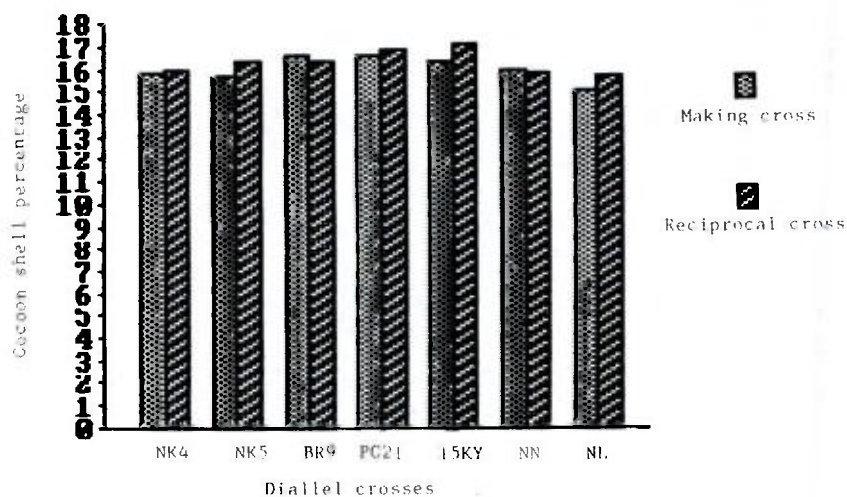


Fig. 5. Cocoon shell percentage of diallel crosses:  
K1 vs 7 Thai multivoltine races

PERFORMANCE OF DIFFERENT RACES OF SILKWORM, BOMBYX MORI  
UNDER MARATHWADA CONDITIONS

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The present study was carried out to study the comparative merits and relative performance of economic traits in some strains of silkworm, Bombyx mori L. under Marathwada conditions. The experiment was conducted during 1983-84 and a diallel cross set of four genetically diverse parents (multivoltine: HM; bivoltine: NB7, NB18 and NB4D2) including reciprocals were studied in F1 and F2 generations. The analysis was carried out in both generations for 11 and 10 characters respectively. Both in F1 and F2 generations, variances due to treatments were highly significant for all the characters. The comparative performance of diallel set in F1 and F2 revealed superiority of multivoltine x bivoltine crosses HM x NB4D2, HMxNB7 and HMxNB18 in most of the characters studied. The bivoltine hybrids NB7xNB4D2, NB18xNB4D2 and NB7xNB18 and their reciprocals also performed better for the characters total number of eggs laid, hatching percentage, weight of silkglands, shell weight and filament length.

Among the parents NB7 and NB18 were highest in per se mean performance for all the characters. The multivoltine parent, Hosa Mysore (HM) was statistically inferior for all the characters studied over other parents and hybrids.

INTRODUCTION

In Maharashtra, the Maharashtra Khadi and Village Industries Board has been doing the work of sericultural development since 1959. However, the sericultural industry did not spread to any significant extent in the State. There are many constraints, among which availability of a suitable race and lack of research on silkworm rearing practices were the major ones. The Marathwada Agricultural University initiated research on silkworm rearing in 1978. This study indicated that under Marathwada

conditions July to March is the suitable period for silkworm rearing. The pioneering research of this University on silkworm rearing, silkworm races, mulberry culture and the economics of raw silk production induced the farmers of this non-traditional region to take up commercial production of raw silk (Tayade, 1978, 1983 a.c).

At present, the strains evolved at Mysore (Karnataka State) are being reared in Maharashtra. These races and other hybrid combinations are acclimatized over a long period under Mysore conditions and they seem to have acquired fair amount of stability in regards to crop production. However, these strains face problems to the relatively drier and warmer climate of this region. Therefore, a project has been initiated in the Marathwada Agricultural University, Parbhani to evolve suitable races of mulberry silkworm. The present work forms a part of this project. The present work experimentally assesses the comparative merits of the various combinations and their relative performance under Marathwada conditions in particular and Maharashtra in general.

#### MATERIAL AND METHODS

Foundation stock of the four promising races of silkworm, *Bombyx mori*, viz., Hosa Mysore (HM), NB7, NB18 and NB4D2 was procured from Central Sericultural Research and Training Institute, Mysore (Karnataka). These four parents were reared in the laboratory by adopting the technology suggested by Krishnaswami (1978). The adult males and females reared from this foundation stock were mated with each other as per the desired cross. Crosses in all possible combinations including reciprocals were attempted. Thus twelve crosses and four parents were studied. Randomly selected five disease free layings for each combination were released at once for the study.

During early larval stage mass rearing was done. The larvae, after coming out of second moult, were distributed into five replications. Each replication consisted of 100 worms. The technique of Krishnaswami (1978) was followed for rearing of these sixteen cultures. The rearing of F1 generation was started on 13.9.1983 while the cocoons were harvested between 17th and 22nd October, 1983.

The cocoons obtained from the F1 generation of each cross and parents were released after recording the observations for developing F2 population. A set of 12 F2 populations was developed by intermating the adults of respective F1 hybrids. The experiment including 12 F2 populations and four parents was laid out in randomized block design with five replications each having 100 worms. The rearing started from 3.11.1983.

Observations were recorded and computed on different economic traits in the parental, F1 and F2 generations; and presented in Table I and II.

#### RESULTS AND DISCUSSION

The analysis was carried out in F1 and F2 for 11 and 10 characters, respectively. The mean values for all the characters along with their standard errors are given in Tables I and II for parents, their F1's and reciprocals; and parents and F2's respectively. Significant treatment differences in F1 and F2 indicated that there was adequate amount of variability involved in the material under study. The ecogeographically divergent parents from peninsular and exotic sources may have contributed to the increased variability.

The overall results of F1 and F2 are discussed below.

Among the parents, egg laying capacity of HM, NB7 and NB18 was quite satisfactory (500-600) and at par. The parent NB4D2 showed poor fecundity (399.4 and 413.6). The highest number of eggs laid in F1 and F2 was observed in HMxNB7 (582.4 and 723.4 respectively) followed by HMxNB4D2 and HMxNB18. In reciprocal crosses the fecundity was in the range of 343.6 to 456.6. Reciprocal differences indicated that egg laying capacity of the hybrid was higher when the multivoltine race was used as the female parent. Benchamin *et al.* (1983) suggested that the bivoltine hybrid could be utilized as male parent with multivoltine breed for preparation of commercial seed and the performance was on par with that of bivoltine pure races.

Significant differences in the egg production efficiency were observed between pure races and hybrids. Similar results have been reported by Yokoyama (1974), Benchamin and Krishnaswami (1980 a,b). Higher egg laying capacity of the F2 and F1 could be attributed to hybrid vigour of the females. The high egg production and reproductive efficiency involved could be effectively applied to cut down the seed production costs and to improve silk yield if the parental stocks are selected and combined properly.

The hatching percentage ranges from 78.05 to 97.60 and 77.93 to 99.09 respectively during F1 and F2 rearing. The hatching percentage was high in majority of the races except NB4D2xNB18 (78.41), NB7xHM (78.05) and NB4D2 (83.30) in F1. The highest hatching percentage was recorded in HMx NB4D2 (97.60) and NB7xHM (99.09) in F1 and F2 respectively. The trend of hatching was mostly same as reported by earlier workers (Benchamin and Krishnaswami, 1980 a,b; Anonymous, 1981, 1982; Jolly, 1983; Krishnaswami, 1983; Tayade, 1983 a,b,c; Datta, 1984).

There was significant variation in the larval growth. Significantly highest larval weight was observed in HMxNB4D2 (44.66 g). The next best performance was observed in the hybrids HMxNB18 (37.68 g) and HMxNB7 (36.62 g). The lowest weight was observed in HM (19.36 g). The results are in agreement with those of earlier workers (Anonymous, 1981, 1982; Krishnaswami, 1983; Jolly, 1983 and Datta, 1984). The respective reciprocals were light in weight with the range of 28.00 to 34.02 g. The poor performance of reciprocal crosses, particularly bivoltine x multivoltine has been reported earlier (Anonymous, 1982; Benchamin *et al.*, 1983).

The shortest larval duration was observed in F1 hybrid NB7xHM (21.97 days). Early maturity was also observed in the hybrids HMxNB18, HMxNB4D2 and HMxNB7. The longer larval period was observed in NB4D2 (25.35 days). Similar observations were recorded by Narasimhan and Chandrakanth (1983) and Datta (1984).

The larval period during F2 generation ranged from 36.19 to 44.06 days. The longest larval period was observed in NB4D2xNB18 population (44.06 days). The longer larval period was observed due to cooler temperature of 8 to 10°C prevailing during the period of F2 rearing. The seasonal variation in the larval period was reported by Narasimhan and Chandrakanth (1983). The longer larval period upto 39 days under Marathwada conditions was reported in certain parents and hybrids (Tayade, 1983 c).

The heaviest silkglands were reported in NB4D2xNB7 (1.3582 g) which was statistically similar to NB7xNB4D2 and HMxNB18.

The heaviest single cocoon was observed in HMxNB4D2 (2.011 g). Next heavier cocoons were observed in HMxNB18 and HMxNB7. The poor results obtained in F2 population may be due to inbreeding depression and seasonal effect. In F1 rearing, silk content of the races ranged from 14.15 to 21.44 per cent. The highest shell percentage was observed in the bivoltine hybrid NB4D2xNB7 which was on par with the other bivoltines viz., NB18xNB4D2 and NB7xNB4D2. Krishnaswami (1983) stated that the bivoltinism is genetically correlated with cocoon weight and silk shell weight, hence

there is more production of silk from the bivoltines. But this is true under certain sets of conditions only.

The bivoltine parents showed lowest floss percentage ranging from 0.12 to 0.56, exceptionally it was 1% in NB4D2. The multivoltine parent HM had high floss percentage (1.65%). It is a fact that the content of the floss is always associated with the nature of voltinism. Amongst hybrids, HMxNB7 (0.37%) was comparable to the best parent.

During F1 generation, maximum filament length was observed in the bivoltine hybrid NB7xNB18 (936.8 m) which was statistically similar to other bivoltines like NB7xNB4D2, NB4D2xNB7 and NB7.

In F1 diallel, the highest cocoon yield was recorded in HMxNB7 (16.401 kg) which was statistically similar to HMxNB4D2 and HMxNB18. The lowest yield was observed in HM (10.743 kg). In F2, the highest yield was obtained from the HMxNB4D2 population (11.208 kg).

The multivoltine parent HM was significantly inferior for all the economic traits studied. The multivoltine x bivoltine hybrids, particularly HMxNB7, HMxNB4D2 and HMxNB18 exhibited significantly superior performance for most of the characters except shell content, weight of salivary glands and filament length. The bivoltine hybrid NB7xNB18 was another best hybrid in this sequence. The results are more or less similar to those reported by earlier workers with respect to parents and multivoltine x bivoltine hybrids for most of the characters studied (Krishnaswami and Tikoo, 1971; Sidhu, 1973, 1974; Anonymous, 1981, 1982; Tayade, 1983 a,b,c; Krishnaswami, 1983; Jolly, 1983; Datta, 1984; Tayade and Jawale, 1984).

The results of F1 and F2 generations could not be compared because of two quite different environments. During F2 rearing, the season was cold (minimum and maximum temperature being 10-14°C and 27-30°C respectively) which substantially delayed the larval period. The longer larval period resulted in poor performance in respect of overall characters. Majority of the researchers reported superior performance of bivoltine hybrids under Karnataka conditions. It may be attributed to the more or less constant temperature for longer period coupled with humid climate prevailing in Karnataka State which suits the bivoltine hybrid. On the other hand, the temperature fluctuations are very common in our environment. The temperature is always high, around 30°C and above with drier climate. This set of conditions is not congenial for bivoltines and their hybrids. Hence, the performance of multivoltine x bivoltine was far better and superior.

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| Treatment           | No. of eggs<br>per laying | Hatching<br>Percentage<br>(%) | Weight of<br>fullgrown<br>larvae<br>(g) | Larval<br>duration<br>(days) | Weight of<br>silk glands<br>(g) | Single<br>cocoon<br>weight<br>(g) |
|---------------------|---------------------------|-------------------------------|-----------------------------------------|------------------------------|---------------------------------|-----------------------------------|
| 1. Hosa Mysore (HM) | 500.8                     | 95.02(77.36)                  | 26.66                                   | 24.53                        | 0.6494                          | 1.1914                            |
| 2. NB7              | 477.6                     | 94.66(77.30)                  | 38.48                                   | 23.40                        | 1.0880                          | 1.6344                            |
| 3. NB18             | 453.4                     | 96.57(79.84)                  | 33.68                                   | 24.74                        | 1.1099                          | 1.5021                            |
| 4. NB4D2            | 399.4                     | 78.41(62.33)                  | 31.70                                   | 25.35                        | 1.0524                          | 1.4547                            |
| <u>Hybrid</u>       |                           |                               |                                         |                              |                                 |                                   |
| 5. HM x NB7         | 582.4                     | 93.55(75.88)                  | 36.62                                   | 23.67                        | 1.1714                          | 1.8322                            |
| 6. HM x NB18        | 503.8                     | 96.70(80.22)                  | 37.68                                   | 22.92                        | 1.3277                          | 1.8872                            |
| 7. HM x NB4D2       | 542.4                     | 97.60(81.13)                  | 44.66                                   | 23.66                        | 1.1924                          | 2.0113                            |
| 8. NB7 x NB18       | 344.4                     | 93.44(75.78)                  | 31.20                                   | 23.87                        | 1.1789                          | 1.6746                            |
| 9. NB7 x NB4D2      | 395.0                     | 83.55(68.75)                  | 34.96                                   | 23.88                        | 1.3454                          | 1.7299                            |
| 10. NB18 x NB4D2    | 450.0                     | 95.57(77.85)                  | 32.38                                   | 25.14                        | 1.1149                          | 1.4976                            |
| <u>Reciprocals</u>  |                           |                               |                                         |                              |                                 |                                   |
| 11. NB7 x HM        | 343.6                     | 78.05(62.04)                  | 32.08                                   | 21.97                        | 1.1186                          | 1.5692                            |
| 12. NB18 x HM       | 350.4                     | 93.83(75.82)                  | 28.18                                   | 23.01                        | 1.0932                          | 1.3755                            |
| 13. NB4D2 x HM      | 353.0                     | 93.08(74.97)                  | 30.42                                   | 23.02                        | 1.1327                          | 1.5747                            |
| 14. NB18 x NB7      | 456.6                     | 91.72(74.87)                  | 34.02                                   | 24.74                        | 1.0952                          | 1.6746                            |
| 15. NB4D2 x NB7     | 451.0                     | 93.75(76.82)                  | 33.84                                   | 24.87                        | 1.3582                          | 1.5385                            |
| 16. NB4D2 x NB18    | 388.2                     | 83.30(67.36)                  | 28.00                                   | 24.21                        | 0.8591                          | 1.3906                            |
| S.E. $\pm$          | 19.212                    | 3.042                         | 0.452                                   | 0.313                        | 0.0325                          | 0.0332                            |
| C.D. at 5%          | 54.339                    | 8.606                         | 1.279                                   | 0.886                        | 0.0919                          | 0.0940                            |

to be continued...

Table I. Mean performance of parents and hybrids for different economic characters in silkworm in F1 generation.

| Treatment           | Shell weight (g) | Shell percentage | Floss percentage | Filament length (m) | Yield per 10,000 larvae brushed (kg) |
|---------------------|------------------|------------------|------------------|---------------------|--------------------------------------|
| 1. Hosa Mysore (HM) | 0.1682           | 14.15(22.08)     | 1.65(7.32)       | 404.6               | 10.743                               |
| 2. NB7              | 0.3157           | 19.35(26.08)     | 0.56(4.16)       | 886.8               | 12.502                               |
| 3. NB18             | 0.2939           | 19.57(26.23)     | 0.40(2.22)       | 672.0               | 13.458                               |
| 4. NB4D2            | 0.2804           | 19.42(26.11)     | 1.00(5.67)       | 597.0               | 11.514                               |
| <u>Hybrids</u>      |                  |                  |                  |                     |                                      |
| 5. HM x NB7         | 0.3226           | 17.62(24.81)     | 0.37(3.19)       | 843.6               | 16.401                               |
| 6. HM x NB18        | 0.3249           | 17.21(24.49)     | 1.10(5.79)       | 674.4               | 16.345                               |
| 7. HM x NB4D2       | 0.3594           | 17.90(25.00)     | 1.26(6.44)       | 827.4               | 16.388                               |
| 8. NB7 x NB18       | 0.3311           | 19.78(26.39)     | 1.08(5.95)       | 936.8               | 14.581                               |
| 9. NB7 x NB4D2      | 0.3473           | 20.07(26.61)     | 1.25(6.44)       | 904.4               | 14.639                               |
| 10. NB18 x NB4D2    | 0.3027           | 20.23(26.72)     | 0.64(4.60)       | 684.4               | 13.593                               |
| <u>Reciprocals</u>  |                  |                  |                  |                     |                                      |
| 11. NB7 x HM        | 0.2724           | 17.36(24.60)     | 0.08(1.96)       | 769.2               | 12.288                               |
| 12. NB18 x HM       | 0.2270           | 16.50(23.97)     | 0.97(5.67)       | 581.6               | 11.743                               |
| 13. NB4D2 x HM      | 0.3095           | 19.73(26.37)     | 0.95(5.67)       | 762.6               | 12.762                               |
| 14. NB18 x NB7      | 0.3162           | 18.90(25.76)     | 0.94(5.55)       | 834.8               | 14.502                               |
| 15. NB4D2 x NB7     | 0.3300           | 21.44(27.57)     | 1.12(6.12)       | 888.4               | 13.294                               |
| 16. NB4D2 x NB18    | 0.2631           | 18.99(25.83)     | 0.85(5.23)       | 676.6               | 12.339                               |
| S.E. $\pm$          | 0.0067           | 0.364            | 0.277            | 29.823              | 0.225                                |
| C.O. at 5%          | 0.0191           | 1.032            | 0.785            | 84.353              | 0.638                                |

Figures in parentheses are transformed values

Table 1. (continued)

| Treatment           | No. of eggs<br>per laying | Hatching<br>percentage | Weight of<br>fullgrown<br>larvae (g) | Larval<br>period<br>(days) | Single<br>cocoon<br>weight (g) | Shell<br>weight<br>(g) |
|---------------------|---------------------------|------------------------|--------------------------------------|----------------------------|--------------------------------|------------------------|
| 1. Hosa Mysore (HM) | 546.80                    | 90.53(71.79)           | 19.36                                | 39.28                      | 0.956                          | 0.150                  |
| 2. NB7              | 597.20                    | 97.86(81.69)           | 28.70                                | 37.78                      | 1.215                          | 0.262                  |
| 3. NB18             | 442.40                    | 91.84(77.35)           | 28.00                                | 39.39                      | 1.297                          | 0.250                  |
| 4. NB4D2            | 413.60                    | 95.70(79.12)           | 25.60                                | 41.30                      | 1.252                          | 0.244                  |
| 5. HM x NB7         | 723.40                    | 97.76(82.34)           | 24.32                                | 40.13                      | 1.115                          | 0.220                  |
| 6. HM x NB18        | 617.40                    | 94.75(77.15)           | 23.28                                | 40.11                      | 1.182                          | 0.206                  |
| 7. HM x NB4D2       | 699.20                    | 93.56(75.64)           | 24.68                                | 39.14                      | 1.277                          | 0.232                  |
| 8. NB7 x NB18       | 538.20                    | 96.36(79.33)           | 24.46                                | 40.22                      | 1.238                          | 0.255                  |
| 9. NB7 x NB4D2      | 598.80                    | 98.28(81.05)           | 21.60                                | 41.31                      | 1.199                          | 0.221                  |
| 10. NB18 x NB4D2    | 518.20                    | 95.41(77.95)           | 28.86                                | 42.40                      | 1.323                          | 0.201                  |
| 11. NB7 x HM        | 614.00                    | 99.09(84.49)           | 25.88                                | 38.85                      | 1.177                          | 0.197                  |
| 12. NB18 x HM       | 420.80                    | 98.19(83.12)           | 28.52                                | 36.19                      | 1.096                          | 0.235                  |
| 13. NB4D2 x HM      | 560.60                    | 93.47(79.79)           | 23.18                                | 41.49                      | 1.140                          | 0.200                  |
| 14. NB18 x NB7      | 540.40                    | 98.67(83.61)           | 25.18                                | 41.33                      | 1.252                          | 0.241                  |
| 15. NB4D2 x NB7     | 534.80                    | 92.63(77.58)           | 24.90                                | 44.04                      | 1.134                          | 0.212                  |
| 16. NB4D2 x NB18    | 464.00                    | 77.93(63.68)           | 23.24                                | 44.06                      | 1.166                          | 0.211                  |
| S.E. $\pm$          | 20.819                    | 2.511                  | 0.372                                | 0.341                      | 0.035                          | 0.008                  |
| C.D. at 5%          | 59.091                    | 7.102                  | 1.054                                | 0.964                      | 0.099                          | 0.023                  |

to be continued

Table II. Mean performance of parents and hybrids for different economic characters in silkworm in F<sub>2</sub> generation.

| Treatment           | Shell<br>percentage | Floss<br>percentage | Filament<br>length (m) | Yield per 10,000<br>larvae brushed (kg) |
|---------------------|---------------------|---------------------|------------------------|-----------------------------------------|
| 1. Hosa Mysore (HM) | 15.87(23.43)        | 0.91(5.93)          | 385.40                 | 8.873                                   |
| 2. NB7              | 21.54(27.61)        | 0.12(2.26)          | 761.80                 | 10.510                                  |
| 3. NB18             | 19.29(26.04)        | 0.27(3.00)          | 691.40                 | 10.943                                  |
| 4. NB4D2            | 19.53(26.20)        | 0.58(4.34)          | 695.60                 | 10.744                                  |
| 5. HM x NB7         | 19.83(26.43)        | 0.93(5.46)          | 711.00                 | 9.633                                   |
| 6. HM x NB18        | 17.50(24.70)        | 1.36(6.60)          | 599.60                 | 10.210                                  |
| 7. HM x NB4D2       | 18.18(25.23)        | 1.03(5.70)          | 629.40                 | 11.208                                  |
| 8. NB7 x NB18       | 20.61(27.01)        | 1.16(6.15)          | 755.80                 | 10.384                                  |
| 9. NB7 x NB4D2      | 18.52(25.45)        | 0.87(5.37)          | 565.00                 | 10.200                                  |
| 10. NB18 x NB4D2    | 15.28(22.98)        | 0.80(5.14)          | 648.40                 | 11.173                                  |
| 11. NB7 x HM        | 16.74(23.13)        | 1.00(5.38)          | 651.00                 | 10.600                                  |
| 12. NB18 x HM       | 21.51(27.60)        | 0.94(5.41)          | 555.80                 | 9.305                                   |
| 13. NB4D2 x HM      | 17.58(24.78)        | 1.05(5.95)          | 658.40                 | 9.196                                   |
| 14. NB18 x NB7      | 19.36(26.07)        | 0.93(5.32)          | 736.40                 | 10.800                                  |
| 15. NB4D2 x NB7     | 18.67(25.61)        | 1.06(5.84)          | 666.20                 | 9.738                                   |
| 16. NB4D2 x NB18    | 18.12(25.18)        | 1.02(5.79)          | 501.60                 | 9.636                                   |
| S.E. $\pm$          | 0.414               | 0.427               | 29.433                 | 0.051                                   |
| C.D. at 5%          | 1.173               | 1.209               | 83.251                 | 0.146                                   |

Figures in parentheses are transformed values.

Table II. (continued)

FOOD UTILIZATION IN DIFFERENT RACES OF SILKWORM BOMBYX MORI L.  
(LEPIDOPTERA : BOMBYCIDAE)

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*Consumption and utilization of food in three races, namely Pure Mysore, NB4D2 and KA of silkworm Bombyx mori, fed ad libitum with Morus alba, is reported from hatching to pupation. Food consumption in KA and NB4D2 races is two times more than in Pure Mysore race and the semi-exotic races are better converters ( $K_1 = 20.5\%$ ) than the Pure Mysore race ( $K_1 = 8.8\%$ ). However, assimilation efficiency averages 51.8% in indigenous Pure Mysore race and about 39.3% in semi-exotic races. Moreover, the Pure Mysore race consumes and assimilates the food at a higher rate of 1.6477 and 1.5169 mg/mg/day than the semi-exotic races. There exists a linear relation between the rates of feeding, assimilation, conversion and the body weight of the larvae belonging to three different races. The adaptive potentials of different races of B. mori are discussed.*

INTRODUCTION

Consumption and utilization of food (Yamamoto and Fujimaki, 1982), adaptability to high temperature and susceptibility or resistance to diseases (Aruga, 1983; Riba *et al.*, 1982) varies among different races of silkworm (Periasamy *et al.*, 1984). There exist enormous literature on food intake and utilization in insects (Slansky and Scriber, 1982) or on the effects of various environmental factors on nutritional and water requirements of insects (Scriber and Slansky, 1981; Delvi and Naik, 1984; Naik and Delvi, 1984; Kapil, 1963, 1967; Legay, 1958; Ito, 1967; Hiratsuka, 1920; Poonia, 1978; Joshi, 1984; Periasamy *et al.*, 1984; Pant and Katiyar, 1983). A thorough knowledge of the nutritional ecology of insects is a prerequisite to understanding their biology and behaviour and this has been too often neglected (Scriber

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and Slansky, 1981). Different resistant races of the silkworm *Bombyx mori*, have been introduced, in an attempt to improve the commercial characters. Little information is available on the difference in food utilization among the existing commercial races (Periasamy *et al.*, 1984) of *B. mori*. The present paper reports the consumption and utilization of food in three different races of silkworm *Bombyx mori* L.

## MATERIALS AND METHODS

Disease free egg layings of *Bombyx mori* (1. Pure Mysore race, 2. NB4D2 race, 3. KA race) obtained from the sericulture section of the department were used in the present study. Freshly hatched larvae were removed in separate terraria (plastic trays size: 36x26x4 cm) and maintained in the laboratory fed *ad libitum* on the mulberry leaves *Morus alba* at the room temperature of  $26\pm 2^{\circ}\text{C}$ ,  $80\pm 10\%$  R.H. following the method given in "The new technology of silkworm rearing" (Krishnaswami, 1978). 150 freshly hatched larvae in each race were selected weighed and divided into three groups of 50 larvae each. Three series of feeding experiments with three replicates in each race were commenced. Since, larvae belonging to all the test races fed throughout the day, the fresh leaves were offered four times a day. Uneaten food and faeces were collected daily and dried at  $90^{\circ}\text{C}$  to weight constancy. The larvae were weighed at the beginning and at the end of each instar. Amount of daily food intake was calculated following standard gravimetric method described by Waldbauer (1968). To estimate the amount of dry food converted into body substance, few larvae were dried just before commencing the respective feeding experiments and their dry weight was assumed to represent the initial weight of the chosen larvae for respective experiments (Sacrifice method of Maynard and Loosli, 1962).

The scheme of food utilization budget followed in the present investigation is that of the IBP formula (Petrusewica and Mac Fadyen, 1970) represented as  $C = P + R + F + U$ , where C is food consumption, P the production, R the energy lost as heat due to metabolism, F the undigested food and U the nitrogenous excretory products. Since the quantity of uric acid in faeces in insects is negligible (0.2 to 0.5% of faeces; Waldbauer, 1968) it was not estimated. C was estimated by subtracting the dry weight of uneaten from dry weight offered daily. P was estimated by subtracting the dry weight of the initial larva from that of the terminal larvae. R can be calculated by subtracting production from assimilation. Conversion efficiency,  $K_1$  and  $K_2$ , was calculated in percentage relating P to food consumed and assimilated respectively. Assimilation efficiency was calculated in percentage by subtracting dry faeces weight (F) from dry weight of food consumed (C).

Various indices and different terms of food intake and utilization have been devised by different workers to express the rates of consumption, digestion and conversion of food in insects. In the present study feeding rate is expressed in terms of mg of dry food consumed per mg of live insect per day. Assimilation rate is expressed in mg of dry food assimilated per mg of live insect per day. Conversion rate is expressed in mg of dry substance converted into body substance per mg of live insect per day.

## RESULTS

Total food consumption and utilization budget of the three different races of *Bombyx mori* L. is given in Table I. Comparison of mass budget parameters of the three races reveals several interesting aspects. For comparative purpose the data reported by Hiratsuka (1920) for Japanese race of *B. mori* are recalculated and presented (Table I). The indigenous races took about 34 days as against 30.5 days by semioctotic races to complete five larval instars. The pattern of food utilization remains more

or less same in all the three tested races. The amount of food consumption is the minimum in the first instar and gradually increases to the maximum in the last instar in all the three races. Similar trends are found for total food assimilated, converted into body substance and used for body maintenance. However, in NB4D2 race the food assimilated reduces from 18.6 mg during first instar to 15.2 mg during the second instar period. Then it doubles and redoubles to reach the maximum of 1849.5 mg during the final instar.

The rates of feeding, defaecation, assimilation and conversion are maximum during the first instar in all the three races. There after these rates gradually decreased to the minimum during the last instar. It is interesting to note that about 54% of the total larval period is spent during fourth and fifth instar, while the food intake during these stages is 95% of the total consumption. About 93% of the consumed food is assimilated during the last two stages. This is true only when the feeding life stages are considered as a single unit. It is not clearly known whether the higher intake and utilization of food is a feature limited to one or more life stage(s) or depends on body weight and/or age; if it is so, to what extent the food utilization is altered during the different instars depending on body weight and/or age in *B. mori*. With a view to compare the quantitative data on food intake, assimilation and conversion as a function of life stages and body weight, the basic data were calculated on the basis of amount of dry food per live weight of insect per day as a function of particular life stage (instar). Striking changes in the feeding rate body weight/life stage relation have been noted.

In the NB4D2 race the inverse relation between rates of feeding and assimilation and body weight is linear for individuals weighing between 12.92 mg (11 instar) and 1446.9 mg (final moult). This straight line relation is altered below 12.9 mg (the first instar). The alteration below 12.9 mg is not due to inaccurate estimations of food consumption (Davey, 1954; Kastings and McGinnis, 1959; Delvi and Pandian, 1972) but due to the high rate of consumption and defecation. Hence, the regression line for the rates of feeding and assimilation body weight relationship in NB4D2 race have been calculated for the weight range 12.9 mg and 1446.9 mg. The formula  $Y = a + bX$  has been applied (Baily, 1959). The regression equations for NB4D2 race of *B. mori* are:

$$\text{Feeding rate } Y = 0.4403 - 0.000064X$$

$$\text{Assimilation rate } Y = 0.2037 - 0.000054X$$

The corresponding inverse relations obtained for KA race of *B. mori* are also linear from 11 instar to final instar and the equations are:

$$\text{Feeding rate } Y = 0.4829 - 0.000093X$$

$$\text{Assimilation rate } Y = 0.2634 - 0.000089X$$

While the straight relation is altered below the second instar (13 mg) in KA race, it is altered below the third instar in Pure Mysore race. Hence, the regressions are calculated for rates of feeding and assimilation in Pure Mysore race from third instar (35 mg). The equations are:

$$\text{Feeding rate } Y = 0.6695 - 0.000053X$$

$$\text{Assimilation rate } Y = 0.5475 - 0.000059X$$

The conversion rate is related to body weight of the test individuals and is found to be linear. The rate decreases per se with the increase in the body weight (Fig. 1-3). The regression equations obtained are:

$$\text{Pure Mysore race } Y = 0.2407 - 0.00000026X$$

$$\text{NB4D2 race } Y = 0.0297 - 0.0000018X$$

$$\text{KA race } Y = 0.0299 - 0.0000011X$$

## DISCUSSION

The foregoing account on the silkworm *Bombyx mori* has brought many interesting results. For comparative purpose the basic data on *B. mori* (Japanese strain) reported by Hiratsuka (1920), are recalculated and presented in Table I. The energy budget in *B. mori* is more or less similar in all the four races. The most striking differences can be summarised as follows. 1. The lowest food consumption and assimilation in Pure Mysore race is compensated by highest feeding and assimilation rates. It is surprising to note that lower consumption and assimilation in Japanese strain of *B. mori* did not increase the rates of feeding and assimilation. This may be due to the fact that Japanese race of *B. mori* was reared at lower temperature of 22°C. 2. Assimilation efficiency is the highest (62.8%) in Japanese variety which consumed 3111.4 mg of food; similarly in the Pure Mysore race of *B. mori* the food consumption amounts to 3081.8 mg only and the assimilation efficiency is as high as 52% of the food consumed. It is interesting to note that in NB4D2 and KA races the food intake is about two times more than in the Japanese and Pure Mysore races. However NB4D2 and KA races of *B. mori* exhibited a lower assimilation efficiency of about 40%. In *P. ricini* (unpublished data) the efficiency is as high as 61% even though the consumption is also higher amounting to 6398.1 mg, but rates of feeding and assimilation averaged 0.4872 and 0.3458 mg/mg/day. The highest assimilation efficiency values reported for herbivorous animals range from 21% to 70% (Waldbauer, 1968). It is surprising to know that the first instar of *B. mori* exhibits assimilation efficiency ranging from 91 to 98%. These values are higher than the corresponding values reported for the carnivorous insects (Odonata: *Pyrphosoma*, 94%, Lawton, 1971; Coleoptera: *Melanoplus*, 90.3%, Dutton, 1968), which are known to exhibit relatively higher efficiency for reasons discussed by Delvi *et al.* (1986) elsewhere. 3. Conversion efficiency values remain lowest at about 9% for Pure Mysore race whereas the Japanese race exhibited highest conversion efficiency. Conversion values in NB4D2 and KA races and in *P. ricini* average about 20%. Some lowest conversion efficiency values reported for the lepidopteran insects are 14% for *Mamestra brassicae* fed on *Ipomoea batatas* (Hirano and Noguchi, 1963), 16% for *Prodenia eridania* fed on *Antirrhinum majus* and 19% when fed on *Viola* sp. and 18% when fed on *Prunus serotina* (Soo Hoo and Praenkel, 1966), 24% for *Chilo suppressalis* fed on rice stem (Hirano and Ishii, 1962) and 8% for *Anagasta kuehniella* fed on wheat flour (Fraenkel and Blewett, 1944). Delvi and Pandian (1971) showed that the lepidopterans, which feed only during the larval period and accumulate sufficient food energy to tide over the subsequent non-feeding pupal and adult stages by feeding relatively faster and by saving relatively a greater part of infested material via better assimilation and conversion efficiencies than those of the Orthopterans, which feed throughout their life. When an animal has to accumulate nutrient matter to tide over unfavourable or non feeding periods, it may do so by either increasing feeding level, assimilation or conversion efficiency or by a combination of one or more of these possibilities. Some lepidopterans like the silkworm *B. mori* appears to have utilized all the possibilities. Moreover, each race of *B. mori* exhibits adaptive potential by modifying one or more of the above mentioned combinations. For instance, the low food consumption in Japanese variety of *B. mori* is compensated by high feeding and assimilation rate. Lower conversion of *B. mori* are compensated by increasing food consumption by nearly two times. The most striking finding is the highest metabolic activity found in the first instar larvae of all the three series (see also Delvi and Pandian, 1972). Such high rates of metabolism during the first two instars are also found in other insects like *Oxya velvox* (Delvi and Pandian, 1971), *Schistocerca gregaria* (Hussain *et al.*, 1946), *P. pictus* (Delvi, 1972). In these insects the feeding rate is found to be highest during 2nd instar and decrease as the weight/age increases. Nayak *et al.* (1985), working on *Antheraea mylitta* fed on *Terminalia tomentosa*, have found that the food consumption is directly proportional to age and shows extraordinary increase during last stage of the larva i.e. 5th instar larva. It is true that about 97-98% of the total amount of food consumed is during the final two instars in lepidopteran insects

(Waldbauer, 1968). However, there exists an inverse relationship of feeding rate with age/weight i.e. early development stages consume high amount of food per unit body weight per day (Delvi and Pandian, 1972; Evan, 1939; Mishra, 1972; Carne, 1966). Nayak *et al.* (1985) have not calculated the feeding rate by have concluded depending on the mass of food consumed per instar.

In the silkworm *B. mori*, as much as 240 mg of 20% of the assimilated matter is channelled for synthesis of silk and only 13 mg or 1% of the assimilated energy is used for the production of puparium. *P. ricini* spends similar amount of assimilated matter on silk production. In *Hyalophora cecropia* (Schroeder, 1971) no silk is produced but it exhibits high conversion value of 53.1%. Conversion efficiency values in herbivores range from 1 to 87% depending on the type of food (Delvi, 1972). Therefore increase or complete presence of metabolic pathways of silk synthesis in *B. mori* and *P. ricini* might not have interfered in reducing the conversion efficiency.

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| Parameters                  | Pure Mysore race | NB4D2 race | KA race | Japanese race* |
|-----------------------------|------------------|------------|---------|----------------|
| Larval period (day)         | 34.5             | 30.5       | 30.5    | 33.0           |
| Consumption (mg)            | 3081.8           | 5845.4     | 6472.6  | 3111.4         |
| Assimilation (mg)           | 1597.5           | 2263.0     | 2582.1  | 1952.7         |
| Conversion (mg)             | 248.3            | 458.4      | 535.0   | 610.9          |
| Feeding rate mg/mg/day      | 1.6477           | 0.7111     | 0.8157  | 0.1810         |
| Assimilation rate mg/mg/day | 1.5168           | 0.4927     | 0.6082  | 0.1136         |
| Conversion rate mg/mg/day   | 0.0276           | 0.0337     | 0.0324  | 0.0335         |
| Assimilation efficiency (%) | 51.8             | 38.7       | 39.9    | 62.8           |
| Conversion efficiency (%)   | 8.8              | 20.3       | 20.7    | 31.3           |
| $K_2$                       |                  |            |         |                |

\* Recalculated data of Hiratsuka (1920): temperature 22°C.

Table 1. Data on energetics of the silkworm *Bombyx mori* fed *ad libitum* on mulberry leaf *Morus alba* at 26°C; 70±20% R.H.

SUSCEPTIBILITY OF DIFFERENT LARVAL INSTARS OF THE SILKWORM  
BOMBYX MORI LINNAEUS TO ASPERGILLUS TAMARII KITA

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*Effect of spore infection of Aspergillus tamaraii Kita on different larval instars of Silkworm, Bombyx mori Linnaeus. From a series of experimental infectivity tests on the five larval instars, it was observed that the first and second instar larvae were more susceptible and registered 100% larval mortality compared to third, fourth and fifth instars, where larval mortality of 23.30, 22.60 and 9% were recorded, respectively indicating less susceptibility to pathogen. Further, maximum cocoon formation of 91% was recorded when fifth instar larvae were infected, followed by fourth and third instar infection with 77.30 and 77% cocoon formation, respectively.*

INTRODUCTION

The silkworm, *Bombyx mori* Linnaeus that has been under domestication since time immemorial is prone to the attack of a number of diseases. Among the infectious diseases of silkworm : muscardine, pebrine, grasserie and flacherie are more important. Muscardines are contagious and dreaded diseases of silkworm. They are of different kinds and are commonly known by their colour, viz. white muscardine, green muscardine, yellow muscardine, red and purplish red muscardine and aspergillosis.

In Japan, *Aspergillus* disease of silkworm is popularly known as 'Koji-Kabi' disease. In addition to *Aspergillus tamaraii* Kita, the disease is reported to be caused by more than ten species of the genus *Aspergillus*, particularly those belonging to the *Aspergillus flavus* group (Kawakami, 1982). The *Aspergillus* disease has been considered to be one of the serious diseases which occur on young silkworms in Chawki rearing centres resulting in great loss. This is due to the fact that adequate tempe-

perature and relative humidity are being maintained in Chawki rearing centre from the view point of silkworm growth. These conditions are also very favourable for the growth and multiplication of the disease. Differences in susceptibility to *Aspergillus flavus* infection observed among different larval instars of *Bombyx mori* L. (Aoki, 1971 ; Aoki *et al.*, 1972 ; Kawakami and Mikuni, 1973). In India for the first time, Chinnaswamy (1983) reported the *Aspergillus* disease caused by *Aspergillus tamarii* Kita in young silkworms. Among the several isolates of *Aspergillus* sp. isolated from both diseased and dust samples collected from young silkworm rearing houses, *Aspergillus tamarii* was predominant. As the literature is scanty on the disease caused by *Aspergillus tamarii*, the present study was undertaken to have clear ideas about differences in larval susceptibility.

## MATERIALS AND METHODS

### a) Isolation of fungus :

The *Aspergillus* diseased silkworm cadaver was cut into bits with the help of a sterilized scalpel. These bits were surface sterilized with 0.1% mercuric chloride and subjected to dipping in a series of Petri dishes containing sterile distilled water and were finally placed on Petri dishes having Rose Bengal Agar Medium (R.B.A.) The R.B.A. medium had the following ingredients :  $\text{NaNO}_3$ , 1g.,  $\text{K}_2\text{HPO}_4$ , 1g., Sucrose 10 g., Rose Bengal 50-70 mg. and Agar 15 g., dissolved in 1 litre of distilled water. After 3 days of incubation, fungus culture was transferred to R.B.A. slants (Kawakami, 1967). Fungus, thus isolated from silkworm cadaver was identified as *Aspergillus tamarii* Kita from Commonwealth Institute of Mycology, England.

### b) Preparation of the inoculum :

The fungus, *Aspergillus tamarii* was subcultured on several slants of R.B.A. and incubated for seven to eight days at the prevailing room temperature and relative humidity (23.40°C to 24.90°C and 88.20 to 91.80%). Conidia were harvested by shaking thoroughly with 3 ml. of sterile distilled water to each slant. Spore suspension from all such slants was pooled to obtain required quantity of spore suspension. Spore count was made by using 'Neubauer' haemocytometer (improved double ruling).

### c) Spore inoculation and rearing :

All the five instars of race Kalimpong. A. were inoculated at the beginning of each instar by spraying with spore suspension containing  $275 \times 10^4$  spores per ml., using 'Amber glass Brovon Midget inhaler'. After inoculation, larvae were reared under normal rearing conditions. For each instar, six replications, each with 50 larvae, were maintained. Observations were made on development of external symptoms, larval mortality and cocoon formation. Data were analysed by adopting completely randomised design, (Sundaraj *et al.*, 1972).

## EXPERIMENTAL RESULTS

Effect of larval instars for infection was ascertained through a series of infectivity tests using all the five instars. Effects of *Aspergillus tamarii* infection at each instar was adjudged, based on the symptomatology, subsequent larval mortality, re-isolation and examining of the pathogen from cadavers of the silkworm.

#### a) Larval mortality :

When first instar larvae were infected, the mortality rate in the first and subsequent instars showed a decreasing trend (Table I). When infection was made at second instar, the mortality was 24.67, 61.33 and 14.00% at second, third and fourth instar, respectively. The data further revealed that when third instar larvae were infected, larval mortality of fourth and fifth instar was 15.33 and 8.00% respectively. Percentage of larval mortality was 6.33 and 16.33 at fourth and fifth instars respectively, when fourth instar larvae were infected and 9.00% larval mortality at fifth instar was observed when fifth instar larvae were infected.

Data presented in Table I also shows that total larval mortality when first and second instar larvae were infected was 100.00%, followed by third (23.30%), fourth (22.60%) and fifth instar larval infection (9.00%).

The statistical analysis (Sundarraaj *et al.*, 1972) reflected that the total larval mortality did not differ significantly when the larvae were infected at third and fourth instars. Similarly the total larval mortality did not vary significantly between first and second larval infection.

Mortality at fifth instar was highest (16.33%) when fourth instar was infected followed by fifth (9.00%) and third instar infection (8.00%). When second instar larvae were infected, the mortality observed in fourth instar was 14.00% which has been followed by infection in third instar (15.33%) and fourth instar (6.33%). The mortality in the second instar was 61.33% and 2.00% when second and first instar larvae were infected respectively. The percentage of larval mortality at second instar was 25.33 when first instar was infected followed by second instar infection (24.67%). First instar larval mortality was 72.67% when newly emerged larvae were infected. The resulting total larval mortality, due to inoculation during third and fourth instars did not differ statistically and the same trend was also observed between first and second instar infection.

All the five larval instars showed susceptibility to *Aspergillus tamaraii* infection. Larval susceptibility decreased as the instars advanced with age, first and second instars, larvae showed more susceptibility to infection. However, third, fourth and fifth instar larvae showed less susceptibility and some of the larvae remained healthy and formed cocoons.

#### b) Cocooning :

Rate of cocooning and pupation greatly depended upon the instar at which the inoculation was done (Table II). The rate of pupation was observed to be 91.00% when fifth instar larvae were infected followed by fourth instar infection (77.30%) and third instar infection (77.00%). As there was 100.00% mortality in first and second instar, no cocooning was observed.

#### c) Pupal mortality :

The pupal mortality was highest (29.30%) when fifth instar was infected followed by fourth instar infection (28.88%) and third instar infection (17.75%), (Table II).

### DISCUSSION

During the present study, all the first instar larvae infected with *Aspergillus tamaraii* succumbed before completing third instar and the second instar infected worms

showed complete mortality before completion of fourth instar resulting in 100% crop failure. These findings indicate that this disease is of serious nature during first and second instar worms and confirms the observations of Kawakami and Mikuni (1973). Further, data reveal that the susceptibility to infection decreases with the advancement of the age of the larvae. Consequent to the reduction in the larval mortality in the later-instars, the percentage rate of cocooning increased and agreed with Aoki, 1971, Aoki *et al.* 1972. The pupal mortality recorded assumes greater significance, if the cocoon crop is meant for seed production. The cumulative crop loss in this case, due to larval mortality, as well as pupal mortality without adult emergence is 40%, 51% and 38% when infected at third, fourth and fifth instar respectively. These findings clearly illustrate that the crop loss varied with stage of infection and also with purpose of rearing.

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| LARVAL INSTARS |        | LARVAL MORTALITY (%) |               |              |               |              | TOTAL   |
|----------------|--------|----------------------|---------------|--------------|---------------|--------------|---------|
|                |        | FIRST INSTAR         | SECOND INSTAR | THIRD INSTAR | FOURTH INSTAR | FIFTH INSTAR |         |
| 1st            | Instar | 72.67                | 25.33         | 2.00         | 0.0           | 0.0          | 100.00  |
|                |        | (59.50)              | (30.20)       | (8.13)       |               |              | (90.00) |
| 2nd            | Instar | 0.0                  | 24.67         | 61.33        | 14.00         | 0.0          | 100.00  |
|                |        |                      | (29.80)       | (51.33)      | (21.97)       |              | (90.00) |
| 3rd            | Instar | 0.0                  | 0.0           | 0.0          | 15.33         | 8.00         | 23.30   |
|                |        |                      |               |              | (21.39)       | (16.33)      | (28.59) |
| 4th            | Instar | 0.0                  | 0.0           | 0.0          | 6.33          | 16.33        | 22.60   |
|                |        |                      |               |              | (14.54)       | (23.81)      | (28.40) |
| 5th            | Instar | 0.0                  | 0.0           | 0.0          | 0.0           | 9.00         | 9.00    |
|                |        |                      |               |              |               | (17.46)      | (17.46) |

Data in parentheses represents angular transformed values

Mean larval (Total) mortality : S.E.m  $\pm$  0.69

C.D at 5% 2.004

Table I : Larval mortality when different larval instars of *Bombyx mori* were infected with *Aspergillus tamaris* spores.

| N° OF INSTAR<br>INFECTED | TOTAL NUMBER<br>OF LARVAE | COCOONING<br>(NUMBER OF COCOONS) | COCOONING<br>(%) | PUPAL<br>MORTALITY (%) |
|--------------------------|---------------------------|----------------------------------|------------------|------------------------|
| 1st Instar               | 300                       | 0.0                              | 0.0              | 0.0                    |
| 2nd Instar               | 300                       | 0.0                              | 0.0              | 0.0                    |
| 3rd Instar               | 300                       | 231                              | 77.00            | 17.75                  |
| 4th Instar               | 300                       | 232                              | 77.30            | 28.88                  |
| 5th Instar               | 300                       | 273                              | 91.00            | 29.30                  |

Table II : Cocooning and pupal mortality of *Bombyx mori* when different larval instars were infected with *Aspergillus tamaris* spores.

## THE EFFECT OF CHEMOTHERAPY ON PEBRINE DISEASE OF BOMBYX MORI

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The use of bavistin, benomyl and thiophanate as antimicrosporidian agents to control Nosema bombycis Naegeli in the silkworm (Bombyx mori) was investigated. The suspension of Nosema spores which had been smeared on the mulberry leaves were fed for 4 hours to the 5th instar larvae just after ecdysis at the concentration of  $10^3$ - $10^5$  spores/ml. Then these infected larvae were separated into some groups, the tested groups were fed mulberry leaves containing bavistin or benomyl after infection for 0-36 hours, at dosages of 10000-40000 ppm 1 to 3 times every day. The results were as follows: at concentrations of 10000-40000 mg/l, bavistin, benomyl and thiophanate were all effective in suppressing or eliminating the development of Nosema bombycis in the silkworm. the group fed with bavistin, benomyl or thiophanate resulted in complete almost freedom from Nosema infection, while the control group only reared on mulberry leaves had 61-94% infection. Bavistin, benomyl and thiophanate are, therefore, three novel drugs for controlling a Nosema disease of the silkworm, Bombyx mori.

The therapeutic effect of bavistin (carbendazin) to control transovarian transmission of Nosema in silkworm was investigated. The newly hatched transovarially infected larvae were fed on mulberry leaves which had been smeared bavistin at the concentration of 10,000 ppm, twice each day until moulting of third instar larvae. The results showed that bavistin was effective in preventing transovarian transmission of Nosema in silkworm, Bombyx mori L. The disease incidence of the progeny infected from the adults reared as larvae on bavistin containing mulberry leaves was much less than that of the control group (no bavistin).

Finally, the effect of artificial diets containing bavistin on the Nosema of Bombyx mori was also studied. The newly hatched, transovarially infected pebrine larvae were reared on artificial diets containing 100 ppm bavistin during all the instars, after emergence these adults were examined to be free of Nosema spores. It suggests that a new method for the control pebrine disease will be developed.

## INTRODUCTION

Pebrine is a main disease attacking silkworms. It threatens the sericulture and the silkworm seed production especially. For over one century, Louis Pasteur Method has been continually used to the diagnosis of *Nosema bombycis* in sericulture. Owing to the research development of therapeutic drugs these years, chemical control over *Nosema* of insects has begun to produce the desired results. Benomyl has already been proved fairly effective on *Nosema* of alfalfa weevil (Hsiao *et al.*, 1973) and some elimination on *Nosema whitei* (Shinhloster, 1974), *Nosema* of fly (Armstrong, 1976), *Nosema* of corn earworm (Brooks, 1978), and so on. The present study was designed by the author to determine the effectiveness of benomyl and other like drugs in controlling *Nosema bombycis* of *Bombyx mori* conducted from 1978 to 1981.

## MATERIALS AND METHODS

### 1. Test materials:

Silkworm race Guangnong-3, a multivoltine in Guangdong province. As pathogen of pebrine collected and purified *Nosema* spores from Guangdong sericultural area.

### 2. Test drugs:

Bavistin, benomyl and thiophanate, etc. Totally 12 fungicides.

### 3. Methode to test curative effect:

Mulberry leaves smeared with suspension containing  $10^3$ - $10^6$  *Nosema* spores/ml were used to feed 5th instar larvae just after ecdysis. Then, they were separated into two groups being fed with mulberry leaves containing various chemicals at different concentration 1-3 times a day after infection for 12-36 hours until they all come to maturity, except the control group with no chemical added. After the moths emerged, they were examined by microscope. The index of incidence was finally calculated and used as the curative effect.

### 4. Method to test the curative effect on transovarial transmission of *Nosema* in silkworm:

The moth's layings with different degrees of infection were selected and hatched for test. The newly hatched larvae were separated into two parts for each laying, one for chemical treatment and the other for check. The treated larvae were fed with chemicals at different concentration twice a day until they became third instar moulting larvae. Then both the experimental and control larvae were examined individually to calculate the disease incidence and the index of infection.

## RESULTS

### 1. The result from chemical screening for the control over pebrine disease of *Bombyx mori*.

The results are shown in Table 1. Nine of the 12 chemicals have found effective against pebrine disease of *Bombyx mori*. They are all fungicides and very much the same in terms of their chemical structures. Thiophanate was especially found somewhat toxic to silkworm larvae making them for at least 1 to 2 hours paralyzed. Though the other 7 ones did not have obvious toxicity to silkworms, they did affect the growth and development of the larvae and reduce the cocoon yield in the case of dense concentration of the chemicals.

## 2. The curative effects of bavistin and benomyl on pebrine disease of silkworm.

The results are shown in Table II. The 5th instar larvae were fed once a day with mulberry leaves treated in 4% bavistin or benomyl solutions by 12 hrs postexposure to *Nosema* spores suspension at  $10^3$ - $10^5$  spores/ml concentration. The result (see Table II) showed that the index of infection of bavistin-treated group was 0-0.8%, the benomyl-treated group 0-5.3%, and the curative effect up to 94.7-100% at the highest significance level.

## 3. The curative effects of bavistin on the transovarian transmission of *Nosema* in silkworm.

In the N1-N3 groups, three layings were found to be lightly infected by pebrine. Each laying was separated into two parts. One for the control group, the other for treated group. The larvae in treated groups were fed on mulberry leaves with 1% bavistin once a day from newly hatched larvae to third moulting. The results (Table III) showed that the average of disease incidence was 11.9% in control group, whereas no infection was found in the treated group. The same procedure was taken on the other three layings, which were N4-N6 and heavily infected. N4-N6 incidence of infection was 61.9% for the control group, and only 3.8% for the treated group.

## 4. The effect of artificial diets containing bavistin on *Nosema* of *Bombyx mori*.

Eight infected layings were selected for test, then each laying was separated into two parts for control and treated groups respectively. The newly hatched larvae from these infected layings were fed with artificial diets 0.1-10mg/g bavistin added for the treated ones through all the instars. The results (Table IV) showed that the incidence of infection was 92.4-100.0% for the control groups, while the treated groups were completely free from *Nosema* infection, indicating very satisfactory curative effects. It suggested that the transovarially infected pebrine larvae could completely be cured, if artificial diet containing bavistin is used to rear them through all the instars.

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| Name of drugs      | Concentration of drugs (%) | Number of tested silkworms | Number of examined silkworms | Index of infection (%)* |
|--------------------|----------------------------|----------------------------|------------------------------|-------------------------|
| Benomyl            | 0.5                        | 111                        | 109                          | 7.3                     |
| Bavistin           | 0.5                        | 73                         | 72                           | 5.5                     |
| Thiophanate-methyl | 0.25                       | 68                         | 65                           | 11.1                    |
| Thiophanate        | 0.25                       | 78                         | 75                           | 15.1                    |
| 7313               | 0.5                        | 114                        | 113                          | 6.0                     |
| 7314               | 0.5                        | 75                         | 74                           | 0                       |
| 7315               | 0.25                       | 66                         | 65                           | 24.2                    |
| 7321               | 0.5                        | 73                         | 73                           | 21.6                    |
| 7322               | 0.5                        | 76                         | 76                           | 0                       |
| Control            | /                          | 93x3                       | 87x3                         | 100.0                   |

$$* \text{ The index of infection } = \frac{\text{disease incidence in treated groups}}{\text{disease incidence in control groups}} \times 100\%$$

Table I. Curative effect of selected drugs against pebrine disease of silkworm.

| Concentration of <i>Nosema</i> spores to be fed | Treatment   | Number of tested silkworms | Number of cocoons | Counts of emerged adults | Disease incidence (%) | Index of infection (%) |
|-------------------------------------------------|-------------|----------------------------|-------------------|--------------------------|-----------------------|------------------------|
| $10^3$ /ml                                      | 4% bavistin | 148                        | 148               | 148                      | 0                     | 0                      |
|                                                 | 4% benomyl  | 136                        | 135               | 134                      | 0.7                   | 5.3                    |
|                                                 | Control     | 132                        | 132               | 129                      | 13.2                  | 100.0                  |
| $10^4$ /ml                                      | 4% bavistin | 135                        | 134               | 130                      | 0                     | 0                      |
|                                                 | 4% benomyl  | 140                        | 140               | 140                      | 0                     | 0                      |
|                                                 | Control     | 140                        | 139               | 137                      | 61.3                  | 100.0                  |
| $10^5$ /ml                                      | 4% bavistin | 130                        | 130               | 128                      | 0.8                   | 0.8                    |
|                                                 | 4% benomyl  | 137                        | 134               | 133                      | 0                     | 0                      |
|                                                 | Control     | 145                        | 138               | 130                      | 94.5                  | 100.0                  |

Table II. The curative effects of bavistin and benomyl on pebrine disease of silkworm.

| Serial number<br>of infected<br>layings | Layings<br>infection<br>degree | Treatment | Number of<br>counted<br>silkworms | Disease<br>incidence<br>% | Index of<br>infection<br>% |
|-----------------------------------------|--------------------------------|-----------|-----------------------------------|---------------------------|----------------------------|
| N1-N3                                   | lightly                        | control   | 84                                | 11.9                      | 100.0                      |
|                                         | lightly                        | treated   | 84                                | 0                         | 0                          |
| N4-N6                                   | heavily                        | control   | 84                                | 61.9                      | 100.0                      |
|                                         | heavily                        | treated   | 80                                | 3.8                       | 6.1                        |

Table III. The curative effects of bavistin on the infected layings.

| Serial no. and<br>infection degree<br>of laying | Contents of<br>bavistin in<br>artificial diet | Number of<br>tested<br>silkworms | % infection<br>of 5th instar | %<br>infection<br>of moths | Total<br>infection<br>% |
|-------------------------------------------------|-----------------------------------------------|----------------------------------|------------------------------|----------------------------|-------------------------|
| 01-02<br>heavily                                | 10mg/g                                        | 60                               | 0                            | 0                          | 0                       |
|                                                 | 0 (control)                                   | 59                               | 100                          | 100                        | 100                     |
| 03-04<br>heavily                                | 1mg/g                                         | 53                               | 0                            | 0                          | 0                       |
|                                                 | 0 (control)                                   | 56                               | 100                          | 100                        | 100                     |
| 05-06<br>medium                                 | 0.5mg/g                                       | 72                               | 0                            | 0                          | 0                       |
|                                                 | 0 (control)                                   | 61                               | 96.4                         | 100                        | 98.4                    |
| 07-08<br>medium                                 | 0.1mg/g                                       | 89                               | 0                            | 0                          | 0                       |
|                                                 | 0 (control)                                   | 66                               | 87.2                         | 100                        | 92.4                    |

Table IV. All instar rearing result with artificial diets containing bavistin.

## STUDY ON SOME MATERIALS TO CONTROL APPROPRIATE MICRO-ENVIRONMENTAL CONDITIONS FOR YOUNG SILKWORM REARING

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*Creation of an appropriate micro-environment for young silkworm rearing (the 1st-2nd instar) by adopting paraffin paper and foam rubber strips. The object is to prevent withering of chopped leaves and also help to maintain proper humidity in the rearing bed. By this procedure robust and healthy larvae can be obtained for further rearing.*

### INTRODUCTION

High temperature and high humidity play an important part in the growth of young silkworm (28°C and 85% of relative humidity). In tropical countries, low humidity has to be faced during some rearing seasons such as from October of the first year to June of the next. This study was carried out to find out some materials which prevent withering of chopped leaves and create appropriate environment in the rearing bed. Vigorous and healthy larvae will be obtained in such a crop.

### MATERIALS AND METHOD

Silkworm race: K1xK8

Four replications of single laying have been made for each treatment. The treatments are described below:

T.1. Rearing the 1st-2nd instar in natural conditions (control).

T.2. Rearing the 1st-2nd instar as the base and the upper were covered with paraffin paper.

T.3. Rearing the 1st-2nd instar with foam rubber strips as the base and the upper was covered with paraffin paper.

T.4. Rearing the 1st-2nd instar with foam rubber strips as the base and the upper was covered with transparent plastic.

T.5. Rearing the 1st-2nd instar as the upper was covered with wet cloth.

The 1st-2nd instar larvae were reared with the treatments described above. The foam rubber strips must be dipped in water before resorting and placed in the bed. During moulting period all the materials used have to be removed to keep the rearing bed dried. The feeding time in each day is 08.00, 11.00, and 16.00 o'clock. This experiment was carried out in May, August, October 1984 and January 1985 at Ubon Sericultural Experiment Station.

The principal items measured, calculated and observed were as follows:

1. The larval duration.
2. The average weight of 10 mature worms.
3. Effective rate of rearing (sound pupa ratio).
4. Single cocoon weight.
5. Single cocoon shell weight.
6. Cocoon shell ratio.

## RESULTS

The results are presented in Tables I-VI.

In Table I: the larval duration of T.1 is longer than in other treatments.

In Tables II-V: T.2 to T.5 have shown better than T.1 in all principal aspects especially in the item of single cocoon, and single cocoon shell weight.

## DISCUSSION

It is observed that T2 to T5 give shorter larval period duration than T1. Creation of an appropriate micro-environment by adopting foam rubber strips, paraffin paper and transparent plastic plays an important role for the vigor and health of silkworm. During the rainy season the rearers have to keep in mind to adopt some materials for the period of 1st and 2nd instar rearing. If low relative humidity was faced some materials should be applied.

## CONCLUSION

Creation of environmental conditions for young silkworm rearing by adopting suitable materials plays an important role for low relative humidity season and results in the increasing of single cocoon, single cocoon shell weight as well as the uniform growth and strength of larvae.

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| Treatment | Rearing season |       |             |       |              |       |              |       |
|-----------|----------------|-------|-------------|-------|--------------|-------|--------------|-------|
|           | May 1984       |       | August 1984 |       | October 1984 |       | January 1985 |       |
|           | Days           | Hours | Days        | Hours | Days         | Hours | Days         | Hours |
| T1        | 20             | 05    | 19          | 08    | 20           | 05    | 23           | 06    |
| T2        | 19             | 08    | 19          | 08    | 20           | 05    | 22           | 06    |
| T3        | 19             | 08    | 19          | 08    | 20           | 05    | 22           | 06    |
| T4        | 19             | 08    | 19          | 08    | 20           | 05    | 21           | 06    |
| T5        | 20             | 00    | 19          | 08    | 20           | 05    | 22           | 06    |

Table I. The larvae duration.

| Treatment | Average weight of<br>10 mature worms<br>(g) | E.R.R.<br>(%) | Single cocoon<br>weight<br>(g) | Single cocoon<br>shell weight<br>(cg) | Cocoon shell<br>ratio<br>(%) |
|-----------|---------------------------------------------|---------------|--------------------------------|---------------------------------------|------------------------------|
| T1        | 34.94 b                                     | 89.00         | 1.44 b                         | 32.22 c                               | 22.30 ab                     |
| T2        | 39.38 a                                     | 90.32         | 1.63 a                         | 53.15 b                               | 21.58 ab                     |
| T3        | 39.82 a                                     | 91.25         | 1.66 a                         | 36.25 ab                              | 21.88 ab                     |
| T4        | 37.78 a                                     | 90.32         | 1.69 a                         | 36.88 a                               | 21.32 b                      |
| T5        | 38.13 a                                     | 89.35         | 1.66 a                         | 37.25 a                               | 22.50 a                      |
| CV. (%)   | 3.3                                         | 3.0           | 3.8                            | 3.0                                   | 2.8                          |

Table II. The means on May, 1984.

| Treatment | Average weight of<br>10 mature worms<br>(g) | E.R.R.<br>(%) | Single cocoon<br>weight<br>(g) | Single cocoon<br>shell weight<br>(cg) | Cocoon shell<br>ratio<br>(%) |
|-----------|---------------------------------------------|---------------|--------------------------------|---------------------------------------|------------------------------|
| T1        | 44.35 b                                     | 89.75 a       | 1.96 a                         | 39.80 b                               | 20.30 ab                     |
| T2        | 44.65 ab                                    | 81.37 bc      | 2.03 a                         | 41.25 ab                              | 20.30 ab                     |
| T3        | 45.15 a                                     | 83.12 ab      | 2.06 a                         | 41.52 a                               | 20.12 ab                     |
| T4        | 45.27 a                                     | 75.37 c       | 1.95 a                         | 41.25 ab                              | 21.22 a                      |
| T5        | 45.80 a                                     | 84.00 ab      | 2.05 a                         | 41.25 ab                              | 20.10 b                      |
| CV. (%)   | 2.3                                         | 2.8           | 4.0                            | 2.4                                   | 3.3                          |

Table III. The means on August, 1984.

| Treatment | Average weight of<br>10 mature worms<br>(g) | E.R.R.<br>(%) | Single cocoon<br>weight<br>(g) | Single cocoon<br>shell weight<br>(cg) | Cocoon shell<br>ratio<br>(%) |
|-----------|---------------------------------------------|---------------|--------------------------------|---------------------------------------|------------------------------|
| T1        | 36.8 b                                      | 97.7          | 1.90 b                         | 38.9 c                                | 20.5                         |
| T2        | 40.9 a                                      | 97.6          | 2.02 a                         | 40.4 bc                               | 19.9                         |
| T3        | 41.2 a                                      | 97.0          | 2.11 a                         | 42.4 a                                | 20.1                         |
| T4        | 42.1 a                                      | 96.7          | 2.09 a                         | 42.4 a                                | 20.3                         |
| T5        | 42.1 a                                      | 97.1          | 2.04 a                         | 41.2 ab                               | 20.2                         |
| CV. (%)   | 4.8                                         | 0.8           | 3.7                            | 2.9                                   | 2.7                          |

Table IV. The means on October, 1984.

## IMPROVEMENT OF THE STOUTNESS OF PURE BIVOLTINE SILKWORM RACES

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*Improvement of the stoutness of pure bivoltine silkworm races that were used as parent to produce the F1 hybrid to the farmers was undertaken. We are carrying the Thai polyvoltine current to produce the stronger lineage of pure bivoltine silkworm races. Our breeding started in 1984 by "Mass Selection" and "Back crossing".*

### INTRODUCTION

The pure bivoltine races are higher in productivity but lower in viability than Thai Polyvoltine races. To increase the stoutness of pure bivoltine silkworm races, we are using the usual Thai polyvoltine races in crossing, to produce a stronger lineage of pure bivoltine silkworm race. From the selection we obtain a new race, stronger than the pure bivoltine silkworm race and of the same productivity.

### MATERIAL AND METHOD

Races used are K8, K16 (Chinese races), K1, K9, K13, K15, PN39 (Japanese races) and Thai polyvoltine yellow cocoon from Chaiyapoom.

"Mass Selection" was performed on the following items:

1. Larval duration
2. High hatchability of eggs
3. Growth uniformity.
4. Stoutness with high cocooning ratio and high sound pupa ratio
5. Heavy weight of cocoon and cocoon shell.

Successive "Back crossing" with pure bivoltine silkworm race and Thai polyvoltine race were done, e.g. K8 x THAI and then F1 hybrid from K8 x THAI crossing with pure bivoltine (K8) for 6 times, e.g. K8 x THAI X K8'. Selection and study were

performed on white cocoons and plain or marking like the parents only.

## RESULT AND DISCUSSION

The results are shown in Table II and III.

From the selection, we obtain the new race which is stronger than the pure bivoltine silkworm race and with the same productivity, e.g. survival 4th age percentage and sound pupa percentage of K8 x THAI x K8<sup>7</sup> (BC6) higher than K8, but shell percentage of BC6 neighbouring K8.

From this experiment, we have the new races with high productivity and viability, e.g. K8 x THAI x K8<sup>7</sup>, K1 x THAI x K1<sup>7</sup>, K9 x THAI x K9<sup>7</sup>, K13 x THAI x K13<sup>7</sup>, and PN39 x THAI x PN39<sup>7</sup>.

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| Rearing season |      | Temperature °C |         |         | relative humidity % |         |         |
|----------------|------|----------------|---------|---------|---------------------|---------|---------|
|                |      | maximum        | minimum | average | maximum             | minimum | average |
|                |      |                |         |         |                     |         |         |
| May            | 1984 | 35.0           | 24.5    | 29.8    | 96                  | 60      | 78      |
| July           | 1984 | 34.5           | 24.0    | 28.8    | 96                  | 49      | 69      |
| September      | 1984 | 33.0           | 25.0    | 29.3    | 96                  | 50      | 70      |
| January        | 1985 | 33.0           | 20.0    | 26.1    | 89                  | 40      | 63      |
| June           | 1985 | 32.0           | 26.0    | 29.1    | 90                  | 50      | 73      |
| August         | 1985 | 31.0           | 25.5    | 28.1    | 90                  | 58      | 75      |
| November       | 1985 | 28.5           | 21.0    | 25.3    | 98                  | 59      | 81      |
| June           | 1986 | 32.5           | 26.0    | 29.4    | 99                  | 54      | 76      |

Table I. Temperature and humidity in rearing room during rearing period

| Race             | Term<br>1-5 stage<br>d h |    | Hatch-<br>ability<br>% | Normal<br>cocoon<br>% | Survival<br>4th age<br>% | Cocoon<br>-ing<br>% | Sound<br>pupa<br>% | Whole<br>cocoon/<br>gm | Cocoon<br>shell/<br>cg | Shell<br>% |
|------------------|--------------------------|----|------------------------|-----------------------|--------------------------|---------------------|--------------------|------------------------|------------------------|------------|
| THAI             | 18                       | 23 | 90.0                   | 80.3                  | 94.8                     | 100.0               | 99.3               | 0.66                   | 8.4                    | 12.7       |
| K8               | 19                       | 23 | 91.2                   | 78.1                  | 91.3                     | 98.0                | 92.0               | 1.10                   | 24.2                   | 22.0       |
| K8 x THAI        | 19                       | 20 | 94.1                   | 84.1                  | 97.9                     | 97.5                | 96.5               | 1.01                   | 17.4                   | 17.2       |
| K8 x THAI x K8   | 19                       | 20 | 96.4                   | 74.7                  | 94.9                     | 89.0                | 74.5               | 0.82                   | 14.6                   | 17.8       |
| BC6              | 20                       | 20 | 93.9                   | 88.9                  | 96.5                     | 99.5                | 94.0               | 1.12                   | 22.6                   | 20.2       |
| THAI             | 18                       | 23 | 90.0                   | 80.3                  | 94.8                     | 100.0               | 99.3               | 0.66                   | 8.4                    | 12.7       |
| K16              | 20                       | 23 | 94.0                   | 83.7                  | 91.0                     | 95.0                | 86.0               | 0.95                   | 19.8                   | 20.8       |
| K16 x THAI       | 19                       | 20 | 97.1                   | 92.5                  | 96.1                     | 100.0               | 98.0               | 0.87                   | 14.6                   | 16.8       |
| K16 x THAI x K16 | 20                       | 05 | 95.5                   | 84.8                  | 97.0                     | 95.5                | 91.5               | 1.12                   | 21.4                   | 19.1       |
| BC6              | 20                       | 05 | 97.6                   | 80.2                  | 92.9                     | 88.5                | 80.5               | 1.04                   | 20.0                   | 19.2       |

Remark : Data of Thai Polyvoltine Race were collected from May 1984 rearing season.

Table II. Comparison on Thai Polyvoltine, Pure Chinese Bivoltine and BC6 (June 1986)

| Race           | Term<br>1-5 stage |    | Hatch-<br>ability | Normal<br>cocoon | Survival<br>4th age | Cocoon-<br>ing | Sound<br>pupa | Whole<br>cocoon/<br>one | Cocoon<br>shell/one | Shell |
|----------------|-------------------|----|-------------------|------------------|---------------------|----------------|---------------|-------------------------|---------------------|-------|
|                | d                 | h  | %                 | %                | %                   | %              | %             | gm                      | cg                  | %     |
| THAI           | 18                | 23 | 90.0              | 80.3             | 94.8                | 100.0          | 99.3          | 0.66                    | 8.4                 | 12.7  |
| K1             | 20                | 05 | 86.6              | 86.6             | 83.8                | 94.9           | 93.5          | 0.85                    | 14.5                | 17.0  |
| K1 x THAI      | 19                | 20 | 93.7              | 88.5             | 97.7                | 96.0           | 94.0          | 1.05                    | 19.8                | 18.9  |
| K1 x THAI x K1 | 19                | 20 | 93.5              | 83.3             | 97.4                | 93.0           | 90.5          | 0.83                    | 14.0                | 16.9  |
| BC6            | 19                | 04 | 95.1              | 90.6             | 97.7                | 95.5           | 93.5          | 1.29                    | 27.0                | 20.0  |
| THAI           | 18                | 23 | 90.0              | 80.3             | 94.8                | 100.0          | 99.3          | 0.66                    | 8.4                 | 12.7  |
| K9             | 20                | 23 | 90.4              | 79.3             | 92.1                | 84.5           | 78.0          | 0.89                    | 16.8                | 18.9  |
| K9 x THAI      | 19                | 20 | 90.1              | 95.0             | 94.9                | 100.0          | 100.0         | 0.86                    | 13.0                | 15.1  |
| K9xTHAIxK9     | 20                | 20 | 91.2              | 83.3             | 98.9                | 93.0           | 86.0          | 1.00                    | 17.8                | 17.8  |
| BC6            | 20                | 23 | 90.8              | 86.0             | 97.1                | 89.0           | 86.5          | 1.02                    | 20.6                | 20.2  |
| THAI           | 18                | 23 | 90.0              | 80.3             | 94.8                | 100.0          | 99.3          | 0.66                    | 8.4                 | 12.7  |
| K13            | 20                | 23 | 89.9              | 77.8             | 89.2                | 81.0           | 72.7          | 1.14                    | 23.2                | 20.4  |
| K13 x THAI     | 19                | 05 | 92.9              | 94.2             | 96.5                | 94.5           | 93.0          | 1.93                    | 16.8                | 18.1  |
| K13xTHAIxK13   | 20                | 05 | 92.9              | 87.3             | 93.7                | 98.0           | 94.5          | 1.19                    | 22.6                | 19.0  |
| BC6            | 21                | 20 | 90.9              | 78.6             | 90.4                | 91.0           | 83.0          | 1.12                    | 23.0                | 20.5  |
| THAI           | 18                | 23 | 90.0              | 80.3             | 94.8                | 100.0          | 99.3          | 0.66                    | 8.4                 | 12.7  |
| K15            | 20                | 05 | 95.3              | 78.7             | 93.9                | 98.5           | 95.5          | 0.93                    | 16.4                | 17.6  |
| K15xTHAI       | 19                | 20 | 95.2              | 85.9             | 89.6                | 99.5           | 98.5          | 0.85                    | 13.2                | 15.5  |
| K15xTHAIxK15   | 19                | 23 | 90.7              | 71.9             | 83.7                | 89.0           | 87.0          | 0.86                    | 14.8                | 17.2  |
| BC6            | 19                | 23 | 97.3              | 82.6             | 94.5                | 95.0           | 92.5          | 0.94                    | 16.4                | 17.5  |
| THAI           | 18                | 23 | 90.0              | 80.3             | 94.8                | 100.0          | 99.3          | 0.66                    | 8.4                 | 12.7  |
| PN39           | 20                | 23 | 94.1              | 77.3             | 96.0                | 94.5           | 85.0          | 1.28                    | 28.2                | 22.0  |
| PN39xTHAI      | 19                | 20 | 90.1              | 81.9             | 90.8                | 94.0           | 91.0          | 1.08                    | 18.4                | 17.0  |
| PN39xTHAIxPN39 | 20                | 20 | 94.0              | 75.2             | 95.5                | 78.5           | 73.0          | 1.21                    | 22.6                | 18.7  |
| BC6            | 20                | 05 | 96.8              | 76.6             | 97.0                | 96.0           | 83.0          | 1.23                    | 25.2                | 20.5  |

Remark : Data of Thai Polyvoltine race were collected from May 1984 rearing season.

Table 111. Comparison on Thai Polyvoltine, Pure Japanese Bivoltine and BC6  
(June 1986)

## SOME CHEMICALS DISSOLVE NUCLEAR POLYHEDROSIS VIRUS OF SILKWORM

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*Grasserie or Polyhedrosis Virus is one of the most serious diseases of silkworm in Thailand. Polyhedron are easily dissolved in alkaline solution and release the free virus. Free virus loses its pathogenicity in a relatively short time. This experiment is dropping different chemical solutions on the polyhedron and the time of dissolution is observed by microscope. The concentrations of each chemical solution are NaOH(40%) 1:3000 KOH (56.11) 1:1000, Chlorinated Lime 1:200 and three kinds of lime 2:100.*

### INTRODUCTION

Grasserie or Nuclear Polyhedrosis Virus is one of the most serious disease of silkworm in Thailand. Polyhedron keeps its pathogenicity for several years in rearing room. As reported, polyhedron are easily dissolved in alkaline solution. Free virus loses its pathogenicity within 10 minutes at 50°-60° C. The purpose of the experiment is to find a suitable concentration of alkaline solution. This will be useful in the local parts of Thailand, where sericulture farmers cannot find formaline, sprayer machine and mask for disinfection, tools or rearing room.

### MATERIAL AND METHOD

The chemicals used in this experiment are NaOH (40%), KOH (56.11%), chlorinated lime (60%), three kinds of lime and ash. These chemicals are mixed with water (pH 6.68) in different concentrations. Complete polyhedron dissolution on the whole field of the microscope is observed after five minutes.

## RESULTS AND DISCUSSION

The solutions of each chemical more concentrated than NaOH (40%) 1:3000, KOH (56.11%) 1:1000, chlorinated lime (60%) 1:200, limes A.B.C. 2:100 and ash 30:100 lead to dissolved polyhedron on the whole field in about five minutes.

Some chemicals will be used for controlling grasserie disease in pooa areas, such as chlorinated lime and limes. Disinfection method consists of dipping or spraying on tools and rearing room. After that, the free virus is killed by sunlight. This method will decrease the population of Nuclear polyhedrosis virus.

## REFERENCES

- JAPAN OVERSEAS COOPERATION COLUNTEER, 1975, Silkworm disease in tropical countries. Text Book of Tropical Sericulture, 557.
- KITAKURA INDUSTRY CO Ltd., The principle of silkworm rearing.

| Chemicals               | Concentration | Period of dissolve polyhedron/sec |                 |     |
|-------------------------|---------------|-----------------------------------|-----------------|-----|
|                         |               | First polyhedron                  | Last polyhedron | %   |
| NaOH<br>(40%)           | 1:2000        | 7-15                              | 55-75           | 100 |
|                         | 1:3000        | 15-25                             | 180-300         | 100 |
|                         | 1:4000        | 35-50                             | -               | 30  |
| KOH<br>(56.11%)         | 1:100         | 3-4                               | 5-6             | 100 |
|                         | 1:1000        | 15-20                             | 120-240         | 100 |
|                         | 1:2000        | 30-40                             | -               | 10  |
| Chlorinated<br>Line 60% | 3:100         | 16-25                             | 50-120          | 100 |
|                         | 2:100         | 30-35                             | 210-270         | 100 |
|                         | 1:100         | 30-35                             | 210-270         | 100 |
|                         | 1:200         | 45-60                             | 210-240         | 100 |
| Lime A                  | 4:100         | 3-5                               | 35-60           | 100 |
|                         | 3:100         | 3-5                               | 35-65           | 100 |
|                         | 2:100         | 10-15                             | 300             | 100 |
|                         | 1:100         | 10-41                             | -               | 50  |
| Lime B                  | 4:100         | 5-7                               | 50-90           | 100 |
|                         | 3:100         | 5-8                               | 50-90           | 100 |
|                         | 2:100         | 9-15                              | 120-210         | 100 |
|                         | 1:100         | 45-50                             | -               | 50  |
| Lime C                  | 4:100         | 7-10                              | 55-120          | 100 |
|                         | 3:100         | 7-10                              | 60-120          | 100 |
|                         | 2:100         | 10-15                             | 90-180          | 100 |
|                         | 1:100         | 10-20                             | -               | 50  |
| Ash                     | 30:100        | 25-30                             | 180-270         | 100 |
|                         | 20:100        | 210-240                           | -               | 30  |
|                         | 0:100         | -                                 | -               | 0   |

Remarks: Period of dissolve polyhedron from 3 replications.

Table. Dissolubility of polyhedron in alkaline solutions.

## STUDY ON APPROPRIATE TIME OF BED CLEANING AT THE 5th STAGE OF SILKWORM LARVAE

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### INTRODUCTION

The appropriate time of bed cleaning was studied to decrease the labour for the farmers. They work hard in 5th instar of silkworm rearing especially for feeding and preparing the mounting of silkworms. Another reason of bed cleaning in suitable time is for avoiding the infection.

### MATERIAL AND METHOD

F1 hybrid bivoltine race of K1xK8

Randomized complete block design with 5 treatments and 4 replications.

Bed cleaning once a day,  
Bed cleaning once in two days  
Bed cleaning once in three days  
Bed cleaning once in four days  
Bed cleaning once in five days.

Feeding times

6.00 o'clock, 30% of daily supplied leaves  
11.00 o'clock, 30% of daily supplied leaves  
16.00 o'clock, 40% of daily supplied leaves.

Number of silkworm

Newly hatched silkworm larvae 1gm/replication

1000 larvae of 5th stage (200 larvae x 5 rep/ treatment)

# RESULT

Non significant result among treatments were recognized. The omission of bed cleaning in the 5th stage may have no serious effect on the physiology of silkworms.

|             |    | Mean Squares       |                     |                           |                                  |                                  |                                   |
|-------------|----|--------------------|---------------------|---------------------------|----------------------------------|----------------------------------|-----------------------------------|
| SV          | df | Moulting<br>number | Cocooning<br>number | Sound<br>cocoon<br>number | Whole<br>cocoon<br>weight<br>(g) | Cocoon<br>shell<br>weight<br>(g) | Cocoon<br>shell<br>percent<br>(%) |
| Replication | 3  | 3.6000             | 4.1833              | 8 5833                    | 0.0004                           | 0.1587                           | 0.0152                            |
| Treatment   | 4  | 0.9250ns           | 1.2000ns            | 29.8000ns                 | 0.1006**                         | 23.8758**                        | 0.8308**                          |
| Error       | 12 | 5.3917             | 7.2000              | 25.8333                   | 0.0007                           | 0.1958                           | 0.0281                            |
| CV %        |    | 1.1                | 1.3                 | 2.6                       | 1.5                              | 1.2                              | 0.8                               |

Table 1. Analysis of variance, August.

| Treatment      | Mounting<br>number | Cocooning<br>number | Sound<br>cocoon<br>number | Whole<br>cocoon<br>weight<br>(g) | Cocoon<br>shell<br>weight<br>(cg) | Cocoon<br>shell<br>percent<br>(%) |
|----------------|--------------------|---------------------|---------------------------|----------------------------------|-----------------------------------|-----------------------------------|
| Control        | 199 a              | 198 a               | 195 a                     | 1.53 e                           | 31.30 e                           | 20.32 a                           |
| After 6 hours  | 198 a              | 198 a               | 196 a                     | 1.65 d                           | 33.95 d                           | 20.52 a                           |
| After 12 hours | 198 a              | 197 a               | 194 a                     | 1.75 c                           | 35.00 c                           | 19.97 b                           |
| After 18 hours | 199 a              | 198 a               | 192 a                     | 1.84 b                           | 36.32 b                           | 19.70 c                           |
| After 24 hours | 198 a              | 198 a               | 189 a                     | 1.94 a                           | 37.72 a                           | 19.40 d                           |

Table II. Table of means, August.

| SV          | Mean squares |                    |                     |                           |                                  |                                   |                                   |
|-------------|--------------|--------------------|---------------------|---------------------------|----------------------------------|-----------------------------------|-----------------------------------|
|             | df           | Mounting<br>number | Cocooning<br>number | Sound<br>cocoon<br>number | Whole<br>cocoon<br>weight<br>(g) | Cocoon<br>shell<br>weight<br>(cg) | Cocoon<br>shell<br>percent<br>(%) |
| Replication | 3            | 4.8500             | 4.0500              | 237.3833                  | 0.0002                           | 0.1205                            | 0.0213                            |
| Treatment   | 4            | 4.8250ns           | 4.6250(< 1)         | 35.3250ns<br>(1.03)       | 0.0556**<br>(126.99)             | 51.1030**<br>(227.46)             | 4.0618**<br>(161.93)              |
| Error       | 12           | 3.0583             | 7.0917              | 34.2583                   | 0.0004                           | 0.2247                            | 0.0251                            |
| CV %        |              | 0.8                | 1.3                 | 3.2                       | 1.5                              | 1.8                               | 0.8                               |

Table III. Analysis of variance, October.

| Treatment      | Mounting<br>number | Cocooning<br>number | Sound<br>cocoon<br>number | Whole<br>cocoon<br>weight<br>(g) | Cocoon<br>shell<br>weight<br>(cg) | Cocoon<br>shell<br>percent<br>(%) |
|----------------|--------------------|---------------------|---------------------------|----------------------------------|-----------------------------------|-----------------------------------|
| Control        | 198 a              | 197 a               | 177 a                     | 1.22 d                           | 21.47 e                           | 17.35 e                           |
| After 6 hours  | 197 a              | 196 a               | 178 a                     | 1.25 d                           | 22.52 d                           | 17.92 d                           |
| After 12 hours | 199 a              | 196 a               | 173 a                     | 1.33 c                           | 24.97 c                           | 18.70 c                           |
| After 18 hours | 198 a              | 198 a               | 181 a                     | 1.42 b                           | 27.72 b                           | 19.50 b                           |
| After 24 hours | 196 a              | 196 a               | 180 a                     | 1.50 a                           | 30.07 a                           | 19.92 a                           |

Table IV. Table of means, October.

## STUDY ON THE EFFICIENCY OF SILKWORM REARING AREA

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*The data concerning the efficiency of silkworms rearing area were collected in 1983-1984 to study how to reduce the capital and increase cocoon production. Because of a high rearing house expense, we got the idea to make worthy silkworm rearing areas. Three spaces were set on our trail : 3, 4, 5 m<sup>2</sup> per 5,000 larvae or 12, 16, 20 m<sup>2</sup> per box in three silkworm rearing periods. The conclusion says that 20 m<sup>2</sup> per box gives the highest cocoon production and price but the unit cost of 12 m<sup>2</sup> per box gets the highest income.*

### INTRODUCTION

Sericulture is an agriculture work which many farmers started on because the silkworm hybrid gives high money return and has no market problem. But the rearing house and instrument expenses are high. So a capital reduction for farmers is desirable. We got the idea to make worthy silkworm rearing area in our trail. There are three spaces of 12, 16 and 20 m<sup>2</sup> per box. If the hypothesis of a small scale rearing is possible, it might be a good guidance to reduce the capital and increase farmers' income.

### MATERIAL AND METHOD

30,000 silkworm hybrids were reared on 1x2 m<sup>2</sup> table in three different spaces as 3, 4, 5 m<sup>2</sup> per 5,000 larvae in three rearing periods starting in October 1st 1983, May 8th and July 4th 1984. Three feedings per day at 6.00, 11.00 a.m. and 4 p.m. were distributed; shoot rearing for old silkworm was done without bed cleaning but body disinfection was done every two days. 1,500 mature larvae were used for a rotary cocooning frame. Reeling factory was responsible to code the price.

## DISCUSSION

The rearing result form the trail derived out into two ideals:

1. The rearing method says 20 m<sup>2</sup>/box is the best,
2. The economist says 12 m<sup>2</sup>/box is the best in cost per unit, when compared to 20 m<sup>2</sup>/box as 1,310.16 Baht.

|                                                    | 12 m <sup>2</sup> /box | 16 m <sup>2</sup> /box | 20 m <sup>2</sup> /box |
|----------------------------------------------------|------------------------|------------------------|------------------------|
| Larvae contained/m <sup>2</sup>                    | 1,666                  | 1,250                  | 1,000                  |
| Return per one unit<br>over 20 m <sup>2</sup> /box | 1,310.16               | 541. 96                | 0                      |

In small scale rearing areas without bed cleaning, one must beware of easily caused diseases. On the other hand, mulberry consumption is less and larval duration is shorter than in control.

| Description                        | 3 m <sup>2</sup> per<br>5,000 larvae | 4 m <sup>2</sup> per<br>5,000 larvae | 5 m <sup>2</sup> per<br>5,000 larvae |
|------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| Mulberry for young<br>silkworm/box | 20.60                                | 20.60                                | 20.60                                |
| Mulberry for old<br>silkworm/box   | 338.20                               | 362.20                               | 362.20                               |
| Mulberry<br>1-5 instar/box         | 358.80                               | 382.80                               | 382.80                               |
| N° of mature silkworm              | 4,484                                | 4,543                                | 4,595                                |
| % of larvae survival               | 89.68                                | 90.86                                | 91.90                                |
| N° of good cocoons                 | 3,987                                | 3,968                                | 4,002                                |
| N° of bad cocoons                  | 193                                  | 206                                  | 268                                  |
| Wt. of good cocoon                 | 5.78                                 | 5.9                                  | 6.12                                 |
| Wt. of bad cocoon                  | 0.35                                 | 0.31                                 | 0.47                                 |
| Average 1kg. cocoon<br>weight      | 692                                  | 675                                  | 654                                  |
| Single cocoon wt*                  | 1.50                                 | 1.54                                 | 1.55                                 |
| Single cocoon shell<br>wt.**       | 29.17                                | 29.90                                | 30.30                                |
| % cocoon shell                     | 19.45                                | 19.42                                | 19.55                                |

\* Means gram

\*\* Means centigram

Table I. Results obtained with different areas.

| Treatment                               | Product/<br>box | Kg.<br>price | Price/<br>box | Price/<br>m <sup>2</sup> | Addi-<br>tional<br>area | Increased<br>income | Price/<br>unit | Different<br>price |
|-----------------------------------------|-----------------|--------------|---------------|--------------------------|-------------------------|---------------------|----------------|--------------------|
| 3m <sup>2</sup> (12m <sup>2</sup> /box) | 23.12           | 85.00        | 1965.20       | 163.77                   | 8                       | 1310.16             | 3275.36        | 1084.40            |
| 4m <sup>2</sup> (16m <sup>2</sup> /box) | 23.64           | 91.71        | 2167.79       | 135.49                   | 4                       | 541.96              | 2709.75        | 518.79             |
| 5m <sup>2</sup> (20m <sup>2</sup> /box) | 24.48           | 89.50        | 2190.96       | 109.55                   | 0                       | 0                   | 2190.96        | 0                  |

Table II. Production and cocoon price.

## THE DATA COLLECTION ON (K1.K13)xK8 HYBRID RACE

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*The Sericulture Institute has been undertaking several researches in order to obtain a better and higher yield and at the same time to contribute and share its experience with sericulture farmers. The (K1.K13)xK8 multiplication seed is found to be the most suitable one, especially to be used for training purposes.*

*Under the four researches undertaken, 5,000 young (D1.K13)xK8 silkworms were placed on the rearing m2 table and fed with chopped young mulberry leaves. At the same time the other elder 1,000 larvae were also reared on the other m2 table but fed with shoot rearing. Of these four rearing times, the findings were:*

*The average cocoon production was 25.32 kg/box (20,000),*

*The cocoon shells were 20.21%.*

*The Center could then conclude that the (K1.K13)xK8 was well accepted to be the best hybrid in both quality and quantity.*

## INTRODUCTION

Emphasizing on both quality and quantity, new multiplication silkworms hybrids are being continuously experimented at the Center. The outcomes of the experiment have always enabled farmers to gain more income. Up to now, the newly best bred multiplication seed ever found at the Center is the (K1.K13)xK8. The experiments on the (K1.K13)xK8 have all been undertaken here at the Center. The experimental conditions of the many settings were merely the same. For example, the experiments and the whole work were run by the trainees who had less or no experience in working with silkworms. Thus, chances for silkworms to contract harmful diseases seemed easy. Anyhow, data collecting could presumably find its standard (Tables I-IV).

## MATERIAL AND METHOD

At the training time, the trainees were divided into 10 groups, to work on the experiment. Trainees would rear silkworms, the hybrid (K1.K13)xK8 with mulberry variety named 'Noi' on the tables in the training in-door. Then three feeding times per day were followed: at 6.00 a.m., 11.00 a.m. and 4.00 p.m. respectively - chopped mulberry leaves for young silkworms (5,000 larvae per m<sup>2</sup>) and shoot rearing to old silkworms (1,000 larvae per m<sup>2</sup>). In the four-time experiments, works before and after preparation of hakitake, area enlargement, bed cleaning, disease control, cocoon harvesting and cocoon selection, etc, were carefully taken care of.

The data were collected on September 20th, 1984, January 10th, 1985, June 10th, and October 30th, 1985.

## DISCUSSION

From the four rearing times, the outcomes are as follows:

|                           |           |
|---------------------------|-----------|
| Average cocoon production | 25.32 kg  |
| Cocoon shell              | 20.21%    |
| Mulberry 1-5 instar       | 371.63 kg |

The amount of mulberry consumption from these data was remarkably less than those used for feeding the K1xK8 meanwhile the cocoon shells were equal in number.

The F1 hybrid (K1.K13)xK8 reared by the farmers could produce 20 kg/box but the trainees could do better as shown in Table I, II and IV. They could produce 29,29 and 32.50 kg. Table III shows that the silkworms were attacked by insecticide residual effect that broke out 50%. The average cocoon production was 25 kg/box which proved that the production was higher than the target, and that would allow the farmers to raise their income.

| Description                  | 1     | 2     | Groups<br>3 | 4     | 5     | Average<br>20,000 |
|------------------------------|-------|-------|-------------|-------|-------|-------------------|
| Mulberry                     | 36.98 | 36.98 | 36.98       | 36.98 | 36.98 | 369.80            |
| Larvae survival              | 1 800 | 1 667 | 1 820       | 1 790 | 1 838 | 17 830            |
| % larvae survival            | 90.00 | 83.35 | 91.00       | 89.50 | 91.90 | 89.15             |
| No. of good cocoons          | 1 683 | 1 475 | 1 483       | 1 618 | 1 542 | 15 602            |
| No. of bad cocoons           | 101   | 145   | 196         | 110   | 182   | 1 474             |
| Good cocoon wt.              | 2.95  | 2.80  | 2.80        | 3.00  | 2.95  | 29.00             |
| Bad cocoon wt.               | 0.20  | 0.25  | 0.35        | 0.20  | 0.30  | 2.60              |
| Single cocoon wt. (g)        | 1.84  | 1.95  | 1.90        | 1.83  | 1.86  | 1.86              |
| Single cocoon shell wt. (cg) | 38.50 | 40.50 | 38.50       | 37.50 | 36.50 | 38.30             |
| Cocoon shell %               | 20.92 | 20.26 | 20.26       | 20.49 | 20.27 | 20.59             |

Table I. Result of silkworm rearing on September 20th, 1984.  
(each group 2,000 larvae)

| Description                  | 1     | 2     | Groups<br>3 | 4     | 5     | Average<br>20,000 |
|------------------------------|-------|-------|-------------|-------|-------|-------------------|
| Mulberry                     | 47.25 | 47.25 | 47.25       | 47.25 | 47.25 | 472.50            |
| Larvae survival              | 1 800 | 1 915 | 1 735       | 1 780 | 1 774 | 17 864            |
| % larvae survival            | 90.00 | 95.75 | 86.75       | 85.40 | 88.70 | 89.32             |
| No. of good cocoon           | 1 648 | 1 785 | 1 687       | 1 740 | 1 600 | 16 920            |
| No. of bad cocoon            | 41    | 48    | 53          | 115   | 137   | 788               |
| Good cocoon wt.              | 2.90  | 3.10  | 2.70        | 2.90  | 2.90  | 29.00             |
| Bad cocoon wt.               | 0.10  | 0.10  | 0.10        | 0.20  | 0.20  | 1.40              |
| Single cocoon wt. (g)        | 1.70  | 1.79  | 1.76        | 1.76  | 1.66  | 1.73              |
| Single cocoon shell wt. (cg) | 35.50 | 37.50 | 35.50       | 35.50 | 34.0  | 35.50             |
| % cocoon shell               | 20.88 | 20.95 | 20.17       | 20.17 | 20.48 | 20.58             |

Table II. Result of silkworm rearing on January 10th, 1985.  
(each group 2,000 larvae)

| Description                  | 1     | 2     | Groups<br>3 | 4     | 5     | Average<br>20,000 |
|------------------------------|-------|-------|-------------|-------|-------|-------------------|
| Mulberry                     | 28.78 | 28.78 | 28.78       | 28.78 | 28.78 | 287.80            |
| Larvae survival              | 1 036 | 961   | 1 071       | 961   | 905   | 9 868             |
| % larvae survival            | 51.80 | 48.05 | 53.55       | 48.05 | 45.25 | 49.34             |
| No. of good cocoon           | 779   | 920   | 816         | 776   | 799   | 8 180             |
| No. of bad cocoon            | 158   | 141   | 56          | 90    | 130   | 1 150             |
| Good cocoon wt.              | 1.00  | 1.15  | 1.15        | 1.10  | 1.00  | 10.80             |
| Bad cocoon wt.               | 0.25  | 0.20  | 0.10        | 0.15  | 0.20  | 1.80              |
| Single cocoon wt. (g)        | 1.41  | 1.29  | 1.30        | 1.33  | 1.33  | 1.33              |
| Single cocoon shell wt. (cg) | 28.50 | 25.50 | 26.00       | 25.50 | 25.50 | 26.20             |
| % cocoon shell               | 20.20 | 19.80 | 20.00       | 19.20 | 19.20 | 19.70             |

Table III. Result of silkworm rearing on June 10th, 1985.  
(each group 2,000 larvae)

Silkworms died because of insecticide residual effect.

| Description                  | Groups |       |       |       |       |       |       |       |       |       | Average<br>20,000 |
|------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------------------|
|                              | 1      | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |                   |
| Mulberry                     | 35.64  | 35.64 | 35.64 | 35.64 | 35.64 | 35.64 | 35.64 | 35.64 | 35.64 | 35.64 | 356.40            |
| Larvae survival              | 1 826  | 1 815 | 1 920 | 1 942 | 1 940 | 1 846 | 1 983 | 1 717 | 1 867 | 1 935 | 18 751            |
| % larvae survival            | 91.30  | 90.75 | 96.00 | 97.10 | 95.00 | 92.30 | 99.15 | 85.85 | 93.35 | 96.75 | 93.75             |
| No. of good cocoon           | 1 654  | 1 733 | 1 863 | 1 834 | 1 802 | 1 760 | 1 907 | 1 630 | 1 776 | 1 680 | 17 641            |
| No. of bad cocoon            | 172    | 17    | 48    | 70    | 74    | 51    | 45    | 43    | 62    | 77    | 660               |
| Good cocoon wt.              | 2.90   | 3.20  | 3.35  | 3.30  | 3.30  | 3.35  | 3.40  | 3.15  | 3.30  | 3.20  | 32.50             |
| Bad cocoon wt.               | 0.35   | 0.50  | 0.10  | 0.15  | 0.10  | 0.10  | 0.10  | 0.10  | 0.15  | 0.20  | 1.40              |
| Single cocoon wt. (g)        | 1.84   | 1.91  | 1.80  | 1.88  | 1.91  | 1.90  | 1.83  | 1.98  | 1.93  | 1.82  | 1.88              |
| Single cocoon shell wt. (cg) | 36.00  | 38.00 | 36.00 | 37.50 | 37.00 | 38.00 | 36.00 | 36.00 | 39.00 | 37.50 | 37.40             |
| % cocoon shell               | 19.57  | 20.16 | 20.00 | 19.95 | 19.37 | 20.00 | 19.67 | 19.70 | 20.21 | 20.60 | 19.89             |

Table IV. Result of silkworm rearing on October 30th, 1985.  
(each group 2,000 larvae)

| Description                  | Rearing time |           |           |           | Average |
|------------------------------|--------------|-----------|-----------|-----------|---------|
|                              | Sept. 20th   | Jan. 10th | June 10th | Oct. 30th |         |
| Mulberry                     | 369.80       | 472.50    | 287.80    | 356.40    | 371.63  |
| Larvae survival              | 17 830       | 17 864    | 9 868     | 18 751    | 14 845  |
| % larvae survival            | 89.15        | 89.32     | 49.34     | 93.75     | 74.22   |
| No. of good cocoon           | 15 602       | 16 920    | 8 180     | 17 641    | 14 586  |
| No. of bad cocoon            | 1 474        | 788       | 1 150     | 670       | 1 018   |
| Good cocoon wt.              | 29.00        | 29.00     | 10.80     | 32.50     | 25.32   |
| Bad cocoon wt.               | 2.60         | 1.40      | 1.80      | 1.40      | 1.80    |
| Single cocoon wt. (g)        | 1.86         | 1.73      | 1.33      | 1.88      | 1.70    |
| Single cocoon shell wt. (cg) | 38.30        | 35.50     | 26.20     | 37.40     | 34.35   |
| % cocoon shell               | 20.59        | 20.58     | 19.70     | 19.89     | 20.21   |

Table V. Data conclusion of silkworm hybrid (K1.K13)xK8 (20,000 larvae).

## EVOLUTION OF BIVOLTINE STRAIN OF SILKWORM (BOMBYX MORI) FOR SUMMER REARING IN VIETNAM

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### INTRODUCTION

Vietnam has a long tradition of sericulture dating back to ancient times. Polyvoltine races with yellow cocoons used to be reared. Though these races are sturdy to withstand the adverse climatic conditions of the tropical country, their productivity in silk and filament length is very low. Besides, the yellow silk is not popular among rearers. The quality of yarn is also inferior. By using exotic genetic resources of Univoltine and Bivoltine silkworm, it has been possible to evolve a number of Bivoltine strains which can be successfully reared in Spring (Feb.-April) and Autumn (Sept.-November). These strains can not resist the adverse climatic conditions of high temperature and high humidity prevailing in the Summer months (May-August). It is therefore a matter of prime importance to evolve Bivoltine strains suited to Summer rearing. The present paper is the report of such an endeavour.

### MATERIALS AND METHOD

27 hybrid combinations were prepared among 7 Polyvoltine indigenous strains and Bivoltine strains maintained in the germplasm bank of the research station. The progenies were exposed to stress conditions of 30-33°C and high humidity of 85-90%. Directional selection was made with higher survival rate and other economic traits. After 20 generations, it was possible to isolate one fixed line which manifests 89.2% survival, hibernated eggs, 450 eggs per moth and 15.6% silk content. The fixed line was designated as 4792. This new line was reared during the Summers of 1981, 1982, 1983 and 1984 with 2 controls, namely RVTB and 79-Polyvoltine with yellow and white cocoon respectively. Subsequently, this new Bivoltine was crossed with standard

Bivoltine lines to study its hybrid performance. The rearing data were pooled and presented in the paper.

## RESULTS AND DISCUSSIONS

The rearing results (average of 5 rearings) are presented in Table I.

From a perusal of table I, it is evident that 4792 has shown better performance almost in all the economic characters as compared to the traditional Polyvoltine races in the Summer months. Though the survival is marginally low as compared to Polyvoltine races, the fecundity, cocoon yield, cocoon and shell weights, silk content and filament length are considerably higher than those of the standard Polyvoltine races of Vietnam. The white silk of 4792, which is liked by consumers is another gain.

The fixed Bivoltine line 4792 was crossed with Bivoltine and Polyvoltine lines and reared in the Summer months with standard Polyvoltine x Bivoltine hybrid as the control. The rearing results are shown in Table II.

The rearing results show that the strain 4792 in hybrid combination with regular Bivoltine and another Summer Bivoltine strain BL in the Summer months outyields the standard Poly x Bivoltine cross by 28 and 5% respectively, though the survival was marginally low. This deficiency was compensated by recording increases in the economic traits, such as cocoon and shell weights, silk ratios and filament length. It has therefore been recommended that this Bivoltine strain should be utilized for commercial rearing during the Summer months with higher return.

## SUMMARY

By a comprehensive breeding programme, it was possible to isolate one Bivoltine line which could be successfully reared as pure line and in hybrid combinations during the Summer months in Vietnam. This line has been recommended for industrial rearing.

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| LINES | REARING CONDITIONS |        | FECUNDITY | HATCHING | LARVAL DURATION | SURVIVAL | PUPAL MORTALITY |
|-------|--------------------|--------|-----------|----------|-----------------|----------|-----------------|
|       | TEMP. °C           | R.H. % | No        | (%)      | (Day)           | (%)      | (%)             |
| 4792  | 30-33              | 85-90  | 450       | 93.3     | 19              | 89.20    | 3.0             |
| 79    | 30-33              | 85-90  | 350       | 95.8     | 19              | 90.90    | 4.0             |
| RVT8  | 30-33              | 85-90  | 285       | 97.2     | 19              | 93.00    | 2.3             |

| LINES | YIELD OF COCOONS<br>per DFL. g | SINGLE WEIGHT |           | SHELL RATIO (%) | FILAMENT LENGTH (m) | COLOUR OF COCOON |
|-------|--------------------------------|---------------|-----------|-----------------|---------------------|------------------|
|       |                                | Cocoon (g)    | Shell (g) |                 |                     |                  |
| 4792  | 353.30<br>(163.10)             | 1.28          | 0.20      | 15.60           | 500<br>(212)        | White            |
| 79    | 250.30<br>(115.50)             | 1.11          | 0.15      | 13.50           | 420.6<br>(179)      | Bluish White     |
| RVT8  | 216.60<br>(100)                | 0.90          | 0.11      | 12.20           | 234.9<br>(100)      | Yellow           |

Figures in parentheses show comparative performance

Table I. Rearing performance of newly evolved Bivoltine line (4792)

| COMBINATION<br>* | REARING CONDITIONS |        | FECUNDITY | HATCHING | LARVAL<br>DURATION | SURVIVAL |
|------------------|--------------------|--------|-----------|----------|--------------------|----------|
|                  | TEMP. °C           | R.H. % | No        | (%)      | (Day)              | (%)      |
| 4792 x 644       | 30-33              | 85-90  | 569       | 91.5     | 20                 | 89.6     |
| 4792 x BL        | 30-33              | 85-90  | 538       | 94.5     | 20                 | 90.5     |
| RV1B x 621       | 30-33              | 85-90  | 482       | 94.1     | 20                 | 91.4     |

| COMBINATION<br>* | YIELD OF<br>COCOONS<br>per DFL. g | SINGLE WEIGHT |           | SILK<br>CONTENT<br>(%) | FILAMENT<br>LENGTH<br>(m) | COLOUR<br>OF<br>COCOON |
|------------------|-----------------------------------|---------------|-----------|------------------------|---------------------------|------------------------|
|                  |                                   | Cocoon (g)    | Shell (g) |                        |                           |                        |
| 4792 x 644       | 524.5<br>(128.4)                  | 1.41          | 0.22      | 16.2                   | 724.5<br>(143.1)          | White                  |
| 4792 x BL        | 431.0<br>(105.5)                  | 1.38          | 0.22      | 15.9                   | 550.0<br>(108.6)          | White                  |
| RV1B x 621       | 408.3<br>(100.0)                  | 1.38          | 0.19      | 14.0                   | 506.0<br>(100.0)          | Yellow                 |

Figures in parentheses show comparative performance

(\*) : 4792 and BL, Summer Bivoltine strains

621 and 644, Regular 8ivoltine strains

RV1B, Polyvoltine strain

Table II. Rearing results of Bi x Bi and Poly x Bi combinations with 4792

## EFFECT OF CERTAIN BED DISINFECTANTS ON THE GROWTH AND DISEASE CONTROL OF SILKWORM, BOMBYX MORI L.

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*The effect of bed disinfectants viz.; benzoic acid, kaolin N.F., paraformaldehyde, turmeric powder, lime and cleaned leaves with cotton on the growth and disease control of silkworm, Bombyx mori L. were studied. The results revealed that all the treatments had beneficial effect of the silkworm growth, silk production and minimising disease incidence over the control. The paraformaldehyde and cleaned leaves with cotton were observed to be superior over other treatments.*

### INTRODUCTION

Tinidazole and metronidazole control intestinal and hepatic amoebiasis, giardiasis and also inhibit anaerobic bacteria in human beings (Plorde, 1972). Cotrimoxazole exerts bactericidal action against wide range of gram-positive and gram-negative bacteria (Anonymous, 1978). Cotrimoxazole was effective in increasing the larval length, larval weight, silk weight and filament length of the cocoons (Radha and Mutakrishnan, 1980). The present study was therefore undertaken to study the effect of the bed disinfectants on the growth, disease control and cocoon production of mulberry silkworm under Marathwada conditions.

### MATERIALS AND METHODS

The disease free layings of (NB7 x NB18) were reared separately on Kanva-2 variety of mulberry. Equal quantity of bed disinfectants was sprayed over the rearing bed once in a day. The five disinfectant treatments viz; benzoic acid, kaolin N.F., paraformaldehyde, turmeric powder and lime besides cleaned leaves with cotton treatment and control were replicated four times. Each replication comprised 100 worms.

The disinfectants were used from the brushing of newly hatched worms upto the spinning of the worms. The experiment was conducted during Sept.-Oct., 1985.

Observations were made on the matured larval weight, single cocoon weight, shell weight, length of reelable silk filament and periodically the number of larvae affected by diseases were recorded.

## RESULTS AND DISCUSSION

From the table, it is observed that all the treatments gave significantly superior results over the control. The paraformaldehyde had significantly higher larval weight (37.300 g). Next best treatment was cleaned leaves with cotton (36.425 g) and turmeric powder (35.975 g) but these were at par with each other.

The turmeric powder treatment had the longest larval duration (25.42 days) and the shortest was obtained in cleaned leaves with cotton treatment (23.16 days). All the treatments gave significantly higher cocoon weight, shell weight and shell percentage over the control. However, paraformaldehyde showed significantly higher cocoon weight, shell weight and shell percentage. The next best treatment was cleaned leaves with cotton.

The maximum filament length was noticed in paraformaldehyde (901 m) followed by cleaned leaves with cotton (852 m) and lime (773 m) but these were at par with each other.

As far as the disease incidence is concerned, it varied from 14.00 to 23.25%. The lowest disease incidence was in paraformaldehyde (14.00%). Next best treatment was cleaned leaves with cotton (15.75%) but these were at par with each other. This is well supported by Anonymous (1985) who have stated that lime water at lower concentrations was found to be relatively more effective against cytoplasmic polyhedrosis when compared with different concentrations of hilite, sodium hypochloride with kaolin, bleaching powder in combination with lime.

Chinnaswamy *et al.* (1986) observed that dusting of paraformaldehyde 2% + benzoic acid 2% + lime from third stage to cocoon formation was effective in controlling the diseases and also improving the economic characters.

All the treatments had beneficial effect on the silkworm growth, silk production and minimizing disease incidence over the control.

However, paraformaldehyde and cleaned leaves with cotton were found to be superior over other treatments.

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| Treatments                     | Weight of<br>10 mature<br>larvae (g) | Larval<br>duration<br>(days) | Single<br>cocoon<br>weight (g) | Shell<br>weight<br>weight (g) | Shell<br>percentage | Filament<br>length<br>(m) | Disease<br>percentage |
|--------------------------------|--------------------------------------|------------------------------|--------------------------------|-------------------------------|---------------------|---------------------------|-----------------------|
| Benzoic acid                   | 30.500                               | 24.35                        | 1.499                          | 0.304                         | 20.33(26.790)*      | 701                       | 21.25(25.942)*        |
| Kaolin N.F.                    | 34.375                               | 24.16                        | 1.555                          | 0.297                         | 19.05(25.870)       | 709                       | 17.50(24.717)         |
| Paraformaldehyde               | 37.300                               | 24.08                        | 1.693                          | 0.357                         | 21.11(27.342)       | 901                       | 14.00(21.952)         |
| Turmeric powder                | 35.975                               | 25.42                        | 1.573                          | 0.314                         | 19.97(26.527)       | 704                       | 19.50(24.695)         |
| Lime                           | 33.425                               | 24.26                        | 1.557                          | 0.317                         | 20.20(26.832)       | 773                       | 19.00(25.822)         |
| Cleaned leaves<br>with cotton  | 36.425                               | 23.16                        | 1.603                          | 0.336                         | 20.97(27.255)       | 852                       | 15.75(23.452)         |
| Control<br>(without treatment) | 29.800                               | 25.16                        | 1.367                          | 0.221                         | 16.20(23.710)       | 626                       | 23.25(28.817)         |
| S.E. $\pm$                     | 0.233                                | 0.285                        | 0.041                          | 0.007                         | 0.238               | 31.062                    | 0.883                 |
| C.O. (P = 0.05)                | 0.695                                | 0.848                        | 0.123                          | 0.022                         | 0.708               | 92.293                    | 2.970                 |

\* angular transformed values

Table I. Effect of different bed disinfectants on economic characters and disease control of silkworm (race : NB7 x NB18), Season : Sept-Oct., 1985.

## EVOLUTION OF PURE LINE SILKWORM RACE FROM HYBRID

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UB1 is a pure line silkworm race evolved from Guang Nong N°3, popularized in Guang Nong Province of Republic of China. Guang Nong N°3 is a hybrid silkworm race which was derived from poly x bivoltine. The characteristics of UN1 are as follows :

- The larval duration is of 18-19 days and 21 days in summer and winter rearing season respectively;
- Plain larvae ;
- Robustness, somewhat resistant to high temperature and relative humidity ;
- High effective rate of rearing ;
- Single cocoon weight, cocoon shell, weight cocoon shell ratio is moderate ;
- Constricted cocoon shape, white cocoon color ;
- Suitable for synchronization of moth emergences and F1 hybrid mass production of Thai poly-voltine silkworm races.

## INTRODUCTION

The development of silkworm breeding plays an important role to improve cocoon crop and earned income of sericulturists (Damrong, 1982). The exploitation of pure line silkworm races was directed to evolve superior F1 hybrid for silkworm rearing and cocoon production purpose. Evolution and maintenance of vigorous pure line silkworm races is a prerequisite for further silkworm breeding programme.

## MATERIALS AND METHODS

1. Refrigerator 5°C,
2. A hybrid silkworm race : Guang Nong N° 3,

3. Cocoon counter
4. Single cocoon weighing balance.
5. Single cocoon shell weighing balance
6. Breeding cage.
7. Others essential equipments for silkworm rearing.

#### Method

1. Selection on 1/6 -1/8 of each batch from 5-6 layings were collected and mass rearing of F1 to F3 was conducted. At the beginning of 4th Instar, 300 larvae are selected for further rearing in each bed.

2. F4 onwards cellular rearing is practised .

3. Selection on plain larvae, white cocoon colour, and constricted cocoon. Individual selection for cocoon assessment and maintain "the best into the best" for the next generation study.

After evaluation is obtained, the vigorous of the race will be maintained.

Principal items to be measured, calculated and observed are as follow :

1. Number of eggs per layings
2. The larval duration
3. The average weight of 10 mature worms
4. Effective rate of rearing (sound pupae ratio)
5. Single cocoon weight
6. Single cocoon weight
7. Cocoon shell ratio.

#### **RESULTS**

The results are presented in Table I.

It was observed that the larval duration, number of eggs per laying, average weight of 10 mature worms, single cocoon weight, single cocoon shell weight and cocoon shell ratio are moderate. The sound pupae ratio is salient.

#### **DISCUSSION**

UB1 is a pure line silkworm race, evolved at Ubon Sericultural Experiment Station. The general characteristics are as follow :

- Number of Bi-voltine eggs is median,
- Plain larvae
- Short larvae duration
- Somewhat resistant to high temperature and humidity

- Constricted cocoon shape, white cocoon color
- Single cocoon weight, single cocoon shell weight, and shell ratio is moderate.

#### ACKNOWLEDGEMENT

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| Rearing season | Generation number | Batches reared | Number of eggs per layings | Larval duration<br>(d) (hrs.) | Average weight of 10 mature worms (g) | ERR % | Single cocoon weight (g) | Single cocoon weight (cg) | Cocoon shell ratio % |
|----------------|-------------------|----------------|----------------------------|-------------------------------|---------------------------------------|-------|--------------------------|---------------------------|----------------------|
| Jun. 1098      | 5                 | 5              | 449                        | 19 00                         | 38.0                                  | 79.8  | 1.28                     | 23.1                      | 18.0                 |
| Aug. 1982      | 6                 | 6              | 387                        | 19 06                         | 29.0                                  | 95.4  | 1.29                     | 24.0                      | 18.6                 |
| Oct. 1982      | 7                 | 5              | 401                        | 18 00                         | 29.5                                  | 78.9  | 1.23                     | 23.1                      | 18.8                 |
| Jan. 1983      | 8                 | 2              | 370                        | 21 00                         | 20.7                                  | 98.0  | 1.15                     | 17.7                      | 15.4                 |
| May 1983       | 9                 | 4              | 330                        | 18 06                         | 25.0                                  | 89.8  | 1.02                     | 18.8                      | 18.4                 |
| Aug. 1983      | 10                | 3              | 289                        | 19 00                         | 23.0                                  | 80.8  | 1.12                     | 19.7                      | 17.6                 |
| Oct. 1983      | 11                | 3              | 378                        | 18 05                         | 23.5                                  | 93.6  | 1.10                     | 18.4                      | 16.7                 |
| Jan. 1984      | 12                | 6              | 416                        | 21 00                         | 21.3                                  | 87.2  | 1.00                     | 15.9                      | 15.9                 |
| May 1984       | 13                | 4              | 337                        | 18 04                         | 23.0                                  | 91.1  | 1.12                     | 20.8                      | 18.6                 |
| Aug. 1984      | 14                | 5              | 345                        | 18 05                         | 29.0                                  | 83.3  | 1.22                     | 20.1                      | 16.5                 |
| Oct. 1984      | 15                | 6              | 438                        | 21 00                         | 21.7                                  | 90.2  | 1.04                     | 18.6                      | 17.9                 |
| Jan. 1985      | 16                | 7              | 388                        | 21 00                         | 20.9                                  | 97.5  | 1.02                     | 18.7                      | 18.3                 |
| May 1985       | 17                | 5              | 338                        | 18 05                         | 23.2                                  | 69.5  | 1.05                     | 17.2                      | 16.4                 |
| Aug. 1985      | 18                | 6              | 370                        | 19 00                         | 23.3                                  | 91.9  | 1.19                     | 21.7                      | 18.2                 |
| Oct. 1985      | 19                | 6              | 264                        | 18 05                         | 24.2                                  | 89.4  | 1.25                     | 21.2                      | 17.0                 |

Remarks : From F1 to F4 were conducted at Sakornnakorn Seri. Expt. Station  
 F13 Combining ability test was launched.

Table I.

## APPROPRIATE TIME FOR COLLECTING MATURED SILKWORM

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### MATERIAL AND METHOD

Silkworm race K1 x K18.

Number of silkworms : 1 gram / replication of newly hatched larvae for young silkworm.

800 larvae (200 x 4 rep.) for old stage.

#### Feeding :

|              |                             |
|--------------|-----------------------------|
| 6.00 o'clock | 30% of daily supply leaves  |
| 11 o'clock   | 30% of daily supply leaves  |
| 16 o'clock   | 40% of daily supply leaves. |

Randomized complete block design, 5 treatments and 4 replications :

- Picking matured worms, with green faeces as control
- Picking matured worms after 6 hours after green faeces
- Picking matured worms after 12 hours after green faeces
- Picking matured worms after 12 hours after green faeces
- Picking matured worms after 24 hours after green faeces.

### RESULT

The matured worms collected after 24 hours of green faeces were better in cocoon weight and cocoon shell weight.

| SV        | df | Mounting<br>number | Sound<br>number | Sound<br>cocoon<br>weight (g) | Whole<br>cocoon<br>weight (g) | Cocoon<br>shell<br>weight (cg) | Cocoon<br>shell<br>percent(%) |
|-----------|----|--------------------|-----------------|-------------------------------|-------------------------------|--------------------------------|-------------------------------|
| Rep.      | 3  | 19.1167            | 24.9833         | 68.333                        | 0.0025                        | 0.133                          | 0.1793                        |
| Treatment | 4  | 18.0000            | 30.3250ns       | 198.1250ns                    | 0.0020ns                      | 0.1750ns                       | 0.2682ns                      |
| Error     | 12 | 14.8667            | 19.3583         | 138.1250                      | 0.0011                        | 0.5083                         | 0.2072                        |
| CV %      |    | 1.9                | 2.2             | 4.0                           | 2.0                           | 2.1                            | 2.3                           |

Table I. Analysis of variance, August.

| Treatment       | Mounting<br>number | Sound<br>number | Sound<br>cocoon<br>weight (g) | whole<br>cocoon<br>weight (g) | Cocoon<br>shell<br>weight (cg) | Cocoon<br>shell<br>percent(%) |
|-----------------|--------------------|-----------------|-------------------------------|-------------------------------|--------------------------------|-------------------------------|
| 1. Every day    | 197 a              | 195 a           | 280 a                         | 1.63 b                        | 32.75 a                        | 20.00 a                       |
| 2. Every 2 days | 199 a              | 198 a           | 290 a                         | 1.65 ab                       | 32.50 a                        | 19.70 a                       |
| 3. Every 3 days | 199 a              | 198 a           | 296 a                         | 1.64 ab                       | 33.00 a                        | 20.12 a                       |
| 4. Every 4 days | 196 a              | 194 a           | 298 a                         | 1.69 a                        | 33.00 a                        | 19.55 a                       |
| 5. Every 5 days | 194 a              | 192 a           | 294 a                         | 1.67 ab                       | 32.75 a                        | 19.57 a                       |

Table II. Table of means, August.

| Treatment | df | Mounting<br>number | Sound<br>number    | Sound<br>cocoon<br>weight (g) | Whole<br>cocoon<br>weight (g) | Cocoon<br>shell<br>weight (cg) | Cocoon<br>shell<br>percent% |
|-----------|----|--------------------|--------------------|-------------------------------|-------------------------------|--------------------------------|-----------------------------|
| Rep.      | 3  | 30.5333            | 354.5833           | 731.2500                      | 0.0014                        | 0.4500                         | 0.0440                      |
| Treatment | 4  | 13.0750<br>1.81ns  | 124.8750<br>1.57ns | 279.3750<br>2.02ns            | 0.0007                        | 0.4250                         | 0.1082                      |
| Error     | 12 | 7.2417             | 79.7083            | 138.5417                      | 0.0027                        | 0.9917                         | 0.5302                      |
| CV %      |    | 1.3                | 4.7                | 4.3                           | 3.4                           | 3.2                            | 3.5                         |

Table III. Analysis of variance , October

| Treatment       | Mounting<br>number | Sound<br>pupa<br>number | Sound<br>cocoon<br>weight (g) | whole<br>weight<br>weight (g) | Cocoon<br>shell<br>weight (cg) | Cocoon<br>shell<br>percent% |
|-----------------|--------------------|-------------------------|-------------------------------|-------------------------------|--------------------------------|-----------------------------|
| 1. Every day    | 197 a              | 192 a                   | 279 a                         | 1.50 a                        | 30.75 a                        | 20.40 a                     |
| 2. Every 2 days | 198 a              | 194 a                   | 272 a                         | 1.50 a                        | 30.75 a                        | 20.40 a                     |
| 3. Every 3 days | 196 a              | 191 a                   | 272 a                         | 1.52 a                        | 30.75 a                        | 20.22 a                     |
| 4. Every 4 days | 198 a              | 198 a                   | 269 a                         | 1.48 a                        | 30.00 a                        | 20.17 a                     |
| 5. Every 5 days | 194 a              | 180 a                   | 256 a                         | 1.52 a                        | 30.50 a                        | 20.05 a                     |

Table IV. Table of means, October.

## STUDY ON SHOOT REARING FOR SILKWORM SEED PRODUCTION

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*The study on shoot rearing with silkworms for the purpose of egg production has been undertaken to find the possibility of the two rearing periods: September 20th 1984 and January 10th 1985 with two space trails, 20 and 16 m<sup>2</sup> per box of the K1xK13 (Japanes race). The experiment has given excellent results which means that shoot rearing can be adopted for a better egg production, as follows:*

|                     | 20m <sup>2</sup> /box | 16m <sup>2</sup> /box |
|---------------------|-----------------------|-----------------------|
| larval survival     | 90.51 %               | 93.14                 |
| cocoon weight       | 27.25 kg              | 24.42 kg              |
| mulberry 1-5 instar | 418.90 kg             | 389.88 kg.            |

## INTRODUCTION

The Sericulture Research and Training Center has undertaken sericulture research works to produce silkworm eggs for farmers and at the same time has worked as the propaganda market in order to popularize the silkworm hybrids among sericulture farmers. The fact is that the demand for silworm eggs has gone too far over what the egg production can handle. Up to present, the egg production is still on at its full speed at the Center. For this purpose, multiplication seed on the three-way cross hybrid (K1xK13)xK8 is being conducted. Rearing is done by putting mulberry leaves on trays (Each tray contains 500 larvae), then the lifting of the trays up and down follows in order to work on the bed cleaning every day with old silkworms. But the heavy problem here is that it is really time-consuming, both when collecting mulberry leaves and when lifting the trays up and down. But by this method, the farmers would in turn gain the benefit of the heavy task i.e. a greater income.

## MATERIAL AND METHOD

The K1.K13 boxes were reared on table for two treatments,  $2m^2(2,000)$ , ten replications in five groups, and  $8m^2(10,000)$  doubling with replications. The silkworm rearings were conducted on September 20th 1984 and on January 10th 1985. The rearing method was the same as the hybrid ones: that is after the cocoon were selected, they were transported to couple with the K8.

## DISCUSSION

Table I and Table II give the following results:

|                     | 20m /box | 16m /box |
|---------------------|----------|----------|
| larvae survival     | 90.51%   | 93.14%   |
| cocoon weight       | 27.25kg  | 24.42 kg |
| mulberry 1-5 instar | 418.90kg | 399.88kg |

Shoot rearing is the most reasonable for multiplication seed, especially because the rearing space is adequate and it saves much labour cost. From the data, the  $16m^2$  is 25 per cent superior to the  $20m^2$  space in egg production purpose.

| Description             | 20 m <sup>2</sup> / box (4 000 larvae |       |       |       |       | 16m <sup>2</sup> /box (10 000 l/gr.) |        |        |                    |
|-------------------------|---------------------------------------|-------|-------|-------|-------|--------------------------------------|--------|--------|--------------------|
|                         | 1                                     | 2     | 3     | 4     | 5     | average<br>/20,000                   | 1      | 2      | average<br>/20,000 |
| Mulberry                | 73.96                                 | 73.96 | 73.96 | 73.96 | 93.96 | 369.80                               | 179.43 | 179.43 | 358.86             |
| Larvae survival (N°)    | 3 500                                 | 3 050 | 3 668 | 3 679 | 3 750 | 17 647                               | 9 300  | 9 875  | 19 175             |
| Larvae survival (%)     | 87.50                                 | 76.25 | 91.70 | 91.97 | 93.75 | 88.23                                | 93.00  | 98.75  | 95.87              |
| N° of good cocoons      | 3 413                                 | 3 236 | 3 000 | 2 776 | 2 923 | 15 348                               | 7 990  | 7 676  | 15 666             |
| N° of bad cocoons       | 265                                   | 230   | 238   | 103   | 275   | 1 111                                | 657    | 657    | 1 320              |
| Good cocoon weight      | 6.05                                  | 5.85  | 5.40  | 5.65  | 5.45  | 27.80                                | 12.85  | 13.70  | 26.55              |
| Bad cocoon weight       | 0.50                                  | 0.50  | 0.50  | 0.20  | 0.55  | 2.25                                 | 1.20   | 1.20   | 2.40               |
| Single cocoon weight    | 1.84                                  | 1.86  | 1.85  | 1.87  | 1.83  | 1.85                                 | 1.82   | 1.81   | 1.815              |
| Single cocoon shell wt. | 36.5                                  | 35.5  | 35.5  | 35.5  | 35.5  | 35.7                                 | 35.5   | 36.5   | 36.0               |
| % cocoon shell          | 19.83                                 | 19.08 | 19.20 | 18.98 | 19.40 | 19.30                                | 19.51  | 20.16  | 19.83              |

Table I. Results obtained with different area, September 20th 1984.

| Description             | 20m <sup>2</sup> /box (4000 larvae/gr.) |       |       |       |       | 16m <sup>2</sup> box (10 000 l./gr.) |        |        |                    |
|-------------------------|-----------------------------------------|-------|-------|-------|-------|--------------------------------------|--------|--------|--------------------|
|                         | 1                                       | 2     | 3     | 4     | 5     | Average<br>/20 000                   | 1      | 2      | Average<br>/20 000 |
| Mulberry                | 46.8                                    | 46.8  | 46.8  | 46.8  | 46.8  | 468.0                                | 220.45 | 220.45 | 440.90             |
| Larvae survival (N°)    | 1 780                                   | 1 800 | 1 932 | 1.894 | 1.874 | 18 558                               | 9 259  | 8 833  | 18.083             |
| Larvae survival (%)     | 89.00                                   | 90.00 | 96.60 | 94.70 | 93.65 | 92.79                                | 92.50  | 88.33  | 90.94              |
| N° of good cocoons      | 1 593                                   | 1.427 | 1.704 | 1.635 | 1.618 | 15 954                               | 6 476  | 7 604  | 14 080             |
| N° of bad cocoons       | 170                                     | 294   | 90    | 118   | 160   | 1 664                                | 432    | 746    | 1 176              |
| Good cocoon weight      | 2.55                                    | 2.45  | 2.85  | 2.75  | 2.75  | 26.70                                | 10.40  | 11.90  | 22.30              |
| Bad cocoon weight       | 0.25                                    | 0.50  | 0.15  | 0.20  | 0.25  | 2.70                                 | 0.80   | 1.00   | 1.80               |
| Single cocoon weight    | 1.68                                    | 1.68  | 1.67  | 1.66  | 1.62  | 1.66                                 | 1.58   | 1.63   | 1.60               |
| Single cocoon shell wt. | 33.5                                    | 34.5  | 35.00 | 34.00 | 32.50 | 33.9                                 | 31.5   | 33.0   | 32.2               |
| % cocoon shell          | 19.94                                   | 20.53 | 20.96 | 20.48 | 20.06 | 20.42                                | 20.06  | 20.24  | 20.12              |

Table II. Results obtained with different area, January 10th 1985.

| Description             | 20 m <sup>2</sup> /box |                 |                   | 16 m <sup>2</sup> /box |        |                   |
|-------------------------|------------------------|-----------------|-------------------|------------------------|--------|-------------------|
|                         | Sept.<br>1984          | January<br>1985 | Average<br>20 000 | 1                      | 2      | Average<br>20 000 |
| Mulberry                | 369.80                 | 468.00          | 418.90            | 358.86                 | 440.90 | 399.88            |
| Nº of larvae survival   | 19 647                 | 18 558          | 18 102            | 19 175                 | 18 083 | 18 629            |
| % larvae survival       | 88.23                  | 92.79           | 90.51             | 95.87                  | 90.94  | 93.14             |
| Nº of good cocoons      | 15 348                 | 15 954          | 15 651            | 15 666                 | 14 080 | 14 873            |
| Nº of bad cocoons       | 1 111                  | 1 664           | 1.388             | 1 320                  | 1 178  | 1 249             |
| Good cocoon wt.         | 27.80                  | 26.70           | 27.5              | 26.55                  | 22.30  | 24.42             |
| Bad cocoon wt.          | 2.25                   | 2.70            | 2.48              | 2.40                   | 1.80   | 2.10              |
| Single cocoon wt.       | 1.85                   | 1.66            | 1.76              | 1.815                  | 1.60   | 1.71              |
| Single cocoon shell wt. | 35.70                  | 33.90           | 34.80             | 36.00                  | 32.20  | 34.10             |
| % Cocoon shell          | 19.30                  | 20.42           | 19.77             | 19.83                  | 20.12  | 19.94             |

Table III.

## THE DATA COLLECTION (K1xK8) HYBRID RACE (1981-1983)

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*The Sericulture Institute has conducted many experiments on hybrid development of silkworm eggs in order to supply to sericulture farmers. From the period of 1981 to 1983, the Sericulture Research and Training Center has tried on the K1xK8 as a multiplication seed to enhance production and for training courses. Data collected had revealed the same satisfactory results throughout. The 5,000 of third instar K1xK8 silkworms were reared on one m<sup>2</sup> table and were given chopped mulberry. At the same time, 1,000 of fifth instar K1xK8 silkworms were reared on another m<sup>2</sup> table with shoot. The cocoon production by this method was 25.23 kg, cocoon shell was 20.48 per cent. That was the highest amount received. The experiment on the hybrid K1xK8 throughout the four years, had produced such a high yield as was suitable for sericulture farmers.*

### INTRODUCTION

Since the Center has always been conducting several experiments on new various hybrid, the Center has always had great chances to share both quantity and quality of its work. From the period of 1981 to 1983, the Center had not only produced and distributed the K1xK8 (as a multiplication seed) to farmers but also used it as a main silkworm for training purpose. With several trials on the K1xK8 carried out to testify its strength, the Center had come up with great satisfaction. The collecting of the data was mainly done by trainees who, during the training, could not prevent having visitors, spectators who were trainees themselves and were intimately allowed to enter the rearing room. Often, those curious visitors have given ways and chances for the worms to contact silkworm diseases and trachinid flies. In spite of that, the K1xK8 found themselves to be the best kind. The Center, then, could assume the K1xK8 to be the most suitable type.

## MATERIAL AND METHOD

At each training course, trainees were divided into 10 groups to work on the ten experiment sets (where each set was fully equipped). For each set, 5,000 of third instar K1xK8 silkworms were reared on one m<sup>2</sup> table and these young worms were fed with chopped mulberry. The other 1,000 fifth instar silkworms were reared on another m<sup>2</sup> table and were fed with shoot. Working in the same condition and control e.g. rearing preparation, area enlargement, bed cleaning, disease control, cocoon harvesting and cocoon selection, etc., for four continuous years, the outcomes remained the same.

## DISCUSSION

Of the two instars of K1xK8 silkworms under the experiment conducted in 1981-1983, the rearing production of the hybrid can be summed up as follows:

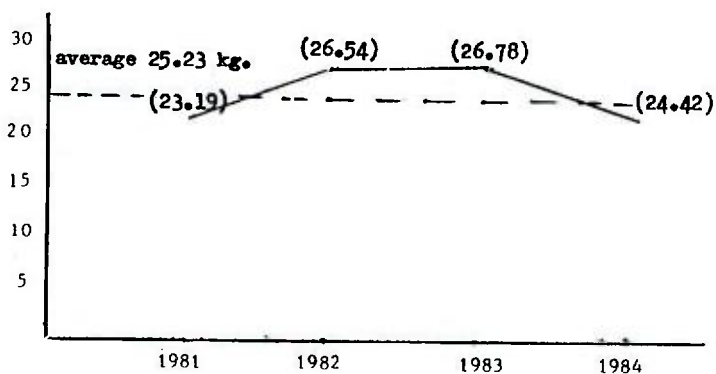
|                                        |              |
|----------------------------------------|--------------|
| average demand of mulberry consumption | 432.00 kg    |
| larvae survival                        | 93.50%       |
| cocoon shell                           | 20.48%       |
| number of good cocoons                 | 15.909       |
| number of bad cocoons                  | 1.178        |
| cocoon weight                          | 25.23 kg/box |
| bad cocoons weight                     | 2.95 kg/box  |

The standard cocoon (run by the trainees) weighed 20 kg/box but those run by the trainees and closely supervised by the agriculturists could even get a higher production, especially in the winter when the average temperature was 22° C: moreover, the silkworms were fatter, and were unlikely to be affected by disease. The data collected on December 25th 1982 gave the highest production, 32 kg/box.

| Description        | 1981   | 1982   | 1983   | 1984   | Average |
|--------------------|--------|--------|--------|--------|---------|
| Mulberry (kg.)     | 467.00 | 435.00 | 435.50 | 392.00 | 432.40  |
| % larvae survival  | 49.75  | 95.48  | 92.87  | 90.95  | 93.50   |
| % cocoon shell     | 20.51  | 20.88  | 20.47  | 20.07  | 20.48   |
| N° of good cocoons | 15,429 | 16,024 | 16,514 | 15,668 | 15,909  |
| N° of bad cocoons  | 2,043  | 2,540  | 1,477  | 1,054  | 1,178   |
| Good cocoons wt.   | 23.19  | 26.54  | 26.78  | 24.42  | 25.23   |
| Bad cocoons wt.    | 3.98   | 3.86   | 1.80   | 2.95   | 2.95    |

Table I. Data collection of K1xK8 (20,000 larvae)

Cocoon wt.



COMBINING ABILITY OF SINGLE COCOON FILAMENT LENGTH IN  $F_1$  MULTIVOLTINE  
AND BIVOLTINE SILKWORM HYBRIDS

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The combining ability of diallel crosses between seven multivoltine strains, namely NK4, NK5, BR9, PC21, 15 KY, NN and NI, and the bivoltine K1 and K8 were observed using the silk filament which is the ultimate yield as a criterion. The positive combining ability was expressed by most of the hybrids from the interbreeding between multivoltine and bivoltine strains. K1 had relatively more influence on silk production than K8.

The intercrossing among the multivoltine strains indicated that NK4 showed high general combining ability with others i.e. hybrids from crosses using this strain as parent potentially produced longer filament length.

No maternal influence on filament length was noted from crosses between K1 and K8. Both ways yielded filament of approximate length. Similar results were recorded among the hybrids between multivoltine strains. However, maternal influence was remarkably high among the hybrids between multivoltine and bivoltine strains. Crosses with multivoltine female yielded longer filament than with bivoltine female. The highest yield was found in 15 KY female x K1 male and K1 female x 15 KY male i.e. 997 meters and 880 meters respectively.

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## INTRODUCTION

Multivoltine silkworm race nowadays are still most popular among Thai sericulturists especially in the North-East area where silkworm rearing is a sub-income for the rice farmers. This is because of their unique yellowish cocoons, high tolerance to adverse environment in the tropical area and high resistance to diseases. However, the multivoltines produce low quantity of silk as regards the length. The farmers who grow domestic silkworms for weft silk, produce their own seeds. This causes inbreeding and weak strains or low yield result. The farmers can not sell the fresh cocoons and have to reel by themselves with hand reeling equipment. So far silk production in Thailand is insufficient for local demand. Bivoltine silkworm with higher cocoon yield is theoretically good to solve this problem but good management of housing and mulberry field needs intensive training. Therefore a synthesizing of new breeds, or hybrids of the multivoltine x bivoltine with yellowish characters, should be an immediate high light in the breeding programme.

This study was conducted in order to obtain information on the nature of combining ability of the Japanese race (K1) and the Chinese race (K8) to seven popular local multivoltine strains.

## MATERIALS AND METHODS

Seven popular local multivoltine silkworm races namely, NK4, NK5, BR9, PC21, 15 KY, NN (Nang Noi), Nang Lueng (NL) and two bivoltines, K1 and K8 were crossed in a 9 x 9 complete diallels and raised under the standard conditions (25-28°C) and 70-90% R.H. in a completely randomized block design under four rearing seasons (March, May, July and September, 1985).

Analysis of general and specific combining ability and reciprocal differences using filament length (m) as a criterion was made according to Griffing (1956) method 1 model 1.

## RESULTS

Significant differences among making and reciprocal crosses of the multivoltine and bivoltine silkworm races were obtained for single cocoon filament length (Table I). To show both the magnitude and direction of the genetic effects, the GCA and SCA were computed for the average of all lines in the populations. The ratio of GCA:SCA is 218.35:1 indicating that the additive gene action is more prominent than the non-additive ones (Table II). Interestingly, significant differences between reciprocal crosses were observed indicating the influence of maternal effect in a trait studied.

### General combining ability (GCA) effects

The effects of general combining ability which measures the comparative performance of seven Thai multivoltine and two bivoltine parents, are shown in Table III. The significant positive GCA effects were found in the bivoltine K1 and K8 and the negative GCA effects for all the multivoltine lines. These results revealed that the bivoltine strains are good general combiners for filament length quality when interbred with multivoltine strains. The results of GCA also indicate that K1 had relatively more influence on filament length than K8.

The negative GCA effects for the multivoltine lines were a reflection of the relatively poor performance of all crosses involving these lines. Among the multivoltine strains, NK4 performed best followed by PC21 and 15 KY while the NL strains were the poorest general combiners.

### Specific combining ability (SCA) effects

Table IV shows the SCA effects for all crosses. It is apparent that K1 x K8, K1 x PC21, K1 x 15KY crosses expressed the highest positive SCA which indicates that the combination between these strains is best with respect to the filament length as compared to other combinations of the strains. The PC21 x 15 KY, NK5 x 15 KY, NK4 x NK5 and PC21 x NN crosses showed highly negative SCA effects. The SCA of the crosses of K1 x NN, NK4 x BR9, K1 x NK5, BR9 x NL, NK4 x NN and K8 x 15 KY (in respective order) although not significantly different, showed rather high SCA effects when compared to others.

### Reciprocal effects

Reciprocal differences were evaluated as shown in Table V. No maternal influence on filament length was noted from crosses between K1 and K8. Both ways yielded a filament of approximate length i.e. 1263 and 1242 m. Similar results were recorded among the hybrids between polyvoltine strains. However, maternal influence was remarkably high among the hybrids between the multivoltine and bivoltine strains. The combinations of K1 with 15 KY, NK5, NL and NK4 as female parents were highly significant for filament length indicating the superiority of these multivoltine strains as female parents. Crosses between PC21 x K1 and NN x K1 were significantly different at 5% level. Data also show that the reciprocal effects were of less influence in K8 strains, only two out of seven hybrids performed 0.5 significant different.

### DISCUSSION

The negative GCA expressed by all the hybrids between the multivoltine indicates that an improvement of the filament length by using all the multivoltine strains is impossible. This is endorsed by the positive result when crossing with the bivoltine strains, among which K1 (GCA 321.64) is a better combiner as compared to K8 (GCA 294.73). NK4 should be used if future interbreeding is to be performed. Since the character studied is of the additive genes effect, NK4, PC21 and 15 KY may probably be improved strains with high yield blood whereas BR9 (GCA -101.75) and NL (GCA -115.75) have the low yield blood.

Our study is in agreement with the work done by Sengupta and Datta (1975), Datta *et al.* (1981, Jolly (1983) and Datta (1984) who extensively used the hybrids between multivoltine and bivoltine for Indian silkworm rearers.

As regards reciprocal recurrent selection our study found that all hybrids between bivoltine and multivoltine races yielded a longer silk filament when using the local multivoltine as a female parent. This turn would be very helpful in selecting desirable parents for further exploitation of the superior breeds. However, the disadvantage of these hybrids was the non-diapause eggs laid by the multivoltine female parents. Also the number of eggs laid was comparatively small. Therefore the desirable good combiner parents would depend on the ultimate goal of breeders for making diapause or non-diapause silkworm seeds.

### ACKNOWLEDGEMENT

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| Source of variation | df  | Mean square             |
|---------------------|-----|-------------------------|
|                     |     | Filament length (meter) |
| Replication         | 3   | 448336.67**             |
| Treatments          | 80  | 229430.00**             |
| Parents             | 8   | 363351.88**             |
| Parents vs hybrids  | 1   | 97509.64**              |
| Hybrids             | 71  | 216198.24**             |
| Crosses             | 35  | 192320.74**             |
| Reciprocals         | 35  | 244119.73**             |
| Crosses vs hybrids  | 1   | 74658.95**              |
| Error               | 240 | 2803.53                 |

\*\* significant at 1% level

Table I. Analysis of variance for filament length of seven multivoltine and two bivoltine silkworm races. (72 crosses)

| Source of variation | df  | Mean square   |
|---------------------|-----|---------------|
| GCA                 | 8   | 555,695.00**  |
| SCA                 | 36  | 2,544.72**    |
| Reciprocal          | 36  | 1,438.86**    |
| Error               | 240 | 700.88        |
| GCA : SCA           |     | 218.35 : 1 ** |

\*\* significant at 1% level

Table II. Analysis of variance for general and specific combining ability and reciprocal difference for seven multivoltine and two bivoltine races.

| Female parent    | Male parent         |                     |                   |                   |                    |                   |                   |                   |                    |
|------------------|---------------------|---------------------|-------------------|-------------------|--------------------|-------------------|-------------------|-------------------|--------------------|
|                  | K <sub>1</sub>      | K <sub>8</sub>      | NK <sub>4</sub>   | NK <sub>5</sub>   | BR <sub>9</sub>    | PC <sub>21</sub>  | 15 KY             | NN                | NL                 |
| K <sub>1</sub>   | 1,035<br>(321.64)** |                     |                   |                   |                    |                   |                   |                   |                    |
| K <sub>8</sub>   |                     | 1,127<br>(294.73)** |                   |                   |                    |                   |                   |                   |                    |
| NK <sub>4</sub>  |                     |                     | 466<br>(-54.98)** |                   |                    |                   |                   |                   |                    |
| NK <sub>5</sub>  |                     |                     |                   | 403<br>(-97.71)** |                    |                   |                   |                   |                    |
| BR <sub>9</sub>  |                     |                     |                   |                   | 393<br>(-101.75)** |                   |                   |                   |                    |
| PC <sub>21</sub> |                     |                     |                   |                   |                    | 437<br>(-74.71)** |                   |                   |                    |
| 15 KY            |                     |                     |                   |                   |                    |                   | 388<br>(-81.61)** |                   |                    |
| NN               |                     |                     |                   |                   |                    |                   |                   | 391<br>(-89.87)** |                    |
| NL               |                     |                     |                   |                   |                    |                   |                   |                   | 347<br>(-115.75)** |

\*\* Significant at 1 % level

Table III. The mean filament length (m) and general combining ability (in brackets) of two bivoltine and seven multivoltine races.

| Female parent    | Male parent    |                   |                 |                 |                 |                  |                   |                 |                             |
|------------------|----------------|-------------------|-----------------|-----------------|-----------------|------------------|-------------------|-----------------|-----------------------------|
|                  | K <sub>1</sub> | K <sub>8</sub>    | NK <sub>4</sub> | NK <sub>5</sub> | BR <sub>9</sub> | PC <sub>21</sub> | 15 KY             | NN              | NL                          |
| K <sub>1</sub>   |                | 1,263<br>(33.07)* | 812<br>(-5.85)  | 789<br>(18.12)  | 787<br>(-12.29) | 841<br>(37.50)*  | 880<br>(95.03)**  | 822<br>(24.66)  | 775<br>(-20.91)             |
| K <sub>8</sub>   |                |                   | 813<br>(7.94)   | 790<br>(7.91)   | 751<br>(-11.80) | 796<br>(13.41)   | 801<br>(16.57)    | 790<br>(9.58)   | 756<br>(-10.80)             |
| NK <sub>4</sub>  |                |                   |                 | 430<br>(-17.00) | 496<br>(24.41)  | 457<br>(9.21)    | 459<br>(6.65)     | 468<br>(17.29)  | 408<br>(-15.09)             |
| NK <sub>5</sub>  |                |                   |                 |                 | 416<br>(13.14)  | 427<br>(9.84)    | 388<br>(-24.88)   | 409<br>(0.89)   | 404<br>(-3.49) <sup>a</sup> |
| BR <sub>9</sub>  |                |                   |                 |                 |                 | 401<br>(-12.61)  | 405<br>(-11.46)   | 421<br>(-2.57)  | 397<br>(19.80)              |
| PC <sub>21</sub> |                |                   |                 |                 |                 |                  | 416<br>(-33.50)** | 417<br>(-15.61) | 423<br>(8.39)               |
| 15 KY            |                |                   |                 |                 |                 |                  |                   | 428<br>(-1.84)  | 414<br>(5.16)               |
| NN               |                |                   |                 |                 |                 |                  |                   |                 | 404<br>(0.05)               |
| NL               |                |                   |                 |                 |                 |                  |                   |                 |                             |

\*, \*\* Significant at 5 % and 1 % respectively

Table IV. The mean filament length (m) and specific combining ability (in brackets) among 36 hybrids of bivoltine and multivoltine strains.

| Female parent    | Male parent       |                  |                 |                 |                 |                  |                |               |    |
|------------------|-------------------|------------------|-----------------|-----------------|-----------------|------------------|----------------|---------------|----|
|                  | K <sub>1</sub>    | K <sub>8</sub>   | NK <sub>4</sub> | NK <sub>5</sub> | BR <sub>9</sub> | PC <sub>21</sub> | 15 KY          | NN            | NL |
| K <sub>1</sub>   |                   |                  |                 |                 |                 |                  |                |               |    |
| K <sub>8</sub>   | 1,242<br>(10.13)  |                  |                 |                 |                 |                  |                |               |    |
| NK <sub>4</sub>  | 916<br>(-52.00)** | 889<br>(-37.88)* |                 |                 |                 |                  |                |               |    |
| NK <sub>5</sub>  | 901<br>(-56.00)** | 826<br>(-18.13)* | 437<br>(-3.75)  |                 |                 |                  |                |               |    |
| BR <sub>9</sub>  | 835<br>(-23.88)   | 818<br>(-33.63)  | 445<br>(25.38)  | 418<br>(-0.88)  |                 |                  |                |               |    |
| PC <sub>21</sub> | 934<br>(-46.63)*  | 877<br>(-40.88)* | 508<br>(-25.38) | 454<br>(-13.13) | 427<br>(-12.88) |                  |                |               |    |
| 15 KY            | 997<br>(-58.50)** | 865<br>(-32.13)  | 488<br>(-14.50) | 410<br>(-11.00) | 412<br>(-3.63)  | 410<br>(2.88)    |                |               |    |
| NN               | 897<br>(-37.38)*  | 845<br>(-27.63)  | 483<br>(-7.13)  | 424<br>(-7.50)  | 397<br>(12.25)  | 429<br>(-6.25)   | 432<br>(-2.13) |               |    |
| NL               | 884<br>(-54.50)** | 789<br>(-14.88)  | 427<br>(-9.38)  | 368<br>(18.00)  | 414<br>(-8.75)  | 419<br>(2.38)    | 408<br>(2.75)  | 391<br>(6.88) |    |

\*, \*\* Significant at 5 % and 1 % respectively

Table V. The mean filament length (m) and reciprocal difference (in bracket) among 36 hybrids of bivoltine and multivoltine strains.

XVe CONGRES SERICICOLE INTERNATIONAL  
XVth INTERNATIONAL SERICULTURAL CONGRESS

\*

SECTION VERS A SOIE NON-MURIER  
NON-MULBERRY SILKWORMS SESSION

\*

CHAIRMAN : Dr. K. SENGUPTA

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## REPORT OF THE NON-MULBERRY SILWORMS SESSION

Dr. K. SENGUPTA

Chairman

For the non-mulberry silks session during this congress, twenty-seven papers were received including twenty-one from India, two from Japan, two from China and two from Thailand against twelve papers received including eleven from India and one from Japan during the previous congress held at Bangalore in 1984. The papers were of quite good standard and covered almost all the disciplines of sericulture viz. host plant cultivation, morphology, rearing technique, physiology, genetics and pathology including reports on the position of the non-mulberry silk production in different countries. Two papers were also received from Japan on the fibre properties of *A. yamamai* silk but those could not be considered for presentation since they had already been published elsewhere. Varietywise papers were received on all the four varieties of non-mulberry silks viz. temperate tussah, tropical tussah, eri and muga. We thus have reasons to hope and expect that in future years, this interest will further extend and expand.

Coming to the production of non-mulberry silks, as already indicated in my paper, it has remained more or less static covering about 5% of the total silk produced. In China, against the production of 2020 tons of tussah silk during 1983, it rose to 2632 metric tons in 1984. However, due to a very adverse climatic condition during 1985, her production came down to 1706 metric tons. I feel that was a temporary phase only and her production will go up again. Coming to India, the second largest non-mulberry silk producing country, her production in totalling has gone up from the level of 742 metric tons in 1983-84 to 868 metric tons in 1985-86. Out of the three varieties of non-mulberry silks she produces, while production of tussah silk rose from 418 to 464, eri silk from 270 to 532, there was a slight reduction in the production of muga silk coming down from 54 to 52 metric tons. As I know, India is conscious of this position and has taken steps to stabilize and increase her production of muga silk.

Regarding the production of non-mulberry silks in other countries, not much of factual information is available with us. To elicit the same I am proposing to send a proforma to all the countries as soon as I go back from this congress and shall be grateful if all the participating countries will send me the relevant data, even if that be a nil data so that we can assess the current production and possibility of expansion of the non-mulberry silks in a more accurate and comprehensive manner.

Coming to future expansion I would like to cite one example mentioning the possibility of utilizing the tapioca leaf in Thailand for the production of eri silk. Yesterday during our tour, on both sides of the road we found lots of tapioca plantation and as I found from the statistics of their export also, tapioca forms Thailand third largest export material after rice and garments. Roots being used for the production of tapioca products, leaves go waste. Fruitful use of these leaves could go a long way in the production of eri, a non-mulberry silk. I hope other states will also take note of such possibilities in their countries.

## CURRENT STATUS OF NON-MULBERRY SERICULTURE AND ITS FUTURE DEVELOPMENT

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During the XIV International Sericultural Congress held at Bangalore, India in 1984, as the Chairman of the Non-mulberry Silks Section I had the occasion to deal with some of the problems and prospects of non-mulberry sericulture suggesting there in possible action towards solving them and greater co-operation between the non-mulberry silk producing countries in the field of visits to each others non-mulberry silk growing regions and exchange of information, literature and live material. During this Congress, I thus thought it worthwhile to have a review of the current status of the industry and possible development in future. It may be mentioned here that though a large number of sericigenous animals belonging to different phila and classes are known including mussel silk and spider silk, discussion has been kept restricted to the four major commercial varieties of silk only viz., Temperate Oak Tasar, Tropical Tasar, Muga and Eri (Table I).

### SHARE OF NON-MULBERRY SILK

Non-mulberry silk covers about 5% of the total silk produced and it has continued to have almost the same position during the last few years as will be evident from Table II.

Country-wise position is discussed below.

### CHINA

China is undoubtedly the largest producer of non-mulberry silks.

#### 1. Oak Tasar

Chinese production of oak tasar (*Antheraea pernyi* G.) silk during the last six years is presented in Table III.

During 1985 owing to a natural disaster in the Liaoning Province which produces about 80% of the Chinese tasar cocoons, the cocoon production in China came down to 32,500 tons and tasar silk to 1706 tons. Percentage of oak tasar cocoon production in different provinces of China are reported to be as follows:

|              |         |
|--------------|---------|
| 1. Liaoning  | 80.00%  |
| 2. Henan     | 10.00%  |
| 3. Shandeeng | 8.00%   |
| 4. Others    | 2.00%   |
|              | <hr/>   |
|              | 100.00% |

## 2. Eri silk

Some quantity of eri silk is also produced in China. It is known to be reared in Gungxi autonomous region, Gungdong, Hebei and Shandong provinces on Tapioca (*Manihot utilissima*) and *Ailanthus* sp. Major production comes from the Gungxi region. No authentic information as to the quantity produced and mode of use are, however, available.

In the XV session of the International Sericultural Congress now being held Mr. Zhu Shao-Lian of the Sericultural Research Institute of the Guangdong Academy of Agricultural Science has presented a paper of eri silkworm (*Philosamia cynthia ricini*) rearing. It is hoped he will be able to give us some detailed information on the present status of the eri silk industry in that country. No other non-mulberry silk is known to be cultivated commercially in China.

## INDIA

India is the second largest non-mulberry silk producing country. Her production of non-mulberry silks during the last six years is presented in Table IV.

In India non-mulberry silks cover about 10% of the total silk production (1985 = 868/7897 or 10.99%).

## NORTH KOREA

North Korea besides the production of 600 tons of mulberry silk produces and exports some quantity of oak tasar (*Antheraea pernyi* G.) silk as well. Her annual export of tasar silk to Japan ranges from 20-25 metric tons. Major oak tasar growing regions of China are situated in the mountaneous area of Liaoning province bordering North Korea and thus the oak tasar culture in North Korea may just be taken as an extension of the same. No exact figure as to her total production is available but even taking that 50% of the quantity produced is exported, her production should be around 50 metric tons.

## JAPAN

The fourth country with a definite background of non-mulberry silkworm rearing is Japan. She has an exquisite variety of temperate tasar reared on oak plants viz. *Antheraea yamamai* G. producing greenish cocoons. It is otherwise called Tensan or heavenly thread. The silk is used almost exclusively for fine embroidery on the mulberry silk fabrics. This silk is very highly valued and sold at about US\$ 4,000 per kg. as against about US\$ 60 per kg. of mulberry silk. The Japanese Government has opened

a special museum at Nagano prefecture to preserve, encourage and increase the production of yamamai silk but its production is for the last few years hovering between 80,000 to 120,000 in number producing about 30 to 45 kg of raw silk.

#### OTHER COUNTRIES

Some other countries of South, South-East Asia and Oceania are also producing some quantity of non-mulberry silk particularly eri silk.

Bangladesh is trying to promote ericulture under the food and fibre programme using tapioca as the host plant, leaf being used for eri rearing and tuber as food. It is also known to be in existence in Thailand. It has also been tried to be developed in Papua New Guinea. But no authentic information as to its extent of production is available.

#### FUTURE DEVELOPMENT

Coming to the future development, a coordinated approach may be necessary for its development with close cooperation between the different countries.

This should include:

a) a detailed study of the present extent of production and scope of expansion in different countries taking into consideration the tradition and the socio-economic condition;

b) identification of the maladies like diseases and pests as well as natural calamities plaguing the industry and adoption of effective steps to fore-stall the same;

c) identification of the best host plants and their augmentation;

d) development of suitable silkworm breeds;

e) strengthening of parental and commercial silkworm seed production;

f) exchange of information;

g) exchange of plant and silkworm material;

h) exchange of scientific and technical personnel for an on-the-spot study of the industry in each other country to gain and exchange experience followed by steps towards the exchange of material.

Unluckily not much advance has been made on these lines except the visit of an eight member Indian delegation to China during 3rd week of April to 1st week of May in 1985. Obviously the period not being the commercial oak tasar rearing period, they could not see much of oak tasar rearing nor due to shortage of time visit the Liaoning province which produces about 80% of the oak tasar cocoons. None the less, some information was exchanged.

On a reciprocal basis China is due to send a team during 1986 including Lin Hua Sen from the Sericultural Research Institute of Liaoning to study the non-mulberry sericulture in India. It is hoped that this will lead not only to exchange of information between these two countries but will be followed by similar visits between other countries and exchange of information, experience and material.

| Variety of silk        | Produced by                                                   | Majority of host plants              |
|------------------------|---------------------------------------------------------------|--------------------------------------|
| Temperate or oak tasar | <u>Antheraea pernyi</u> G.<br>(CHINA)                         | Various oak or<br><u>Quercus</u> sp. |
|                        | <u>Antheraea yamamai</u> G.<br>(JAPAN)                        |                                      |
|                        | <u>Antheraea roylei</u> Mr.<br>(INDIA)                        |                                      |
|                        | <u>Antheraea proylei</u> J.<br>(INDIA)                        |                                      |
| Tropical tasar         | <u>Antheraea mylitta</u> D.<br>(INDIA)                        | <u>Terminalia tomentosa</u>          |
|                        |                                                               | <u>Terminalia arjuna</u>             |
|                        |                                                               | <u>Shorea robusta</u>                |
| Muga                   | <u>Antheraea assama</u> W.<br>(INDIA)                         | <u>Machilus bombycina</u>            |
|                        |                                                               | <u>Litsea polyantha</u>              |
| Eri                    | <u>Philosamia ricini</u> H.<br>(INDIA and other<br>countries) | <u>Ricinus communis</u>              |
|                        |                                                               | <u>Ailanthus</u> sp.                 |
|                        |                                                               | <u>Manihot utilisima</u>             |

Table I. Non-mulberry silkworm varieties reared on commercial scale.

| Kind of silk                                   | 1980   | 1981   | 1982   | 1983   | 1984   | 1985  |
|------------------------------------------------|--------|--------|--------|--------|--------|-------|
| Mulberry                                       | 55,500 | 56,100 | 52,014 | 51,981 | 56,133 | N.A.  |
| Non-mulberry                                   | 3,348  | 3,713  | 2,574  | 2,762  | 3,410  | 2,574 |
| Total                                          | 58,848 | 59,819 | 54,588 | 54,743 | 59,543 |       |
| Non-mulberry percentage of total silk produced | 5.96   | 6.20   | 4.72   | 5.04   | 5.73   |       |

in metric tons

Table II. Production of silk (1980-1985).

| Year | Production in metric tons | Source of information                                                                                         |
|------|---------------------------|---------------------------------------------------------------------------------------------------------------|
| 1980 | 2900                      | China Silk Corporation                                                                                        |
| 1981 | 3265                      | Data presented by the Chinese delegation to XV Congress of I.S.A. held in London                              |
| 1982 | 2040                      | Data presented by the Chinese delegation during Regional Consultative Group on Silk meeting held at Bangalore |
| 1983 | 2020                      | Annual report of the China Silk Corporation                                                                   |
| 1984 | 2632                      | China Silk Corporation                                                                                        |
| 1985 | 1706*                     | China Silk Corporation, quoted by the International Silk Association                                          |

Table III. Oak tasar silk production of China (1980-1985).

| YEAR    | TASAR<br>including tropical tasar<br>( <u>Antheraea mylitta</u> )<br>and temperate tasar*<br>( <u>A. proylei</u> J.) | ERI<br><u>Philosamia ricini</u> | MUGA<br><u>Antheraea assama</u> | TOTAL |
|---------|----------------------------------------------------------------------------------------------------------------------|---------------------------------|---------------------------------|-------|
| 1980-81 | 265                                                                                                                  | 135                             | 48                              | 448   |
| 1981-82 | 257                                                                                                                  | 147                             | 44                              | 448   |
| 1982-83 | 284                                                                                                                  | 213                             | 37                              | 534   |
| 1983-84 | 418                                                                                                                  | 270                             | 54                              | 742   |
| 1984-85 | 444                                                                                                                  | 279                             | 55                              | 778   |
| 1985-86 | 464                                                                                                                  | 352                             | 52                              | 868   |

Production in metric tons

\* Temperate tasar silk (Antheraea proylei J.) production being as yet very small in India 2-5 metric tons, the same is not shown separately.

Table IV. Non-mulberry silk production of India (1980-86).

POTENTIAL HAZARDS OF MICROBIAL INSECTICIDES TO THE ERI SILKWORM,  
PHILOSAMIA RICINI

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The eri silkworm, Philosamia ricini is the wild silkworm currently being promoted to raise for cocoon production in Thailand. Potential hazards of several microbial insecticides used extensively for insect control, to the eri silkworm were investigated. Three doses of each pathogen were administered to the first, third and fifth instar eri silkworm by either peroral or surface inoculation. The results indicated that the bacteria, Bacillus thuringiensis was the most harmful pathogen to all larval instars. The rate of infection by the nematode, Neoplectana carpocapsae was apparently high in the early instar larvae. Beauveria bassiana, Aspergillus flavus and Metarhizium anisopliae were entomopathogenic fungi employed in this study. Among them, Beauveria bassiana was the most infectious pathogen to the eri silkworm. The nuclear polyhedrosis virus of Spodoptera exigua and of Heliothis armigera had no significant effects on the eri silkworm. This study suggested that the harmful effects of microbial insecticides on the eri silkworm should be aware and the efficient protection measures should be promptly investigated and established.

INTRODUCTION

The eri silkworm, Philosamia ricini Boisd., a domesticated multivoltine silkworm was introduced into Thailand from India in 1974 (Sepsawat and Satyavirut, 1977). Extensive cultivations were conducted mainly in the highlands of Northern Thailand with the objective to promote the wild silkworm cultivation as an economic activity for the hill tribes in substitute for opium production (Wongtong *et al.*, 1981). However, the eri silkworm offers an excellent potential for cultivation throughout the country for several reasons. It is a polyphagous insect which allows the extensive distribution. The silkworm itself

is less susceptible to diseases and yields a very rich harvest. Furthermore it is an indoor rearing domestic insect which can be easily cultured by any member of the family in the rural area. Present informations confirm that the eri silkworm cultivation will be practised more extensively in Thailand as a subsidiary cottage industry in the foreseeable future.

The importance of pathogens as safe, economical, and effective agents for pest control is increasingly recognized worldwide. Many entomopathogenic microorganisms have been developed commercially as bioinsecticides. In Thailand, the research is progressing towards the utilization of microbial insecticide not only in agriculture but also in forestry and public health. Several pathogens were practically used in field trials and few were commercially available. There is no doubt that if the microbial insecticides were used extensively, risks for the eri cultivation will have to be taken into consideration. Therefore this study is conducted in an attempt to define potential hazards of those agents to the eri silkworm.

## MATERIAL AND METHODS

### Silkworm culture.

A laboratory stock of eri silkworm was established from eggs obtained from the Royal Ang Khang Highland Research Station. The insects were reared with castor leaves (*Ricinus communis* L.) laid on 80 cm circular screen bamboo trays. The mature larva was placed in each cell of paper screen for cocoon spinning. The freshly emerged male and female healthy moths were tied with cotton thread on hanging stick for coupling. The eggs, deposited in a single layer on the sticks were collected and incubated in the plastic box. Water was added in the box to facilitate egg hatching.

### Pathogens.

Pathogens which have been developed or hold great promise to be developed as microbial insecticides were employed. The tested pathogens were:

1. Two locally isolated nuclear polyhedrosis virus (NPV) of *Heliothis armigera* and of *Spodoptera exigua*.

2. The bacteria, *Bacillus thuringiensis* in pure culture locally isolated from the silkworm, *Bombyx mori* and in commercial preparation under the trade name Thuricide (F HPSO wettable powder (Sandoz) with a stated potency of  $1.60 \times 10^7$  International Units/g.

3. Three entomopathogenic fungi, *Beauveria bassiana*, *Metarhizium anisopliae* and *Aspergillus flavus*. All were locally isolated from different species of insect.

4. The nematode, *Neoaplectana carposcapsae* DD 136 kindly provided by the Division of Biological Control, Department of Agriculture.

Besides Thuricide <sup>®</sup>, all pathogens tested were in partially purified suspension. Dosage determinations were accomplished by hemacytometer count. Specific doses were selected based on the dosage practically used in the field. Serial dilution of the original suspension was made to obtain three specific doses of each pathogen. All preparations were prepared shortly before used.

### Test procedure.

First, third and fifth instar eri silkworms were tested with each pathogen. For

virus, bacteria and nematode inoculations, castor leaves were dipped in each of the serially diluted inoculum, air dried and fed to the larvae for 24 hours. For fungus inoculation, brush was used to apply the inoculum on the cuticle of the insect. Only one time brushing through the entire body was performed for each suspension. Each dose, tested with 20 larvae, was replicated four times. Control larvae were treated with sterile distilled water. Each experimental unit was then placed in the plastic box with metal screen on the lid for better ventilation and incubated under room condition. On subsequent days the untreated castor leaves were supplied to the larvae and the excreta were discarded. Larval mortality was recorded daily. Observations were terminated after 10 days of the experiment. All data were statistically analyzed.

## RESULTS AND DISCUSSION

Response of the eri silkworm to infection with the nuclear polyhedrosis viruses are illustrated in Table 1. Currently the *H. armigera* NPV and *S. exigua* NPV were used to control insects on cotton, tomato and vegetable crops in some areas of Thailand. The range of the virus concentration recommended to use in the field is  $10^7$ - $10^9$  polyhedral inclusion bodies per ml. The relative responses for these two NPV were the same. The concentration of the viruses had no effect on infection. Although it was understood that resistance to diseases increased with the age of the insect, high mortality was obtained in the fifth instar larvae. However the apparent symptoms are not characteristic of the NPV infection. No polyhedral inclusion bodies of both viruses were microscopically detected in the dead larvae. It was assumed that both viruses are not the cause of the death. Mortality occurred may be due to the fact that larvae used were of late instar or about to spin the cocoon and larvae at this stage were virtually susceptible to handling. Furthermore the inoculum may contain some contaminants which were indeed the cause of the death. Statistical analysis indicated that the mortality observed was insignificant except in the first instar larvae inoculated with *H. armigera* NPV of  $10^7$  polyhedra per ml. Handling may be the cause of this error. *P. ricini* was reported to be immune to grasserie, virus disease of silkworm, *B. mori* (Chowdhury, 1970). However the nuclear polyhedral inclusion bodies have been detected, therefore *P. ricini* is considered a healthy carrier of the virus (Jolly *et al.*, 1979). Results from this study and the provided informations suggested that the *H. armigera* NPV and *S. exigua* NPV had no significant effect on the eri silkworm.

In Thailand *Bacillus thuringiensis* has been used to control Lepidopterous insects in Agriculture and Forestry for decades. In recent years, it has been extended the usefulness to control insects vector of human diseases, especially mosquitoes. Therefore, the domesticated animal, for example the eri silkworm must be unavoidably exposed to this bacterium. Data summarized in Table II confirmed the harmful effect of *B. thuringiensis* to eri silkworm. The pure culture preparation and the imported product manufactured as Thuricide ® were both effective to all larval instars. The eri showed a reduction in susceptibility to bacterial infection with increasing larval age. Dosage of the bacterium had noticeable effect on the eri silkworm. Mortality declined with decreasing dose for both bacterium preparations. Diseased larvae putrefied and emitted an unpleasant odour which is typical of bacterium infection. It is interesting to note that commercially produced *B. thuringiensis* was more virulent than the local one. This result suggested that the ingredients added in the commercial preparation such as wetting agents, spreaders, stickers, etc., might facilitate food consumption thus enhance the infection of the disease. The results also indicated that the approximate concentrations of the bacterium practically used in the field,  $10^6$ - $10^7$  viable cells per ml., were infectious to all larval instars. Statistical analysis convinced that *B. thuringiensis* of both preparations were significantly toxic to the eri silkworm. Bacteriosis was reported to cause troublesome to the eri silkworm in the highlands of Northern Thailand

(Wongtong *et al.*, 1981) but no identification of the causal agents was made. It is possible that *B. thuringiensis* is the common and widespread pathogen of the eri silkworm.

Table III summarizes the response of the eri to the fungus infection. It is obvious that *Beauveria bassiana* was the most effective fungus. Susceptibility to mycosis decreased with the increasing larval age. *B. bassiana* caused significant mortality in the first and third instar larvae. The fifth instar larvae virtually resisted to infection. The diseased larvae showed typical symptoms of the white muscardine disease. The cadaver is mummified and covered with white spores. *Metarhizium anisopliae* and *Aspergillus flavus* had apparently no significant effects on the eri silkworm. However mortality with characteristic symptoms was detected. It is surprising that the eri showed resistance to *A. flavus*, the most common fungus which is highly toxic to the mulberry silkworm *Bombyx mori* (Chaitungjit *et al.*, 1985). Green muscardine fungus, *M. anisopliae* was also reported as one of the major diseases of eri in India (Chowdhury, 1970). Differences in response to the pathogen may be affected by the different strains of the host and pathogen and the environmental conditions. The utilization of fungal pathogens for the control of insect pests is at an early stage in Thailand. However there is an attempt to control *Oryctes rhinoceros*, the most serious pest of coconut, by using *M. anisopliae*. Other fungi have been under investigation for potential use in control program. Therefore the potential hazards of the entomopathogenic fungi can not be neglected.

Table IV presents the response of the eri silkworm to the infection with the nematode, *Neoaplectana carpocapsae*. Results indicated the harmful effect of the DD 136 nematode to the eri larvae especially at the early instar. The infected eri died rapidly after inoculation with distinct symptoms. The larvae become soft, flaccid and body colour changed to black. The newly hatched nematode were detected in the nematode collecting box. The DD 136 nematode is presently in the laboratory trials for controlling the American bollworm *Heliothis armigera* in Thailand.

For the data presented in this study the tentative conclusion is advanced that *B. thuringiensis*, the fungi especially *B. bassiana* and the DD 136 nematode were pathogenic to the eri silkworm. Precaution must be exercised strictly in cultivation areas where these microbial agents are utilized for pest control. Viral insecticide has no effects on the eri and this is not unexpected since viruses are well known on their host specific characters. It is also convinced that regulations for proper utilization of the microbial insecticide should be promptly investigated for safety aspect of the eri silkworm cultivation.

#### ACKNOWLEDGEMENT

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| Pathogen                      | Approximate dosage<br>polyhedra/ml | Percent mortality(1) |            |            |
|-------------------------------|------------------------------------|----------------------|------------|------------|
|                               |                                    | 1st instar           | 3rd instar | 5th instar |
| <i>Heliothis armigera</i> NPV | $10^9$                             | 2.5                  | 2.5        | 12.5       |
|                               | $10^7$                             | 15**                 | 0          | 2.5        |
|                               | $10^5$                             | 5                    | 0          | 7.5        |
| <i>Spodoptera exigua</i> NPV  | $10^9$                             | 2.5                  | 0          | 12.5       |
|                               | $10^7$                             | 0                    | 5          | 15         |
|                               | $10^5$                             | 0                    | 0          | 7.5        |
| Control                       |                                    | 2.5                  | 0          | 0          |

(1) average of 4 replicates, 20 larvae per replicate

\*\* P = .01

Table I. Mortality response of the eri silkworm, *Philosamia ricini* to infection with the nuclear polyhedrosis viruses.

| Pathogen                                                 | Approximate dosage<br>viable cells/ml | Percent mortality (1) |            |            |
|----------------------------------------------------------|---------------------------------------|-----------------------|------------|------------|
|                                                          |                                       | 1st instar            | 3rd instar | 5th instar |
| <i>B. thuringiensis</i> (2)<br>Thuricide ®               | $10^8$ - $10^9$                       | 100*                  | 100*       | 100*       |
|                                                          | $10^6$ - $10^7$                       | 100*                  | 100*       | 60*        |
|                                                          | $10^4$ - $10^5$                       | 12.5**                | 72.5*      | 15         |
| <i>B. thuringiensis</i> (3)<br>var. <i>thuringiensis</i> | $10^8$ - $10^9$                       | 100*                  | 100*       | 22.5*      |
|                                                          | $10^6$ - $10^7$                       | 100*                  | 100*       | 10         |
|                                                          | $10^4$ - $10^5$                       | 10**                  | 17.5       | 10         |
| Control                                                  |                                       | 2.5                   | 0          | 0          |

(1) average of 4 replicates, 20 larvae per replicate

(2) commercialized product under the trade name Thuricide ®

(3) pure culture isolated from the silkworm, *Bombyx mori*

\* P = .05

\*\* P = .01

Table II. Mortality response of the eri silkworm, *Philosamia ricini* to infection with the bacteria, *Bacillus thuringiensis*.

| Pathogen (1)                  | Approximate dosage<br>spores/ml | Percent mortality (2) |            |            |
|-------------------------------|---------------------------------|-----------------------|------------|------------|
|                               |                                 | 1st instar            | 3rd instar | 5th instar |
| <u>Beauveria bassiana</u>     | $10^7-10^8$                     | 82.5*                 | 45*        | 17.5       |
|                               | $10^5-10^6$                     | 40*                   | 32.5*      | 10         |
|                               | $10^3-10^4$                     | 20**                  | 20         | 10         |
| <u>Metarhizium anisopliae</u> | $10^7-10^8$                     | 5                     | 7.5        | 17.5       |
|                               | $10^5-10^6$                     | 7.5                   | 0          | 2.5        |
|                               | $10^3-10^4$                     | 7.5                   | 0          | 5          |
| <u>Aspergillus flavus</u>     | $10^7-10^8$                     | 15                    | 10         | 15         |
|                               | $10^5-10^6$                     | 15                    | 7.5        | 7.5        |
|                               | $10^3-10^4$                     | 10                    | 20         | 7.5        |
| Control                       |                                 | 2.5                   | 5          | 0          |

(1) pure culture on Sabouraud Dextrose Agar (SDA) medium

(2) average of 4 replicates, 20 larvae per replicate

\* P = .05

\*\* P = .01

Table III. Mortality response of eri silkworm, *Philosamia ricini* to infection with three entomopathogenic fungi.

| Pathogen (1)                             | Approximate dosage<br>larvae/ml | Percent mortality (2) |            |            |
|------------------------------------------|---------------------------------|-----------------------|------------|------------|
|                                          |                                 | 1st instar            | 3rd instar | 5th instar |
| <u>Neoplectana carpocapsae</u><br>00 136 | $10^4-10^5$                     | 80*                   | 80*        | 12.5       |
|                                          | $10^2-10^3$                     | 5                     | 30*        | 0          |
|                                          | $10^1-10$                       | 12.5                  | 15         | 15         |
| Control                                  |                                 | 2.5                   | 0          | 0          |

(1) the culture isolated from the American bollworm, Heliothis armigera

(2) average of 4 replicates, 20 larvae per replicate

\* P = .05

Table IV. Mortality response of the eri silkworm, *Philosamia ricini* to infection with the nematode, *Neoplectana carpocapsae*.

INVESTIGATION ON THE PROPERTIES OF SEED AND NURSERY TECHNIQUE OF  
TERMINALIA ARJUNA, PRIMARY FOOD PLANT OF TASAR SILKWORM,  
ANTHERAEA MYLITTA D.

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Among the food plants of tasar silkworm *Terminalia arjuna* is the most fast-growing plant. Unfortunately its vegetative propagation is not economically feasible. Therefore, to increase the acreage of the food plants we have to depend upon the sexual propagation method. Nowadays for block and economic plantations a large number of seedlings are required. To rationalise the seedling raising practice, the germination behaviour of seed and basically the structure and construction of seeds should be studied to exploit its ecological aids for the purpose. Several works have been carried out on these aspects. Here it is tried to arrange these findings systematically and draw a general inference for a new nursery technique by reviewing the previous works.

INTRODUCTION

In 1977-78, it was the opinion of Central Tasar Research Station that *Terminalia arjuna* seeds are dormant having hard and impermeable pericarp. That's why a long term treatment of seeds in warm and normal temperature water was done. Das *et al.* (1978-79) found 72.20% germination in hot water treatment followed by 96 hours of soaking in same water and 82.36% in 96 hrs. soaking in water at room temperature. Singh (1982) suggested 96 hrs. of soaking in water.

At Bhagalpur a team of scientists studied the structure of seed and its water imbibition capacity. It was found that its structure favours the rapid absorption of water (Singh *et al.*, 1984). According to Barton (1950), longer than 24 hrs. soaking duration is harmful and has a deleterious effect on germination. On this

view, the soaking duration is reduced only from 12 to 24 hrs. which exhibited a promising response. Recently it was found that the irregular and delayed germination of these seeds can be improved by soaking them in Gibberellic acid (50 ppm) solution for 24 hrs.

All above findings are arranged in the following parts.

## THE SEED

The fruits of *T. arjuna* are one seeded drupe, samara type. The actual seed is spindle shaped and situated in the centre of the fruit. It is so safely incircled inside the pericarp that it can not be easily separated. So, the entire dry fruit is termed the seed.

### Size :

The seeds have 4-5 wings and weigh 1 to 5.5 grams, these are divided in four weight groups, i.e., A (1-2 g), B (2.1-3 g), C (3.1-4 g), and D (4.1 g and above). More than 50% of seeds fall in group C, 30% in group D, 15% in B and less than 2% in A. Volume of a single seed ranges from 5 to 9 ml. They are 2.9 to 5.5 cm long and 2.8 to 4.5 cm wide including wings or only 1 to 1.9 cm wide at wingless area, it was noticed that the width of wingless area was largest in lowest weight group.

### Pericarp :

The seed rests inside the thin layered endocarp which is surrounded by a thick layer of woody but porous mesocarp, the wings arise from this zone, at the micropylar end long fibres are arranged one upon the other in longitudinal direction of seed. The epicarp is the outer most layer. Resin tubes are present longitudinally in the pericarp. In transverse section resin spots are regularly found around the actual seed. Main canals rest between the epi and meso carps. These are thicker at central region and taper towards the end.

### Ecological significance :

Previous workers (Das *et al.*, 1979; Singh, 1982) were of opinion that hard pericarp offers considerable resistance against penetration of water and gaseous exchange thereby resulting in poor, delayed and irregular germination. But recently, the author and his co-workers working since last six years at this Institute, revealed that pericarp is hard no doubt, but its modification has a sound ecological basis and is conducive to germination. Having resin canals they are highly absorbent of water and porous mesocarp provides required air. They can absorb more than 150% water of their dry weight upto 24 hours and weight becomes constant. Here more than 65% of water is imbibed within the first three hours of soaking (Singh *et al.*, 1984). In an other experiment Singh *et al.* (1986) observed that dry seeds placed in moist sand bed started to germinate four days later in comparison to sufficiently presoaked seeds placed in the same bed. It means that dry seeds took 4 days to imbibe the water required for seed activation when directly sown in soil or sand.

The excised embryo as well as confined inside the pericarp showed the equal length of initial days for germination. Thus it is evident that the pericarp does not inhibit the water or oxygen penetration. Of course seeds are of late germinating nature, perhaps due to lack of some growth regulators which is later confirmed by Kumar *et al.* (1986).

The wings have a great significance in dispersal of seeds. They help in floating and flying, at the same time increased diameter due to wings makes the seeds capable

of covering longer distances in lesser turns when rolling.

The porous mesocarp makes the floating easy. It is capable of absorbing water and helpful in supplying moisture to the actual seed for hydration. It is very hard at the place where the seed rests but at the micropylar end the way is easier for radicle and plumule emergence due to presence of longitudinal fibres.

The resin canals are of immense value in absorbing water. Canals are thicker in the middle tapering towards the end in fine tubelets which absorb water readily. Thicker portions of tube rest in the region just above the actual seed. It facilitates quick moistening of seeds.

#### GERMINATION

As already mentioned there was an old convention that pericarp is hard and inhibitor of water and gas penetration, so it was tried to have it broken or weakened. For this purpose seeds were subjected to boiling water for a while and later left soaked for a long duration of 96 hours in the same water cooling down to normal atmospheric temperature (Das *et al.*, 1979). Singh (1982) and Das *et al.* (1979) recommended 96 hours soaking the seeds in cold water. But such a long duration may harm as Barton (1950) found in some other seeds. Further, Singh *et al.* (1984) and Singh *et al.* (1986) obtained good germination percentage by soaking only for 12 hours and then keeping for after-ripening in moist medium. This time germination percentage was always more than 91% whereas in the findings of Das *et al.* (1979) maximum percentage was 82.36. Such type of bad result may be produced due to long soaking duration.

According to Singh *et al.* (1986) the best afterripening medium is moist sand bed which can provide oxygen, moisture and required intensity of light. Hartmann and Kester (1976) also recommended sand as seed bed for tree seeds.

Seeing the long germination period even providing all facilities, some growth regulators were tried out. Recently Kumar *et al.* observed that gibberellic acid (50 ppm) can influence the germination of *T. arjuna* seeds. Germination started on 6th day of treatment, percentage was 99 and the process completed only upto 8th day. Thus the maximum seeds were germinated within 3 days of initiation. This chemical hastened as well as synchronized the process which tends to production of homogeneous seedlings.

Das *et al.* (1979) obtained only 79.38 plant percentage out of 82.36% germinated seeds. In the present finding of Kumar *et al.* (1986) germination is 99%, therefore seeds may be placed directly in rooting media after the treatment. The cost of screening the germinated seeds for placing them in rooting media can be saved and mortality of germinated seeds due to disturbances during transfer from afterripening media to rooting media can be reduced resulting in the increased plant percentage.

A separate reserve stock should be maintained to fill up the failed places. Irrigation and weeding should be done at required intervals depending upon the edaphic condition. A less intensive light should be allowed to fall upon.

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| Group | Wt. range<br>(g) | Frequency | Percentage<br>(%) | Length<br>(cm) | Width (cm)   |                 | Volume<br>(ml) |
|-------|------------------|-----------|-------------------|----------------|--------------|-----------------|----------------|
|       |                  |           |                   |                | with<br>wing | without<br>wing |                |
| A     | 1 to 2           | 1         | 2                 | 2.9            | 2.8          | 1.9             | 5.00           |
| B     | 2.1-3            | 7         | 14                | 3.1-3.9        | 3.0-3.2      | 1.3-1.9         | 5.1-5.4        |
| C     | 3.1-4            | 26        | 52                | 4.0-5.4        | 3.1-3.2      | 1.0-1.4         | 5.5-5.9        |
| D     | 4.1 or more      | 16        | 32                | 4.9-5.5        | 4.0-4.5      | 1.0-1.1         | 8.1-9.0        |

NOTE : Data obtained from a lot of sample size 50 collected by random sampling

Table I. Properties of Arjuna seed.

| Days after<br>treatment | No. of cotyledons emerged |         | Cumulative percentage<br>of germination |         |
|-------------------------|---------------------------|---------|-----------------------------------------|---------|
|                         | treated                   | control | treated                                 | control |
| 10 th                   | 03                        | 00      | 03                                      | 00      |
| 11 th                   | 04                        | 00      | 07                                      | 00      |
| 12 th                   | 03                        | 00      | 10                                      | 00      |
| 13 th                   | 08                        | 00      | 18                                      | 00      |
| 14 th                   | 30                        | 34      | 48                                      | 34      |
| 15 th                   | 20                        | 08      | 68                                      | 42      |
| 16 th                   | 09                        | 19      | 77                                      | 61      |
| 17 th                   | 09                        | 17      | 86                                      | 78      |
| 18 th                   | 06                        | 13      | 92                                      | 91      |
| 19 th                   | 00                        | 00      | 92                                      | 91      |
| 20 th                   | 00                        | 00      | 92                                      | 91      |

NOTE : In treated lot seeds were soaked in water for 12 hours and in control dry seeds were taken, both were placed in the same moist sand bed.

Table II. Effect of short duration soaking on germination of *T. arjuna* seeds.

| Soaking duration (hours) | Time in removing extra water and weighing (minutes) | O'clock weighing time | Seed weight (gms) |
|--------------------------|-----------------------------------------------------|-----------------------|-------------------|
| 1                        | 3                                                   | 0718                  | 36.73             |
| 2                        | 3                                                   | 0821                  | 39.80             |
| 3                        | 3                                                   | 0924                  | 41.80             |
| 4                        | 3                                                   | 1027                  | 43.10             |
| 5                        | 3                                                   | 1130                  | 44.20             |
| 6                        | 3                                                   | 1223                  | 45.61             |
| 7                        | 3                                                   | 1336                  | 46.71             |
| 8                        | 3                                                   | 1449                  | 48.60             |
| 9                        | 3                                                   | 1552                  | 49.90             |
| 10                       | 3                                                   | 1665                  | 51.20             |
| 11                       | 3                                                   | 1758                  | 52.30             |
| 12                       | 3                                                   | 1901                  | 53.40             |
| 13                       | 3                                                   | 1004                  | 54.45             |
| 14                       | 3                                                   | 2107                  | 55.39             |
| 15                       | 3                                                   | 2210                  | 56.46             |
| 16                       | 3                                                   | 2313                  | 57.50             |
| 17                       | 3                                                   | 0016                  | 58.61             |
| 18                       | 3                                                   | 0119                  | 59.80             |
| 19                       | 3                                                   | 0222                  | 59.82             |
| 20                       | 3                                                   | 0325                  | 59.84             |
| 21                       | 3                                                   | 0428                  | 59.83             |
| 22                       | 3                                                   | 0531                  | 59.84             |
| 23                       | 3                                                   | 0634                  | 59.83             |
| 24                       | 3                                                   | 0737                  | 59.82             |

Note : Initial weight of dry seed was 24.2 gms which was soaked in water and weighed at a regular interval of one hour.  
(From Singh et al., 1984)

Table III. Water imbibition by *T. arjuna* seeds.

| Lot | Treatment     | Initiation | Completion | No. of seeds |            | % of germination |
|-----|---------------|------------|------------|--------------|------------|------------------|
|     |               |            |            | taken        | germinated |                  |
| A   | GA3 (50ppm)   | 6th day    | 8th day    | 60           | 59.4       | 99               |
| B   | IBA (50ppm)   | 6th day    | 13th day   | 60           | 58.2       | 97               |
| C   | 2,4-D (50ppm) | 8th day    | 30th day   | 60           | 36.0       | 60               |
| D   | Control       | 8th day    | 30th day   | 60           | 49.8       | 83               |

Note : Seeds were soaked in 50ppm solution of GA3, IBA and 2,4-D and in tap water for control. (From Kumar et al., 1985)

Table IV. Effect of growth regulators on germination of *T. arjuna* seeds.

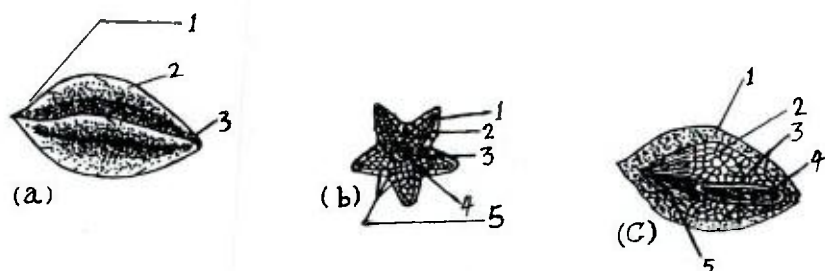


Figure 1. External and internal structure of *T. arjuna* seeds.

- (a) A mature fruit termed 'seed'
1. Mycropyilar end
  2. Wing
  3. Pedicular end
- (b) T.S. of fruit as visible with naked eye
1. Epicarp
  2. Mesocarp
  3. Endocarp
  4. Actual seed
  5. Resin canals
- (c) V.S. of fruit as visible with naked eye
1. Epicarp
  2. Mesocarp
  3. Endocarp
  4. Actual seed
  5. Longitudinal fibres of mesocarp

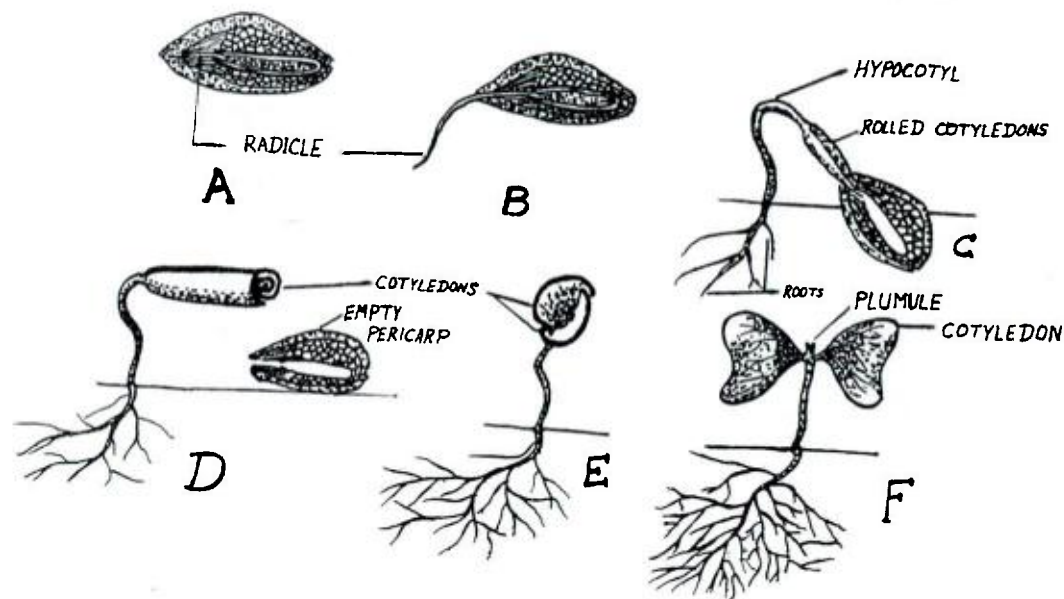


Figure 2. Germination of *T. arjuna* seeds.

- A. Radicle growth started
- B. Radicle came out
- C. Roots formed, hypocotyl grown rapidly and pulling the cotyledons
- D. Cotyledons came out leaving the pericarp empty
- E. Cotyledon started to open
- F. Cotyledons stretched and turned green, plumule growth started

LEAF AND CASTOR BEAN PRODUCTION IN FOUR CASTOR VARIETIES  
FOR DOUBLE EXPLOITATION, PROMOTING ERICULTURE  
AS AN AGROCOTTAGE INDUSTRY

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Four castor varieties, viz., GAUC, NPH, GAUCH and ARUNA, have been studied in relation to erisilk (castor silk) production under two foliation schemes,  $D_0$  (control) and  $D_1$  (40% leaves plucked to feed erisilk larvae and harvest the cocoons together with the beans produced by  $D_1$  plants as also by  $D_0$  plants). Of the four castor varieties, ARUNA yielded the largest leaf biomass (0.196 kg/plant) and NPH the least (0.130 kg) in  $D_1$  scheme. The leaf biomass variance component of ARUNA versus the rest showed this variety better leaf-yielder than the rest at 0.05 level of probability. In bean production, the highest yield, under  $D_0$  was from GAUC (0.133 kg/plant), which is 12% higher than that of the best leaf-yielder ARUNA and NPH was at the bottom (0.114 kg). In  $D_1$ , however, the defoliatory bean-yield reduction was the least in ARUNA (27%), 40% in the best bean-yielder GAUC and NPH suffered the most (47%). In view of the over-all combined highest returns under  $D_1$ , ARUNA turns out to be the best choice because of the lowest defoliatory bean-yield reduction and highest leaf yield (available for silk conversion). Possibilities of much higher revenues than shown in the present study, have been explored from an earlier study (Misra et al., 1985), which indicates much higher revenues, relying on regenerative capacity of leaves during the 33-days non-feeding interval between two feeding cycles of 17 days. Further gains are possible on carrying over the same crop to the following year by continuing irrigation and manuring during the difficult summer months and continuing the rearing programme (the erisilk moth being multivoltine).

## INTRODUCTION

In the context of evaluating the candidature of four castor varieties for ericulture, viz., GAUC, NPH, GAUCH and ARUNA, leaves are the most relevant part of the plant on account of the saturniid moth, *Samia cynthia ricini* (= *Philosamia ricini*) synthesizing two proteins, fibroin and sericin, which constitute the silk, from leaves it feeds on during the 17 days of its larval feeding-period. Leaves, again are the plant part which synthesize substances for bean (seed) formation.

Because of this double role of leaves, the best way of evaluating the castor variety for ericulture would be to determine three things: (1) The leaf and bean yields in  $D_1$  scheme to be converted into monetary values. (2) To estimate the revenue accruing from beans when ericulture is not practiced ( $D_0$ ). (3) As a corollary to the first enquiry, to compute the maximum quantity of leaf biomass and its monetary value that would be available as potential producer of silk.

## METHODOLOGY

A total of 2,400 plants of four castor varieties (mentioned above) were grown in a random block design in a field, measuring  $35m \times 35.8m$  in which the effective crop area (leaving passages) was  $18 \times 48 = 864m^2$  for 48 miniplots, each occupying  $5m \times 3.6m = 18m^2$ , accomodating 50 plants so that each plant covered an average of  $0.36m^2$ . The eight treatment combinations for each variety (occupying  $108m^2$ ) in  $D_0$  (control) and  $D_1$  (40% defoliation by count every month) were distributed in six replicates (Table I).

Per plant, the bean yield in  $D_0$  and the same, together with leaf biomass, in  $D_1$  are based on monthly observations (October through February, 1985: postmonsoon and winter) from 5 out of 50 plants in each miniplot of the eight treatment combinations.

The following factors have been derived from the experimental data for directly calculating yields and revenues of leaf biomass and bean yield per hectare:

- (1) Numbers of plants/ha =  $50 \times 10,000/18 = 27,777.8$  plants ;
- (2) Leaf biomass and bean yield/ha = Plants (1)  $\times$  rates ;
- (3) Cut cocoons produced/kg of leaf = Cut cocoons produced divided by fresh leaves offered =  $0.098995/6.675 = 0.01483$  kg ;
- (4) Notional monetary value of leaf biomass/kg at Rs 50/kg cut cocoons = Amount of cut cocoons produced per kg leaf (Factor in 3)  $\times$  rate of cut cocoon selling =  $0.01483 \times 50 = 0.7415$  (Rupees).

## RESULTS AND DISCUSSION

### A. Leaf biomass available for ericulture in $D_1$ scheme

It will be seen from Table II that the greatest leaf mass came from ARUNA (0.196 kg/plant) followed by that from GAUCH (0.151 kg), GAUC (0.144 kg) and NPH (0.130 kg), in that order. However, from the analysis of variance (ANOVA), the mean yields of the various castor varieties are not significantly different among themselves (*inter*

se). But it was observed all the same that, regarding leaf yield (40% plucking), three varieties out of four, viz., GAUC, NPH and GAUCH, have close mean values, making a group all by themselves, and being different from the mean of ARUNA which becomes isolated in this respect. In order to find statistical validity to the observed distinct position of ARUNA, the variance component of the three close varieties *versus* ARUNA was partitioned and tested against the error component (Little & Hills, 1978). The significant F value of the partitioned component revealed that ARUNA leaf yield is significantly higher (0.05 level) than the rest of the three varieties as a group.

#### B. Bean production under the two foliation schemes

Besides silk production, the other channel of exploitation provided by leaves is beans which are crushed for oil extraction. In the context of ericulture ( $D_1$ ), three considerations are important: the first is the selection of a castor variety which strikes a good balance between foliar production and bean production, so that bean production is not reduced by more than 30% (Table III) on raising the defoliation level for increasing silk production; the second is the consideration that beans produced have high lipid content, increasing their marketability for oil extraction. Finally is the consideration that combined revenue from beans and leaves (converted into silk) is substantially higher than the revenue from beans alone ( $D_0$ ) to cover the overhead expenses and offer lucrative gain. It is this dual exploitation which is the crux of ericulture compared to sericulture (mulberry silk production) in which the only source of revenue comes from leaves to silk.

The Table III gives the yield of castor beans which, in  $D_0$  is the highest for GAUC variety (0.133 kg/plant), 14% higher than the yield from ARUNA (0.117 kg) and the lowest is from NPH (0.114 kg), about 3% lower than that from ARUNA. Although the ANOVA based on *inter se* comparison (as in the case of leaves) does not find the varietal bean yield different significantly, the biological observation shows that NPH bean yield is farthest apart from the rest taken together.

The ranking of this castor variety, with respect to the rest, was therefore tested like the position of ARUNA for leaves. The ANOVA in this comparison gives NPH a lower ranking than the rest at 0.05 level of probability. The reason for the inferior ranking is seen in 47% (the highest) defoliatory bean yield reduction suffered by this castor variety in  $D_1$  scheme. The difference in mean bean yield of this variety from the best variety, i.e. GAUC, is greater than the Critical Difference (C.D. 0.05), while all the other varieties stand more or less together on this criterion. Thus NPH could be identified as the most inferior variety (lowest in bean yield as well as in leaf yield) and is fit to be eliminated as a candidate for ericulture.

From the point of view of lipid content (Table IV), the ANOVA reveals that the varietal differences are significant *inter se*, which is obviously due to unusually low lipid content in two of the seven castor varieties (BILARA and UDAIPUR cultivars) as would be clear from the CD values showing that the four varieties, viz., GAUC, NPH, GAUCH and ARUNA are not significantly different in this group. The same situation is seen in the matter of entire seed weights (Table V), which shows that the four castor varieties are not statistically indistinguishable in seed weight as in lipid content, but, because of the UDAIPUR and BILARA cultivars being noticeably lighter, the *inter se* differences become significant.

#### C. Possibilities of using larger percentage of defoliation for silk production

Since the only plant part convertible into silk is the leaf, it would be proper to explore the extent to which leaf conversion into silk can be pressed for substantially increasing  $D_1$  revenue over  $D_0$ .

An indication of this is available from a previous work (Misra *et al.*, 1985) on a small plot of 23m x 23.5m = 506m<sup>2</sup>, accomodating 1682 ARUNA variety castor plants. In this small plot experiment, weighed amounts of fresh leaves from all the plants grown in four blocks (A, B, C, and D) were offered to the erisilk larvae which were being reared in the laboratory. After each rearing cycle, when the final stage larvae had stopped feeding, preparatory to cocooning, all the mature leaves from all the plants in the four blocks were plucked and weighed to determine the total amount of mature leaf biomass produced by the plants (including the amounts which had been offered to the larvae).

In this small plot experiment, a total leaf mass of 959.9kg was obtained in the manner given above from 1682 plants (computed to 33,241 plants/ha). Thus, 0.5707kg of leaves per plant were obtained by complete defoliation as compered to 0.1963kg obtained in 40% defoliation (Table II). With this rate, the complete defoliation of mature leaves (in the manner given) in a hectare will yield 18,970.6kg of leaves.

This, indeed is a very rosy picture which would need corroboration from a well-planned extension work requiring wider organization. In fact, the picture would be still more attractif if the revenue from whatever small amount of beans that are produced even on complete defoliation (in the manner given) is added. The gap of 33 days between two feeding cycles appears to be sufficient for new leaves to appear, synthesizing substances for seed formation, although reducing the yield considerably. In the small plot experiment, despite complete defoliation, 200kg of beans were harvested, which at the prevailing market rate were worth Rs. 580.

The model of utilizing regenerative capacity of the leaves, with an eye on the 33-days gap of non-feeding period between two silkmoth cycles, suggests enormous possibilities for ericulture, requiring planned extension work to establish it as a fact.

#### D. Rationale of selecting the most suitable castor variety

Ninety-three per cent of the castor production in India comes from Andhra (67.2%), Gujrat (12.7%), Karnataka (7.1%) and Orissa (5.8%) (Anonymous, 1980). Since these states grow castor as an important oilseed crop which forms the backbone of agricultural economy of India, only the seed-promoting foliar role of this crop attracts the fancy in these states for which a high bean yielding GAUC-model is presumed to be in use and utilization of the other, viz., silk conversion foliar role has not occurred to these farmers for the simple reason that ericulture, based on this role is native of the eastern Himalayan region and is practiced by tribal people and small farmers. Transgression of the traditional beliefs and practices always meets resistance requiring a lot of pioneering efforts to affect a change. This explanation answers why ericulture has been able to spill nver only to a few districts in the plains of the adjoining states. The potentials of ericulture are now being slowly realized as it is being understood that climate is not the limiting factor for the multivoltine erisilk moth if it is not for its food plant, because the silkmoth larvae are fed inside rooms without the larvae being obliged to face the climate braved by the plants outside. This is the same way that the only other agriculture-based mulberry silkmoth larvae are fed, although their bivoltine races in tropical regions face problems and diapause handicaps (Vijay, 1985). As for the principal food plant, the castor crop makes no demand on the kind of soil and easily grows in semiarid and derelict lands for which reason ericulture would be ideal in reclamation of derelict lands (Misra, 1987a).

For selecting a suitable castor variety out the three models, viz., GAUC, GAUCH and ARUNA, a comparison is made of the bean-promoting role of leaves ( $D_0$ ) with the double foliar roles in the three models by converting the data of Tables II and III into one, comparable percentage ratios. The leaves have been converted into equivalent cocoon weights on the basis of earlier work (Misra, 1985b: 6.675 kg fresh leaves sufficing (offered) for one DFL, producing 0.098995 kg cut cocoons). To make 40% leaf figures ( $D_1$ ), comparable with bean figures under the two foliar schemes ( $D_0$  and  $D_1$ ), they have been converted into equivalent cocoon weight which they would have produced. The cocoon weights have been multiplied by the price ratio of one kg of cocoon to one kg of the beans ( $\text{Rs. } 50/2.90 = 17.24$ ) to make them comparable with bean in monetary values in  $D_0$  and  $D_1$  (Table VI).

Analysing the relative figures in the table with ARUNA as the frame of reference (100), it becomes apparent that in the seed-promoting role ( $D_0$ ), pursued exclusively in the major castor growing states in India, one unit of GAUC bean will fetch Rs. 113, compared to Rs. 100 from ARUNA and Rs. 102 from GAUCH. However, if ericulture is introduced ( $D_1$ ) the defoliatory reduction in gain from beans will drop from Rs. 113 to Rs. 68. Ericulture can provide an additional amount of Rs. 31 (from 40% leaves), making the total of Rs. 99 against Rs. 113 in  $D_0$ . Obviously drastic defoliatory bean loss, made worse by very low leaf biomass, makes this castor variety unsuitable for ericulture, resulting in a loss of 12%. For ericulture, therefore the model to be selected is ARUNA castor variety, which, although contributes Rs. 73 (against the maximum of Rs. 113 by GAUC), more than makes up by the high leaf biomass contributing Rs. 43 (against Rs. 31 by GAUC leaf biomass), thus ensuring an over-all gain of 16%. This manner of comparison reiterates the conclusion arrived at in the previous paper (Misra, 1987). The strategy for ericulture should be to select the right castor variety and raise the defoliatory level for silk conversion warranted by conclusions from the small plot experiment (*vide supra*).

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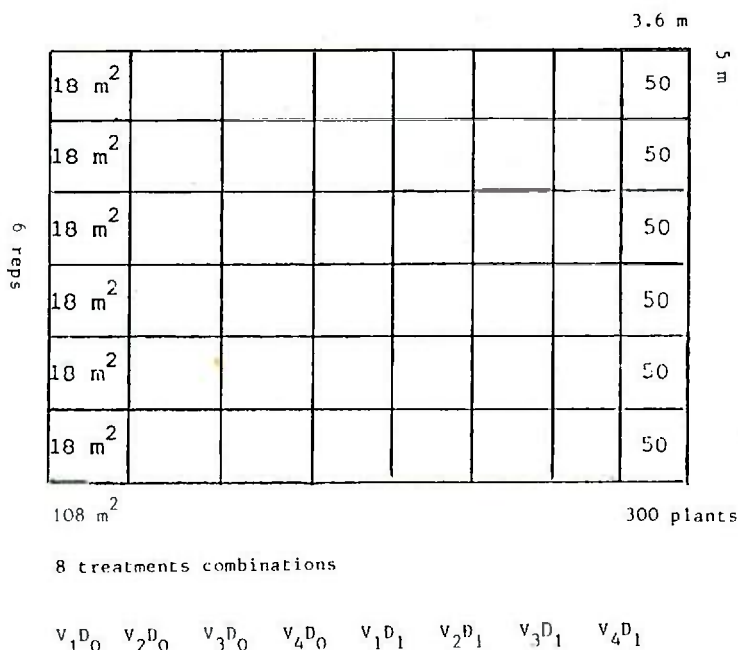


Table 1. Plan of experiment.

Estimation of leaf and bean yields under  $D_0$  (control) and  $D_1$  (experiment) for working out the economics of ericulture for 4 castor varieties. Each variety was provided 108m. space for control and as much for the experiment. The placement of the 8 combination treatments were randomized in 48 miniplots (not shown in plan to simplify understanding).

| Castor var in $D_1$ | GAUC   | NPH    | GAUCH  | ARUNA  | Mean   |
|---------------------|--------|--------|--------|--------|--------|
|                     | 0.1441 | 0.1295 | 0.1511 | 0.1963 | 0.1553 |

| ANOVA              |      |                |              |             |         |      |
|--------------------|------|----------------|--------------|-------------|---------|------|
| Source of variance | d.f. | Sum of squares | Mean squares | Cal F       | Table F |      |
|                    |      |                |              |             | .05     | .01  |
| Replicates         | 5    | 0.00499119     | 0.00099824   | 0.460       | 2.90    | 4.65 |
| Varieties          | 3    | 0.01494472     | 0.0049824    | 2.296       | 3.29    | 5.42 |
| ARUNA vs the rest  | 1    | 0.013492       | 0.13492      | 6.22*       | 4.54    | 8.68 |
| Within the rest    | 2    | 0.00145272     | 0.00073      | less than 1 |         |      |
| Error              | 15   | 0.032549       | 0.00216993   |             |         |      |
| Total              | 23   | 0.052485       |              |             |         |      |

CO (.05) for ARUNA vs the rest 0.046796

Table II. Mean castor leaf yield (kg, fresh wt/plant) in  $D_1$  scheme, from observations on 5 out of 50 plants in miniplots (size  $5 \times 3.6 \text{ m} = 18 \text{ m}^2$ ) of four castor var in six replicates.

| Castor var in $D_0/D_1$ | GAUC    | NPH     | GAUCH   | ARUNA   | Mean    |
|-------------------------|---------|---------|---------|---------|---------|
| $D_0$                   | 0.13263 | 0.11440 | 0.11927 | 0.11720 | 0.12087 |
| $D_1$                   | 0.08010 | 0.06023 | 0.08270 | 0.08583 | 0.07721 |
| Mean                    | 0.10636 | 0.08731 | 0.10098 | 0.10151 | 0.09904 |
| % reduction             | 39.6    | 47.4    | 30.7    | 26.8    |         |

ANOVA

| Source of variance  | d.f. | Sum of squares | Mean squares | Cal F       | Table F |      |
|---------------------|------|----------------|--------------|-------------|---------|------|
|                     |      |                |              |             | .05     | .01  |
| Replicates          | 5    | 0.003124       | 0.000624     | 1.31        | 2.49    | 3.60 |
| Varieties           | 3    | 0.002412       | 0.000804     | 1.69        | 2.88    | 4.41 |
| NPH vs the rest     | 1    | 0.002205       | 0.0002205    | 4.63*       | 4.12    | 7.43 |
| NPH within the rest | 2    | 0.000207       | 0.000104     | less than 1 |         |      |
| Foliar treatment    | 1    | 0.022872       | 0.022872     | 48.01**     | 4.12    | 7.43 |
| Interaction:        |      |                |              |             |         |      |
| V x D               | 3    | 0.001171       | 0.000390     | 0.08        | 2.88    | 4.41 |
| Error               | 35   | 0.016672       | 0.000476     |             |         |      |
| Total               | 47   | 0.046253       |              |             |         |      |

CO (.05) foliar treatment 0.012785; (.01) 0.017194;  
 (.05) NPH vs the rest 0.014763

Table III. Comparison of mean bean yield (kg/plant) in  $D_0$  and  $D_1$  schemes and percentage reduction in  $D_1$ .

| Castor var/cult | GAUC   | NPH    | GAUCH  | ARUNA  | ASSAM  | UDAIPUR | BILARA |
|-----------------|--------|--------|--------|--------|--------|---------|--------|
|                 | 274.82 | 295.14 | 295.70 | 295.12 | 283.43 | 45.13   | 109.68 |

# ANOVA

| Source of variance | d.f. | Sum of squares | Mean squares | Cal F    | Table F |     |
|--------------------|------|----------------|--------------|----------|---------|-----|
|                    |      |                |              |          | .05     | .01 |
| Replicates         | 9    | 61716.78       | 6857.91      | 2.230    |         |     |
| Varieties          | 6    | 663460.80      | 110576.80    | 35.960** | 2.3     | 3.2 |
| Error              | 54   | 166047.70      | 3074.95      |          |         |     |
| Total              | 69   | 891229.70      |              |          |         |     |

CD (.05) for varieties 49.846; (.01) 66.461

Table IV. Mean lipid content (mg/g) in seven castor var/cult of ten samples (replicates) containing ten beans each.

The bean coat was removed for estimating lipid content in the soft part by Soxhlet method.

| Castor var/cult | GAUC  | NPH   | GAUCH | ARUNA | ASSAM | UDAIPUR | BILARA |
|-----------------|-------|-------|-------|-------|-------|---------|--------|
|                 | .2753 | .1786 | .2908 | .2427 | .2613 | .08253  | .06024 |

# ANOVA

| Source of variance | d.f. | Sum of squares | Mean squares | Cal F    | Table F |     |
|--------------------|------|----------------|--------------|----------|---------|-----|
|                    |      |                |              |          | .05     | .01 |
| Replicates         | 9    | 0.0064         | 0.0007       | 0.355    |         |     |
| Varieties          | 6    | 3.4014         | 0.5669       | 282.02** | 2.3     | 3.2 |
| Error              | 54   | 0.1085         | 0.0020       |          |         |     |
| Total              | 69   | 186.08824      |              |          |         |     |

Table V. Mean entire seed weight (g) in seven castor var/cult of ten samples (replicates).

| Foliation scheme |                                          | GAUC |     | GAUCH |     | ARUNA |     |
|------------------|------------------------------------------|------|-----|-------|-----|-------|-----|
| Foliar           | scheme                                   | kg   | % * | kg    | % * | kg    | % * |
| D <sub>0</sub>   | Beans                                    |      | 113 |       | 102 |       | 100 |
| D <sub>1</sub>   | Beans                                    |      | 68  |       | 71  |       | 73  |
|                  | Leaves                                   | 123  |     | 129   |     | 168   |     |
|                  | Equivalent cut cocoon wt.<br>(x 0.01483) | 1.8  |     | 1.9   |     | 2.5   |     |
|                  | Value from price ratio<br>(x 17.24)      |      | 31  |       | 33  |       | 43  |
|                  | Total                                    |      | 99  |       | 104 |       | 116 |

\* Percentages with reference to ARUNA as 100

Table VI. Percentile comparison of yields (kg) and gain (Rs.) in foliar schemes D<sub>0</sub> and D<sub>1</sub> for the three castor varieties.

TOWARDS CLASSIFICATION OF COCOONS IN TASAR SILK INSECT  
ANTHERAEA MYLITTA DRURY (LEPIDOPTERA : SATURNIIDAE)

B.K. NAYAK\*, M.L. GUPTA\*, B.C. GURU\*\* and B.N. SATPATHY\*\*\*

For the first time simple type of tasar cocoons were classified on the basis of pupa, shell, peduncle, loop and stalk. On pupal characters the cocoons were termed as unipupate, bipupate and tripupate cocoons. On shell association cocoons were termed as unishellate, bishellate, trishellate and multishellate cocoons. On peduncle characters the cocoons were classified as apedunculate, unipedunculate and bipedunculate. On loop parameters the cocoons were termed as aloopate, uniloopate, biloopate, triloopate, multiloopate and synoloopate. Cocoons on stalk characters were designated as unistalkate, bistalkate and tristalkate, etc. On stalk combination the cocoons were classified as holojointa and partiojointa. Partiojointa was further divided into epijointa, mesojointa and hypojointa depending upon the position of joining. Cocoons with mixing of two or more of the above characters were also observed showing various complexities.

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## INTRODUCTION

In tasar silk insect cocoon is the protective covering spun by mature larva for the chrysalis and is also economically very valuable. Unlike Eri, Muga and Mulberry, Tasar cocoons are spun in nature and have unique distinction of a shell and a peduncle. On the association and dissociation basis of pupa, shell and peduncle various types of cocoons are noticed in a tasar crop.

Due to lack of cocoon classification, confusions often arise while describing a cocoon and sometimes the cocoons are misinterpreted (Nayak *et al.*, 1986), for which it is often very difficult to diagnose a particular cocoon upon which certain experiments are conducted. In this investigation attempts have been made to classify the tasar cocoons for the first time.

## MATERIALS AND METHODS

Different types of tasar cocoons of *Antheraea mylitta* Drury were collected from the commercial crops during 1984 and 1985 at different tasar cooperative societies of Mayurbhanj district. Outer morphological characters of cocoons on shell and peduncle were observed. The cocoons were also cut open to see the pupal association.

## RESULTS

A typical cocoon of *Antheraea mylitta* Drury is closed, single shelled and unipendunculate with one pupa inside it (Fig. 1). The shell is nonflossy and mostly reelable. At the anterior end there is a dark brown peduncle which has an elongated stalk and a loop at the distal end. The cocoon colour may be yellow or grey. But in this investigation different types of tasar cocoons were classified as follows on the basis of pupa, shell, peduncle, loop and stalk parameters.

### 1. Cocoon on pupal parameter

Cocoon with single, double, triple pupa/pupae were observed which were termed as unipupate, bipupate and tripupate cocoon respectively (Fig. 2a, 2b, 2c). The bipupate cocoon may be called as doubled cocoon and tripupate cocoon may be called as tripled cocoon. Some cocoons with prepupal stage were noticed which may be called as immatured cocoon. All the deformed cocoons belong to this type of cocoons. Bipupate and tripupate may have one, two or three peduncles or any.

### 2. Cocoon on shell parameter

Cocoon with single shell was the typical one and termed as unishellate cocoon (Fig. 1). Combination of two, three or more cocoon shells were also noticed which were termed as bishellate, trishellate and multishellate cocoons respectively (Fig. 3c, 3b, 3a). All the unipupate, bipupate and tripupate cocoons are always with one shell and these are unishellate cocoons. Bishellate, trishellate and multishellate cocoons are jointed and called as double, triple and multiple cocoons respectively. In boarder sense they can be called as jointed cocoons. These cocoons show various complexities in their stalk and loop association which may be jointed or independent in various ways. Also there is evidence of one or more pupa in these shells showing complex conditions.

### 3. Cocoon on peduncle parameter

Some cocoons were observed having no peduncles. They were designated as apedunculate cocoons (Fig. 4c). Cocoon with one peduncle was the typical one and was termed

as unipedunculate cocoons (Fig. 4b). Cocoons with two peduncles were also observed which were termed as bipedunculate (Fig. 4a). Bishellate, trishellate and multishellate cocoons showed converging and diverging peduncles.

#### 4. Cocoon on loop parameter

Some cocoons were observed having no loop. They were designated as aloopate cocoon (Fig. 5d). Cocoons with one loop were the typical ones and were termed as unilopate cocoons (Fig. 5c). Cocoons with two, three or more loops were also observed which were termed as bilopate, trilopate and multilopate cocoons respectively (Fig. 5b & 5a).

In bipupate, tripupate, bishellate, trishellate and multishellate cocoons fusion and combination of loops were also noticed which were termed as synloopate cocoons (Fig. 3b).

#### 5. Cocoon on stalk parameter

On the basis of length of the stalk, two types of cocoon such as elongata and dwarfa varieties were noticed having long and short stalk respectively. One, two or three stalk condition in unipupate, bipupate cocoons were observed which were termed as unistalkate, bistalkate and tristalkate cocoons (Fig. 6a, 6b & 6c). In bishellate, multishellate, bipupate and tripupate type of cocoons the stalks were sometimes combined or fused to each other. The fused type of stalk was termed as synostalkate and was further classified as holiojointa or partiojointa (Fig. 7d, 7c, 7b & 7a). The partiojointa was further classified into epijointa, mesojointa and hypojointa, etc., depending upon the position of joining (Fig. 7c, 7b & 7a).

### DISCUSSION

The above type of cocoons may come under simple type of cocoons as complex forms of cocoons were found in which combination of two or more simple characters as described above were mixed up. In sericigenous insects the generalised cocoon structure is found only in *Antheraea mylitta* Drury and *Antheraea paphia* L. In *Antheraea pernyi*, *Antheraea roylei* and *Antheraea pernyi* peduncle is devoid of the loop. In *Philosamia ricini* H. and *Antheraea assamensis* W. the stalk is ill developed. In mulberry cocoon *Bombyx mori* L. the peduncle is completely absent.

No worker had made any attempt to classify cocoons in a complete manner. Chapman (1982) has broadly recognised three types of cocoons in which silk cocoons are placed under saturnia type. Ford (1955) has only indicated about double and triple cocoons in *Bombyx mori* L. Cocoon categories were given as doubled and double type by various authors while studying the sex association in bipupate cocoons (Govindan & Narayanaswami, 1985; Kumararaj, 1968; Narayanaprakash *et al.*, 1984; Nayak *et al.*, 1986; Rao & Rao, 1961; Saxena & Bhide, 1969; Talukdar, 1961; Tayade, 1982-83). Leftoy (1971) has only indicated about long and short peduncle in tasar cocoon *Antheraea paphia* L. He also indicated that the summer cocoon is flimsier than the winter cocoon where there are two races. Richards and Davis (1977) have only indicated that most perfect type of cocoon is only found in Saturniidae. Jolly (1974) has only described about cocooning, cocoon structure and seed cocoon preservation.

From marketing point of view, Yokoyama (1962) has assorted the mulberry cocoons as bad cocoons which must include, double cocoons, pierced cocoons, stained cocoons, thin cocoons, scaffolding and pressed cocoons, irregular shaped cocoons, rough and wrinkled cocoons and flossy cocoons, etc. From commercial point of view tasar cocoons are also of different type such as Gutti, Baccha, Chupi, Fuki, Deformed, Pressed, Pierced or Damaged cocoons, etc. For the first time the classification of cocoons

on morphological characters was being attempted. Further review and improvement on classification of tasar cocoons alongwith other sericigenous cocoons should be done.

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#### FIGURE LEGEND

Fig. 1. Typical cocoon of tasar silk insect *Antheraea mylitta* Drury.

Fig. 2. Different cocoons of tasar silk insect *Antheraea mylitta* Drury on pupal parameter.

2a: unipupate cocoon, 2b: bipupate cocoon, 2c: tripupate cocoon

Fig. 3. Different cocoons of tasar silk insect *Antheraea mylitta* Drury on shell parameter.

3a: multishellate cocoon, 3b: trishellate cocoon, 3c: bishellate cocoon

Fig. 4. Different cocoons of tasar silk insect *Antheraea mylitta* Drury on peduncle parameter.

4a: bipedunculate cocoon, 4b: unipedunculate cocoon, 4c: apedunculate cocoon

Fig. 5. Different cocoons of tasar silk insect *Antheraea mylitta* Drury on loop parameter.

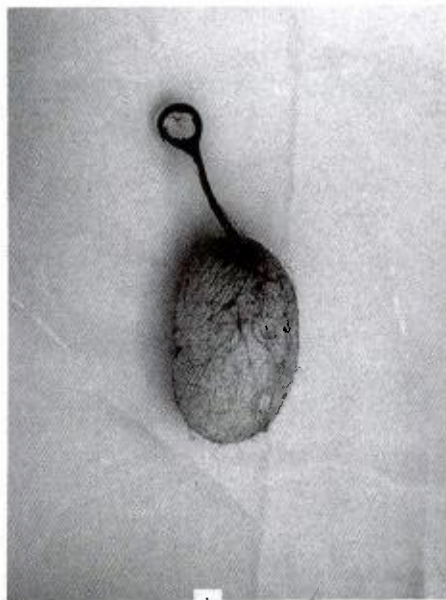
5a: triloopate cocoon, 5b: biloopate cocoon,  
5c: uniloopate cocoon, 5d: aloopate cocoon

Fig. 6. Different cocoons of tasar silk insect *Antheraea mylitta* Drury on stalk parameter.

6a: unistalkate cocoon, 6b: bistalkate cocoon, 6c: tristalkate cocoon

Fig. 7. Different cocoons of tasar silk insect *Antheraea mylitta* Drury on combination of stalks.

7a: hypojointa cocoon, 7b: mesojointa cocoon  
7c: epijointa cocoon, 7d: holojointa cocoon



1

Figure 1.



2a

2b

2c

Figure 2 (a,b,c.).



3a

3b

3c

Figure 3 (a,b,c.).

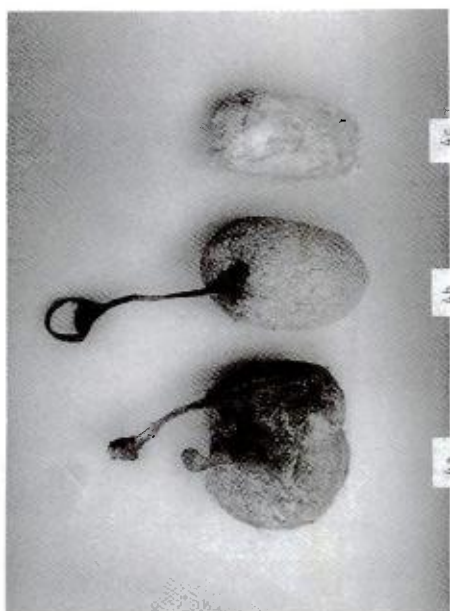


Figure 4 (a, b, c).

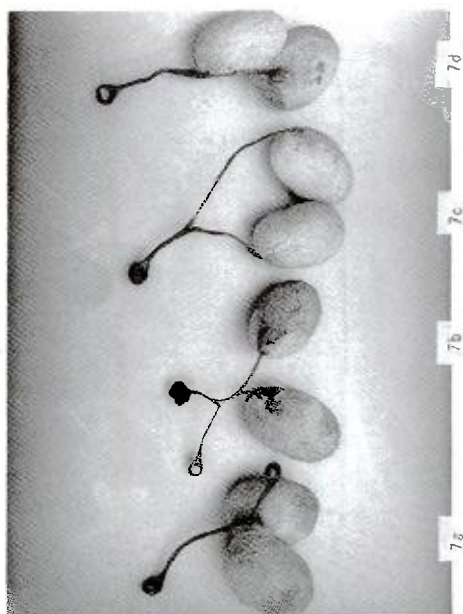


Figure 7 (a, b, c, d).

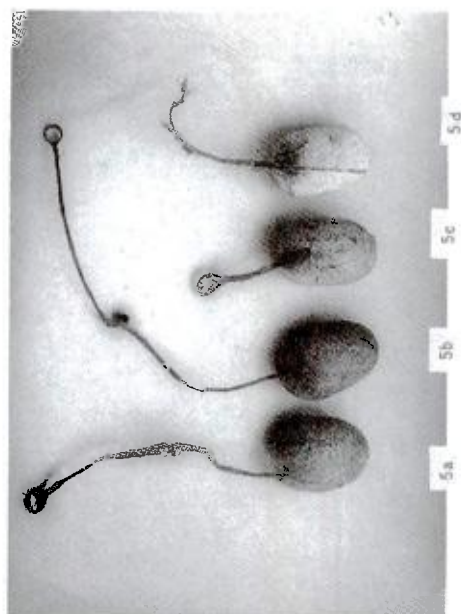


Figure 5 (a, b, c, d).

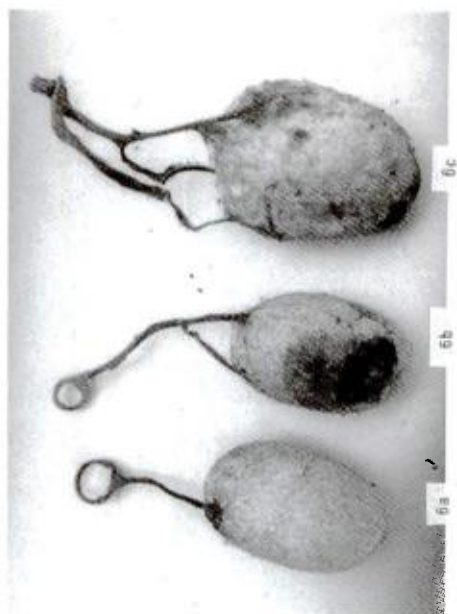


Figure 6 (a, b, c).

FREE AMINO ACID POOLS IN MIDGUT EPITHELIUM, HAEMOLYMPH AND SILK GLANDS  
OF TASAR SILKWORM (ANTHRAEA MYLITTA D.) UNDER THE INFLUENCE OF  
CYTOPLASMIC POLYHEDROSIS VIRUS

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*Free amino acid pools are greatly influenced by the induction of cytoplasmic polyhedrosis virus. This was observed when Antheraea mylitta larvae of 5th instar were inoculated with purified polyhedra and the changes were estimated quantitatively using paper chromatography and simple electrophotometry, in three major tissues, viz., midgut epithelium, haemolymph and silk glands. Altogether 14 FAA were identified in the midgut epithelium of both diseased and control worms. Haemolymph of diseased worms maintained only 14 FAA in comparison to 16 FAA of the control. The silk gland of diseased worms maintained only 15 FAA in comparison to 17 FAA of the control. Cysteic acid, serine, threonine, methionine-sulphoxide, valine and leucine/isoleucine are either absent or show a decline in all the three tissues. On the other hand, aspartic acid, arginine and histidine show their accumulation in diseased tissues. The total amino acid pool in the midgut epithelium, however, remained static in diseased worms in comparison to the control. The haemolymph show a distinct hyperaminoacidemia in infected worms. On the other hand, silk gland show a clear case of hypoaminoacidemia under the influence of CPV. The results suggest that CPV induces active protein synthesis in the midgut epithelium but reduces the same in other tissues in order to meet the demand of the pathogen.*

INTRODUCTION

Cytoplasmic polyhedrosis is one of the major diseases of Antheraea mylitta that takes heavy toll of worms during outdoor rearing in the tropical forests in India.

Literature on the diseases of tasar silkworm are very scanty. FAA play a vital role in protein synthesis, osmoregulation, energy production and cocoon spinning, etc (Chen, 1962; Gilmour, 1961; Florkin, 1959; Wyatt *et al.*, 1956). Comparative studies of diseased and healthy larvae of *Bombyx mori* were made by Ishimori and Muto (1951), Drilhon (1952) and others. A similar kind of study on haemolymph of *A. mylitta* was made by Agarwal *et al.* (1974) on qualitative basis. But no work has been done on quantitative or qualitative basis on the midgut epithelium or silk gland. In the present paper an attempt has been made to find out the FAA pools, on quantitative basis, of three major tissues that are directly or indirectly influenced by the CPV.

## MATERIALS AND METHODS

Polyhedra from CPV of *Antheraea mylitta* were collected from typically dead larvae by thorough shaking of midgut in distilled water and purified following the method of Reinganum (1984). Viral inocula were prepared with the help of Thomas haemocytometer following the method of Miyajima and Kawase (1968). A viral inocula of  $0.02 \text{ ml}$  of  $5 \times 10^6$  polyhedra/ml was administered orally into 5th instar larvae, one day after the 4th moult. To avoid any age difference worms were taken from the same date of hatching. The larvae after inoculation were reared in isolation and taken for study after 72 hours.

FAA were extracted and chromatographed identically following the method of Agarwal *et al.* (1974). The spots on the chromatogram were developed with ninhydrin (0.5% in acetone) and identified by their Rf values against standard samples of pure amino acids run in identical fashion. The spots developed from experimental material were cut and agitated in 4 ml of 50% ethanol and centrifuged at 3000 rpm for 10 min. Optical density of supernatants were measured at 570 nm. Standard curve was prepared with glycine chromatographed identically.

## RESULTS

Altogether 14 FAA were identified in the midgut of both diseased and control larvae (see Table I). The total FAA pool of diseased and control midgut epithelium remained static, although concentrations of individual amino acid varied considerably. In the diseased larvae there was a distinct fall in the level of serine, lysine and  $\alpha$ -alanine with corresponding rise in the level of aspartic acid, asparagine, arginine, histidine and glycine.

Although the haemolymph of diseased larvae showed a little less than two fold increase in the total amino acid pool, some of the amino acids were found to be missing (see Table II). The missing amino acids were cysteic acid and glutamine. The hyperaminoacidemia in haemolymph was found to be associated with high accumulation of aspartic acid, asparagine, arginine and histidine, even when there was a distinct fall in the concentration of threonine, leucine/isoleucine, methionine-sulphoxide and tyrosine.

Hypoaminoacidemia was characteristic of silk glands of diseased larvae. A number of amino acids were either lost or showed a diminishing trend (see Table III). However, an appreciation in the concentration of aspartic acid, glycine, lysine, arginine and proline was noticeable.

## DISCUSSION

Qualitative and quantitative estimations of FAA in the CPV infected midgut epithelium have lent support to the autoradiographic studies by Watanabe (1970) on the enhanced protein synthesis in CPV infected midgut epithelium of *B. mori*. This is evident from the static amino acid pool at an advanced stage of infection and its comparison with that of control. The distinct fall in the level of serine, threonine,  $\alpha$ -alanine indicate their active utilization for viral and polyhedral protein synthesis. The rise in the level of aspartic acid, asparagine, tyrosine and histidine indicates a consequence of histolysis (Duchateau-Bosson *et al.*, 1961) and that of histidine to maintain the changed osmotic pressure (Jeuniaux *et al.*, 1961).

The hyperaminoacidemia in the haemolymph of diseased larvae by dynamic rise in the concentration of aspartic acid, asparagine, arginine and histidine may have been caused, in all probability, by histolysis of the midgut epithelium and change in their osmotic pressure. Identical results were reported by Kawase (1965). However, the possibility of proteolysis in different tissues under physiological stress can not be ruled out. Part of the amino acid released by such hydrolysis may meet the increased demand for polyhedral protein synthesis in the midgut.

This feed-back mechanism is well reflected in the hypoaminoacidemia in the silk glands. The fall in the level of serine, threonine, leucine/isoleucine, valine,  $\alpha$ -alanine and complete absence of methionine, methionine-sulphoxide, cysteic acid and phenylalanine which are essential intermediates in different pathways for silk synthesis appear to be associated with poor synthetic activities in the silk gland.

Thus it may be said that CPV of *Antheraea mylitta* not only changes the physiological status of the midgut epithelium but also of other tissues and organs that are not directly involved in viral multiplication and polyhedra formation.

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| Amino acids identified | Concentration of amino acid<br>(ug/g wet wt.)* |          |
|------------------------|------------------------------------------------|----------|
|                        | CONTROL                                        | DISEASED |
| Aspartic acid          | 1100                                           | 1320     |
| Serine                 | 1225                                           | 105      |
| Glycine                | 300                                            | 550      |
| Threonine              | 300                                            | 225      |
| $\alpha$ -alanine      | 1225                                           | 990      |
| Tyrosine               | 75                                             | 137      |
| Asparagine             | 300                                            | 440      |
| Lysine                 | 650                                            | 440      |
| Arginine               | 425                                            | 658      |
| Histidine              | 325                                            | 1125     |
| Methionine-sulphoxide  | 125                                            | 110      |
| Proline                | 100                                            | 165      |
| Valine                 | 350                                            | 330      |
| Leucine/isoleucine     | 200                                            | 220      |
| TOTAL                  | 6680                                           | 6845     |

\* Data based on a pool of 5 larvae

(Viral inocula = 0.02ml of  $5 \times 10^6$  polyhedra/ml)

Table 1. Free amino acid pool in the midgut epithelium of healthy and diseased (CPV infected) *Antheraea mylitta* larvae, after 72 hrs of inoculation.

| Amino acids identified | Concentration of amino acid<br>( $\mu\text{g/g}$ wet wt)* |          |
|------------------------|-----------------------------------------------------------|----------|
|                        | CONTROL                                                   | DISEASED |
| Cysteic acid           | 150                                                       | -        |
| Aspartic acid          | 1800                                                      | 5000     |
| Glutamic acid          | -                                                         | -        |
| Lysine                 | 800                                                       | 650      |
| Serine                 | 700                                                       | 750      |
| Glycine                | 600                                                       | 600      |
| $\alpha$ -alanine      | 550                                                       | 400      |
| Glutamine              | 600                                                       | -        |
| Proline                | 400                                                       | 250      |
| Tyrosine               | 400                                                       | 350      |
| Threonine              | 450                                                       | 200      |
| Histidine              | 750                                                       | 2250     |
| Arginine               | 450                                                       | 1600     |
| Methionine-sulphoxide  | 600                                                       | 100      |
| Valine                 | 550                                                       | 450      |
| Leucine/isoleucine     | 550                                                       | 200      |
| Asparagine             | 450                                                       | 800      |
| TOTAL                  | 9800                                                      | 13600    |

\* Data based on a pool of 5 larvae  
(virus inocula = 0.02ml of  $5 \times 10^8$  polyhedra/ml)

Table II. Free amino acid pool in the haemolymph of healthy and diseased (CPV infected) *Antheraea mylitta* larvae, after 72 hrs of inoculation.

| Amino acids identified | Concentration of amino acid<br>( $\mu\text{g/g}$ wet wt.)* |          |
|------------------------|------------------------------------------------------------|----------|
|                        | CONTROL                                                    | DISEASED |
| Cysteic acid           | 67                                                         | -        |
| Aspartic acid          | 168                                                        | 468      |
| Serine                 | 1943                                                       | 1155     |
| Glycine                | 134                                                        | 220      |
| Asparagine             | 234                                                        | 193      |
| Lysine                 | 134                                                        | 303      |
| Arginine               | 134                                                        | 440      |
| Histidine              | 302                                                        | 220      |
| Threonine              | 201                                                        | 165      |
| $\alpha$ -alanine      | 268                                                        | 220      |
| Tyrosine               | 603                                                        | 523      |
| Methionine-sulphoxide  | 67                                                         | -        |
| Proline                | 67                                                         | 138      |
| Methionine             | 670                                                        | -        |
| Valine                 | 1072                                                       | 553      |
| Leucine/isoleucine     | 5026                                                       | 2200     |
| Phenylalanine          | 2680                                                       | 1073     |
| TOTAL                  | 14971                                                      | 7871     |

\* Data based on a pool of 5 larvae

(viral inocula - 0.02ml of  $5 \times 10^6$  polyhedra/ml)

Table III. Free amino acid pool in the silk glands of healthy and diseased (CPV infected) *Antheraea mylitta* larvae, after 72 hrs of inoculation.

STUDIES ON THE POTENTIALS OF HETEROSIS IN TROPICAL TASAR  
ANTHRAEA MYLITTA D.

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*The performance of 8 hybrids involving 8 selected races/lines were studied to find out the extent and nature of heterosis. Marked heterosis over mid and better parents was observed in many crosses for almost all the characters. The better parent heterosis for absolute silk yield ranged from 58.14% to 172.64% with a mean heterosis of 17.74%. Three primary yield components viz. fecundity, effective rate of rearing and shell weight also had considerable better parent heterosis. Crosses involving low x low and medium x medium yielding parents showed very high positive and significant heterosis over better parent indicating over-dominant type of gene action. Overall study of the hybrid vigour revealed that cross BMg x YMg is the best cross followed by Laria (P) x Sukinda. These crosses possessed maximum desirable characters and potentials for commercial exploitation.*

INTRODUCTION

Studies on heterosis and exploitation of hybrid vigour is almost a rule not only in crop plants but also in silkworm breeding programme for boosting up the yield as well as fibre quality. Very little or no such real attempt has been made in studying heterosis or hybrid vigour in tropical tasar fauna *Antheraea mylitta* D.

In this paper we report the results of tests in which eight intervarietal crosses and their parents were evaluated for commercial characters with the objectives to understand the relative performance of hybrids and parents for absolute silk yield, the magnitude and direction of heterosis in F1 hybrids, and, the type of gene actions involved.

## MATERIALS AND METHODS

The experimental material for the present investigation comprised a set of 8 intervarietal crosses without reciprocals and their parental populations. The crosses were BMg x YMg, BMg x R57, YMg x GEI, Sukinda x BMg, Laria (P) x R57, Laria (P) x Sukinda, Laria (P) x Daba and Laria 8 x Laria (P).

The crosses were made and rearing was conducted in randomised block design with 5 replications during 1981 commercial crop (September–November) at C.T.R.&T.I. Field laboratory, Nagri, Ranchi. The replications were reared on *Terminalia tomentosa* bushes where plant to plant and row to row distances were 12'x12'. Data were collected and recorded on absolute silk yield/replication, fecundity, effective rate of rearing (E.R.R.), shell weight and shell ratio. E.R.R. has been calculated on the basis of 100 worms per dfl. For calculating fecundity in each replication egg laying of 5 coupled moths were considered both for parental and hybrid populations. For other characters 30 randomly selected cocoons from each replication were analysed. Absolute silk yield per replication was calculated on the basis of cocoons harvested from each replication.

Statistical analysis was done following Panse and Sukhatme (1967).

## RESULTS

The analysis of variance for five characters has been calculated separately for parents, hybrids and parents x hybrids (Table I).

The mean sum of squares of parents, hybrids and parents x hybrids was highly significant in all the attributes except shell weight in parents x hybrids indicating the presence of substantial variability among the populations.

The *per se* performances of the parental varieties and the Fls for absolute silk yield and component characters showed significant differences. Table II reveals that highest and lowest absolute silk yield was recorded from Laria 8 and Sukinda respectively but R57 was characterised with highest E.R.R. and shell weight in parental lines and among the crosses, BMg x R57 had maximum absolute silk yield and E.R.R. whereas BMg x YMg had highest fecundity, shell weight and shell ratio.

Success in selection depends on the magnitude of heritable variations. Phenotypic co-efficient of variation (P.C.V.) was higher in magnitude than genotypic co-efficient of variation as expected (Table III). High heritability was observed in both parents and hybrids.

The heritabilities for E.R.R. were highest both in parental and hybrid progenies, followed by absolute silk yield, where as the lowest heritable variations were observed in shell weight for both the generations.

Out of eight cross combinations prepared and studied on the basis of absolute silk yield, one cross involved low x low yielding varieties, two each, medium x medium, low x medium and high x low yielding parents and only one cross was effected between medium and high yielders (Table II).

The range of heterosis exhibited by the hybrids over their respective mid and better parents for absolute silk yield was -35.22 to 175.65, -41.32 to 172.64 respectively. The mean increase in hybrids was 40.84 and 17.74% over respective mid and better parents (Table IV).

Out of five, four crosses gave positive heterosis over mid and better parents, significant heterosis was recorded only in three crosses over mid parent and in two cross combinations over better parent, of which one was between low x low and the second involved medium x medium yielding parental lines.

The extent of heterosis for component characters exhibited by the hybrids over their respective mid and better parents have been tabulated in Table IV. The average heterosis percentage for fecundity, E.R.R. %, shell weight and S.R. % was recorded to be 2.31, 6.00, 16.33 and -1.46 over better parents respectively.

Significant heterosis over mid and better parent for these component characters was shown by three crosses viz. BMg x YMg, BMg x R57 and Laria (P) x Sukinda, which involved medium x medium, medium x high and low x low yielding parental lines.

The present investigation reveals that out of eight crosses, six cross combinations can be exploited economically as the *per se* performances of the hybrids are higher than popular varieties Daba and Sukinda.

#### DISCUSSION

*A. mylitta* D. is basically a cross breeding species, as such it seems to be potentially a good material for the exploitation of heterosis. Previous studies on heterosis with *A. mylitta* D. by Jolly *et al.* (1969), Bardaiyar *et al.* (1975) did not show any appreciable heterosis in commercial characters and the failure to achieve heterosis must certainly be ascribed to the selection of non divergent and heterogenous parents. Before going into the details of the exploration and utilization of heterosis with present studies, basic informations are required to be gathered.

Partitioning the variance due to treatment indicated that the variance due to parents, hybrids and parents x hybrids differed significantly for almost all the attributes.

All the characters in the present study exhibited very high estimates of heritability in both the populations indicating the substantial role of additive and additive x additive types of gene actions. Greater advances are anticipated if mass selection or any other modified selection procedure is followed.

Present study reveals that BMg x YMg is the best cross followed by Laria (P) x Sukinda. The parents of the former cross were derived from the same population Daba, they would probably be more similar genetically but looking into the genetic background of the hybrid, this cross suggests that all loci by which two parents differed were heterozygous.

The parents of the second cross are from the two distinct ecogeographic areas of the country Bihar and Orissa. They show considerable phenotypic diversity with respect to their commercial attributes. Thus genetic diversity of the parents appears to be a key point as their mean performance in obtaining higher manifestation of heterosis over better parent.

Crosses involving low x low and medium x medium yielding parents showed very high positive and significant heterosis over better parent indicating over-dominant type of gene action which has paramount importance in exploiting the hybrid yield.

On the other hand a negative heterosis was obtained in the cross Laria (P) x R57, it appears that the genetic interaction between the gene systems of these two parental populations are not favourable.

Since absolute silk yield is a complex entity depending upon the multiplicative interaction of its various components, it would be interesting to compare the hybrids for components of yield also. Three immediate components into which the absolute silk yield could conveniently be partitioned are effective rate of rearing, fecundity and shell weight. From the cross it is evident that the best heterotic crosses like BMg x YMc and Sukinda x Laria (P) have considerably higher number of eggs, better E.R.R. and higher shell weight. Non-heterotic crosses showed heterosis if any, mostly for a single trait. It appears from this analysis that the superiority of the hybrids was due to combinations of favourable expression of important yield attributes present with two parental varieties and as such these could be considered as instances of "combinational heterosis" (Hagberg, 1952; Ramanujam *et al.*, 1964; Williams and Gilbert, 1960).

In respect to the secondary character influencing yield less directly, viz. shell ratio, none of the crosses showed significant superiority over better parent.

In conclusion it can be said that the fairly large amounts of heterosis observed in this material support the hybrid approach of tropical tasar improvement.

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| Source of variation | Mean sum of squares |            |           |              |             |
|---------------------|---------------------|------------|-----------|--------------|-------------|
|                     | Absolute silk yield | Fecundity  | E.R.R.    | Shell weight | Shell ratio |
| Treatments          | 31848.96**          | 14843.23** | 1187.72** | 0.31**       | 9.12**      |
| Parents             | 54245.46**          | 30525.71** | 1249.63** | 0.14**       | 13.23**     |
| Hybrids             | 59053.66**          | 35158.57** | 1003.42** | 0.23**       | 11.80**     |
| Parents vs hybrids  | 11106.18**          | 10147.52** | 2040.44** | 2.07         | 51.73**     |

Table 1. ANOVA for quantitative characters in parents and hybrids.

| Combination             | Absolute silk yield (g) | Fecundity (No.) | Effective rate of rearing (%) | Shell weight (g) | Shell ratio |
|-------------------------|-------------------------|-----------------|-------------------------------|------------------|-------------|
| <u>Parent</u>           |                         |                 |                               |                  |             |
| 1. Daba                 | 185.47                  | 241.6           | 57.6                          | 1.64             | 15.9        |
| 2. Sukinda              | 81.32                   | 268.0           | 31.4                          | 1.40             | 12.9        |
| 3. BMg                  | 183.16                  | 276.4           | 60.3                          | 1.58             | 16.6        |
| 4. YMg                  | 174.80                  | 261.2           | 52.2                          | 1.52             | 13.8        |
| 5. GE1                  | 244.50                  | 312.0           | 64.4                          | 1.59             | 14.8        |
| 6. Laria B              | 330.90                  | 289.0           | 62.1                          | 1.69             | 14.6        |
| 7. Laria (P)            | 83.14                   | 164.6           | 41.4                          | 1.00             | 17.0        |
| 8. Railey 57            | 284.30                  | 271.0           | 77.4                          | 1.70             | 14.1        |
| <u>Hybrid</u>           |                         |                 |                               |                  |             |
| 9. BMg x YMg            | 290.60                  | 398.2           | 59.5                          | 2.18             | 17.7        |
| 10. BMg x R 57          | 354.08                  | 343.0           | 77.7                          | 2.04             | 16.8        |
| 11. YMg x GE 1          | 184.76                  | 299.0           | 31.1                          | 1.87             | 15.5        |
| 12. Sukinda x BMg       | 218.80                  | 244.4           | 63.7                          | 2.04             | 15.9        |
| 13. Laria (P) x R 57    | 119.01                  | 194.0           | 65.9                          | 1.54             | 14.9        |
| 14. Laria (P) x Sukinda | 226.67                  | 237.4           | 84.4                          | 1.70             | 15.9        |
| 15. Laria (P) x Daba    | 167.98                  | 240.0           | 68.4                          | 1.68             | 17.2        |
| 16. Laria B x Laria (P) | 194.17                  | 308.0           | 78.8                          | 1.71             | 16.6        |
| <u>CO</u>               |                         |                 |                               |                  |             |
| 5%                      | 88.21                   | 76.70           | 18.2                          | 0.23             | 1.50        |
| 1%                      | 117.70                  | 102.04          | 24.2                          | 0.31             | 1.99        |

Table II. Performance of 8 parents and 8 intervarietal hybrids of *A. mylitta* D. in respect of yield and its components.

| Characters          | Combination | Range        | Mean   | P.C.V. | G.C.V. | Heritability (%) |
|---------------------|-------------|--------------|--------|--------|--------|------------------|
| Absolute silk yield | P           | 61.09-358.05 | 195.95 | 55.65  | 50.53  | 82.43            |
|                     | H           | 71.40-518.76 | 219.50 | 51.69  | 47.30  | 83.74            |
| Fecundity           | P           | 103-400      | 260.47 | 31.75  | 28.13  | 78.49            |
|                     | H           | 116-420      | 284.37 | 31.14  | 28.04  | 81.05            |
| E.R.R.              | P           | 15.63-82.39  | 57.1   | 27.86  | 27.51  | 97.49            |
|                     | H           | 23.97-98.30  | 66.19  | 21.24  | 20.91  | 96.88            |
| Shell weight        | P           | 1.05-2.00    | 1.54   | 12.00  | 7.97   | 64.71            |
|                     | H           | 1.40-2.62    | 1.85   | 12.26  | 10.75  | 76.92            |
| S.R. %              | P           | 9.75-18.05   | 14.96  | 11.63  | 10.43  | 80.49            |
|                     | H           | 14.40-20.25  | 16.31  | 9.96   | 8.82   | 78.38            |

Table III. Phenotypic variability in some quantitative characters in parents (P) and hybrids (H).

| Crosses             | Absolute silk yield<br>(Heterosis %) |           | Fecundity<br>(Heterosis %) |          | E.R.R.<br>(Heterosis %) |          | Shell weight<br>(Heterosis %) |          | Shell ratio<br>(Heterosis %) |        |
|---------------------|--------------------------------------|-----------|----------------------------|----------|-------------------------|----------|-------------------------------|----------|------------------------------|--------|
|                     | MP                                   | BP        | MP                         | BP       | MP                      | BP       | MP                            | BP       | MP                           | BP     |
| MBg x YMg           | +62.36**                             | +58.65*   | +48.13**                   | +44.06** | +5.18                   | -1.33    | +40.64**                      | +37.97** | +16.45**                     | +6.6   |
| BMg x R 57          | +51.49**                             | +24.54    | +25.31*                    | +24.09   | +12.85                  | +0.39    | +24.39**                      | +20.0**  | +9.45*                       | +1.20  |
| YMg x GE 1          | -11.87                               | -24.43    | -4.33                      | -4.17    | -46.65                  | -51.71   | +22.62**                      | +22.22** | +8.39                        | +4.73  |
| Sukinda x BMg       | +65.46                               | +19.46    | -10.21                     | -11.58   | +38.83*                 | +5.64    | +36.91**                      | +29.11** | +7.80                        | -4.22  |
| Laria (P) x R 57    | -35.22                               | -58.14    | -10.93                     | -28.41   | +2.33                   | -14.80   | +6.57                         | -9.41    | -4.18                        | -12.35 |
| Laria (P) x Sukinda | +175.65**                            | +172.64** | +9.75                      | -11.42   | +103.86**               | +64.20** | +37.45**                      | +27.14** | +6.35                        | -6.47  |
| Laria (P) x Daba    | +25.07                               | -9.43     | +18.17                     | -0.66    | +25.73                  | +18.75*  | +18.73*                       | +2.44    | +4.56                        | +1.18  |
| Laria B x Laria (P) | -6.20                                | -41.32    | +35.80*                    | +6.57    | +38.85**                | +26.89   | +18.75*                       | +1.18    | +5.06                        | -2.35  |
| Av. Heterosis %     | 40.84                                | 17.74     | 15.04                      | 2.31     | 22.69                   | 6.00     | 25.75                         | 16.33    | 6.73                         | -1.46  |

MP : Mid Parent

BP : Better Parent

\* : significant at 5%

\*\* : significant at 1%

Table IV. Trend of heterosis for absolute silk yield and its components in *A. mylitta* D.

## EFFECT OF FOLIAR SPRAY OF THE FOOD PLANT WITH UREA ON SOME COMMERCIAL CHARACTERS OF ANTHERAEA MYLITTA D.

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Effect of the feeding of urea sprayed leaf of Terminalia arjuna and Terminalia tomentosa on some commercial characters (viz., larval, cocoon, pupal and shell weights, silk ratio, and rearing and grainage performance) of Antheraea mylitta D., was investigated. Perusal of the data reveals that feeding of various concentrations of urea sprayed leaves of T. arjuna (1%, 1.5% and 2%) significantly enhanced the larval weight, cocoon weight, pupal weight, shell weight and silk ratio percentage of male and female worms. But in case of worms fed on T. tomentosa, only larval weight, shell weight and silk ratio percentage increased.

Larval period was shortened in T. arjuna feeding and lengthened in T. tomentosa feeding worms. Effective rate of rearing percentage (E.R.R.%) was markedly enhanced in urea treated T. tomentosa feeding groups in comparison to the control whereas in case of T. arjuna it was not significant. There was no marked effect on the pupal period. Moth emergence percentage showed an increase in urea treated worms over the control, but there was no effect on coupling percentage. It was interesting to note the increased range of fecundity in the treated lots.

### INTRODUCTION

Information concerning the effect of exogenous elements on tasar worms is scanty. Feeding of nutritionally enriched leaves showed better growth and development of silkworm larvae as well as gain in economic characters of cocoons (Seki and Oshikane, 1959; Venkataramana and Bhat, 1960; Sidhu *et al.*, 1969; Krishnaswami *et al.*, 1971). Influence of micronutrients on larval development and cocoon characters of silkworm (B. mori L.) was also studied (Vishwanath and Krishnamurthy, 1983). It was also reported that foliar spray of urea and sodium hydroxide improved some econo-

mic characters of *A. proylei* J. (Chaudhuri *et al.*, 1983). The present study is an attempt to establish the comparative effect of feeding of urea sprayed leaf of *T. arjuna* and *T. tomentosa* on economic characters of *A. mylitta* D.

## MATERIALS AND METHODS

Daba bivoltine race of *A. mylitta* D. were reared on *T. arjuna* and *T. tomentosa* plants (spacing 3.6 x 3.6 m). Field experiments were conducted during June to August, 1986, under identical conditions of the field. The average minimum and maximum temperature and relative humidity percentage were recorded as 17.2°C, 37.8°C and 65% and 95% respectively. Different concentrations of commercial urea solution (1%, 1.5% and 2%) were sprayed on the leaves of *T. arjuna* and *T. tomentosa* before 24 hours of every transfer. The quantity of urea solution sprayed was 1 litre a bush containing about 2-3 kg of leaf. Control groups of worms were reared on untreated plants (sprayed with plain water) of *T. arjuna* and *T. tomentosa*. Each group of experiment including control was conducted with ten replications and each replication contained 100 worms.

Larval weight and larval period (irrespective of sex), cocoon, shell and pupal weights, silk ratio percentage, E.R.R., pupal period, emergence percentage of moths, coupling percentage and the fecundity were recorded and calculated replication wise of male and female silkworms. The data were statistically analysed and the level of significance was calculated by students' t-test method. Each mean value is the average from 80-100 worms.

## RESULTS

Effect of feeding of urea sprayed leaf of *T. arjuna* and *T. tomentosa* on *A. mylitta*

### a) on larval weight (Fig. 1)

All the doses of urea (1%, 1.5% and 2%) significantly enhanced the larval weight irrespective of sex in comparison to the control. No dose response effect was observed.

### b) on male cocoon weight, pupal weight, shell weight, and silk ratio percentage (Fig. 2)

Worms fed on different concentrations of urea solution (1%, 1.5% and 2%) sprayed on *T. arjuna* leaves showed significant increase in male cocoon weight, pupal weight, shell weight and silk ratio percentage, out of which 1% urea solution showed maximum increase ( $P < 0.05$  or  $0.01$  or  $0.001$ ) with respect to all the parameters. It would noteworthy to point out that in case of urea sprayed *T. tomentosa* feeding groups only male worms showed enhanced shell weight and silk ratio percentage. There was no significant change observed in cocoon and pupal weight.

### c) on female cocoon weight, pupal weight, shell weight, and silk ratio percentage (Fig. 3)

It was observed that feeding of different concentrations of urea solution (1%, 1.5% and 2%) sprayed leaves increased cocoon weight, pupal weight, shell weight and silk ratio percentage in *T. arjuna* group, whereas only silk weight and silk ratio percentage in *T. tomentosa* group. It was also noted from the observations that there was no dose dependent effect in both groups of urea sprayed food plants.

#### d) Rearing and grainage performance (Table I)

Feeding of different concentrations (1%, 1.5% and 2%) of urea solution sprayed leaves of *T. arjuna* shortened larval period in comparison to the control whereas increased larval period was observed in urea sprayed *T. tomentosa* group. Effective rate of rearing percentage and moth emergence percentage were increased with all the doses on feeding of both groups of urea sprayed food plants. There was no marked effect on pupal period and coupling percentage of moths. There is a tendency of increase in the number of eggs though it was not significant but the range of fecundity increased in the treated groups when compared to control.

#### DISCUSSION

It is obvious that all the doses of urea, 1%, 1.5% and 2%, significantly improved many of the commercial characters (viz., cocoon weight, pupal weight, shell weight, silk ratio percentage, E.R.R., range of fecundity and emergence percentage of moths). The absorption of soluble nutrients through stomatal opening is much more quicker than the absorption through the roots (Koren'kov, 1983) and so it may be assumed that urea is absorbed through the stomata more quickly enriches the nutrient contents of leaves. Nutritional studies have led to the suggestions that some insect species have only a limited capacity to synthesize the components of nucleic acids viz., purines and pyrimidines (Candy, 1985). It may thus be suggested that the exogenous urea metabolises and meets the necessity of nucleic acid synthesis. Hence it may be possible that the effect of the different doses of urea is direct.

Increased shell weight and pupal weight of the treated worms may be due to increased synthesis of silk protein, and other major proteins which are synthesized by the fat body of silkworms (Price, 1973; Izumi *et al.*, 1981; Tojo *et al.*, 1980, 1981). Larval period of *T. tomentosa* group increased whereas treated *T. arjuna* feeding group of worms showed shortened larval period, the matter requires further investigation. To probe the effect of urea whether it is direct or indirect, biochemistry of the tissues like silk gland, fat body, gonad and haemolymph is required to be studied.

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| Food plant          | Dose      | Larval period (days) | E.R.R. (%) | Seed cocoon (%) | Pupal period (days) | Moths emergence (%) | Coupling (%) | Fecundity range | Mean $\pm$ SE |
|---------------------|-----------|----------------------|------------|-----------------|---------------------|---------------------|--------------|-----------------|---------------|
| <i>I. arjuna</i>    | Control   | 29                   | 45.33      | 89.13           | 23                  | 81.58               | 96           | 164-308         | 216 $\pm$ 13  |
|                     | 1% urea   | 26                   | 45.06      | 95.56           | 23                  | 88.53               | 95           | 186-295         | 211 $\pm$ 10  |
|                     | 1.5% urea | 27                   | 44.39      | 86.84           | 21                  | 87.69               | 96           | 186-311         | 220 $\pm$ 12  |
|                     | 2% urea   | 28                   | 46.18      | 91.23           | 22                  | 92.15               | 95           | 180-355         | 221 $\pm$ 15  |
| <i>I. tomentosa</i> | Control   | 25                   | 33.14      | 96.00           | 23                  | 83.44               | 93           | 160-250         | 202 $\pm$ 8   |
|                     | 1% urea   | 32                   | 46.49      | 96.48           | 24                  | 91.67               | 92           | 190-290         | 230 $\pm$ 12  |
|                     | 1.5% urea | 28                   | 49.12      | 96.73           | 21                  | 92.55               | 94           | 175-280         | 221 $\pm$ 13  |
|                     | 2% urea   | 31                   | 52.77      | 94.12           | 22                  | 91.36               | 93           | 180-280         | 212 $\pm$ 14  |

SE = standard error

Table I. Effect of various concentrations (1%, 1.5% and 2%) of urea treated leaves of *T. arjuna* and *T. tomentosa* on the rearing and grainage performance of *Antheraea mylitta* D.

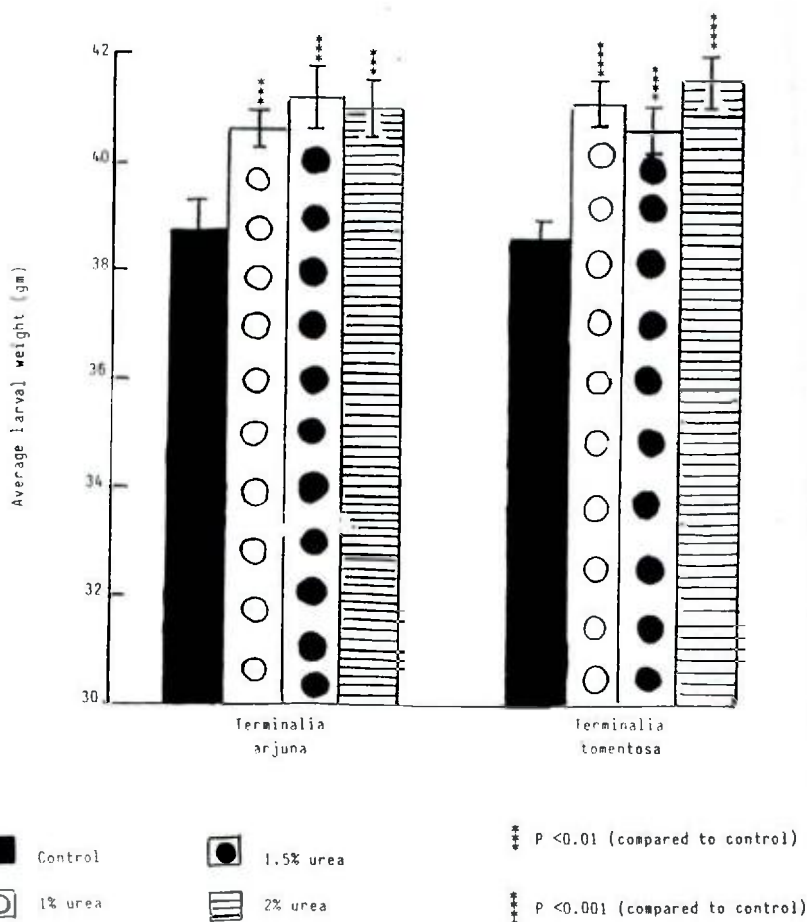


Fig. 1. Effect of different doses of urea treated leaves of *T. arjuna* and *T. tomentosa* on the average larval weight (gm), irrespective of sex, of *A. mylitta* D. Each mean value is the average from 80-100 worms and the vertical bars on the figure represent the standard error of the mean.

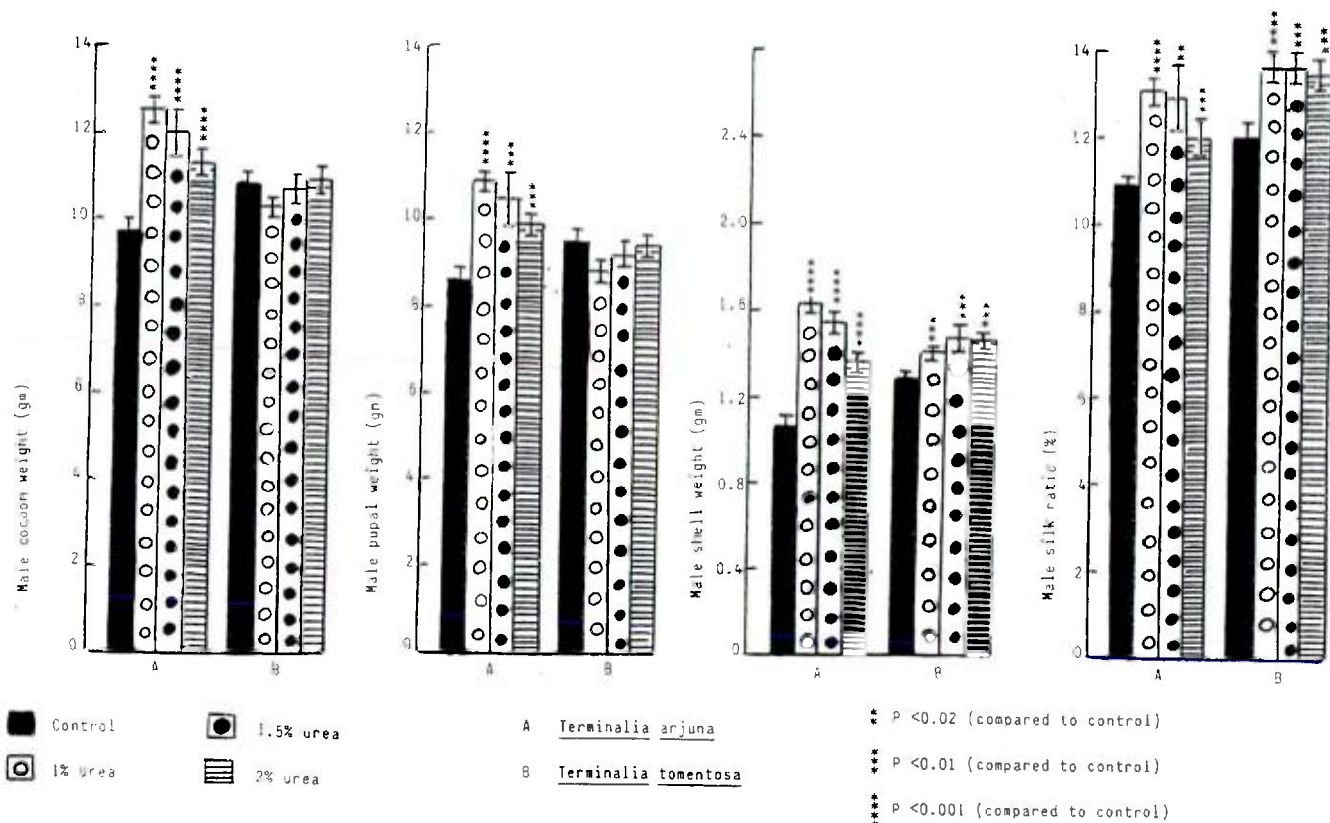


Fig. 2. Effect of different doses of urea treated leaves of *T. arjuna* and *T. tomentosa* on the cocoon, pupa, shell weights (gm) and silk ratio percentage of male *A. mylitta* D.

Each mean value is the average from 80-100 worms and the vertical bars on the figures represent the standard error of the mean.

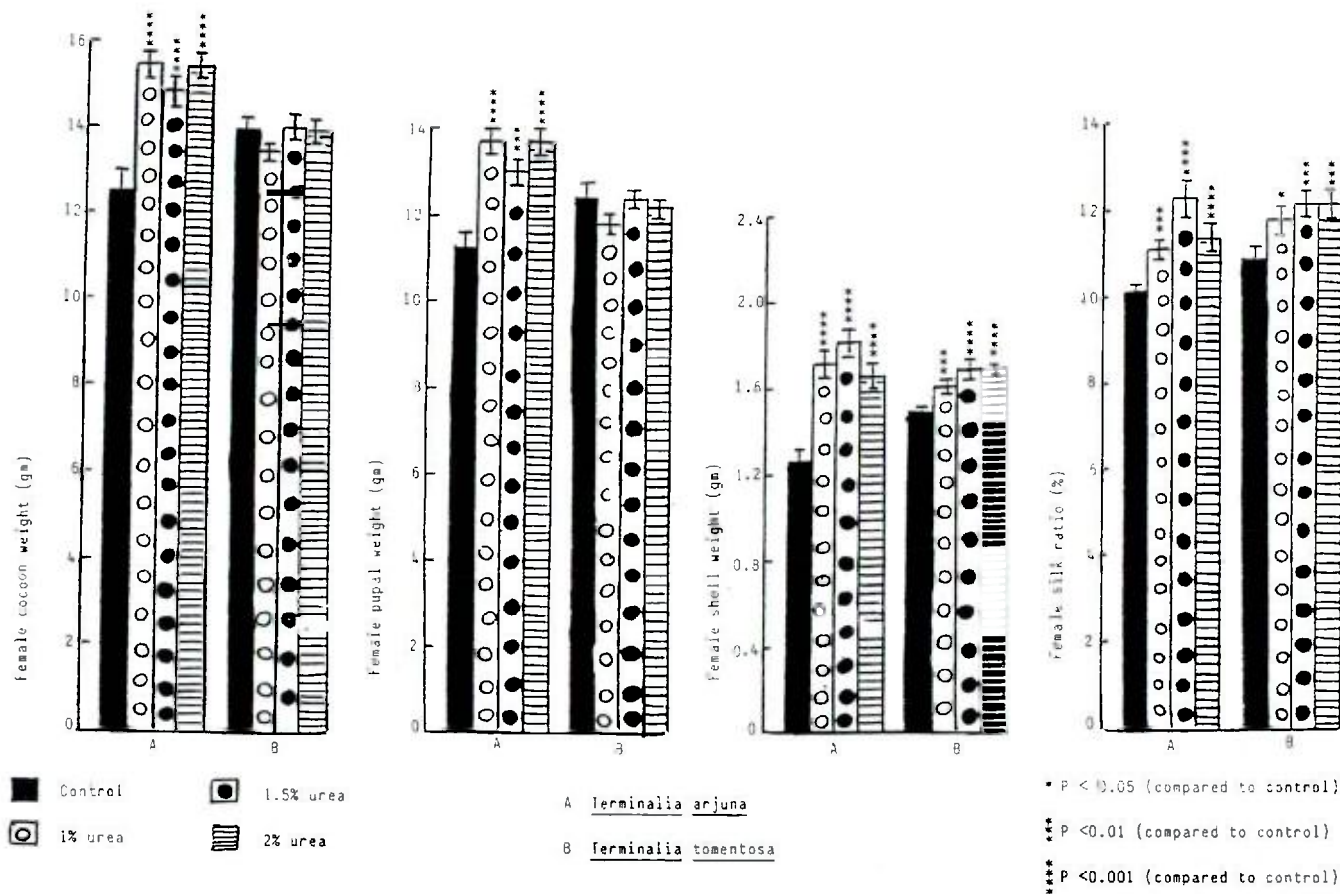


Fig. 3. Effect of different doses of urea treated leaves of *T. arjuna* and *T. tomentosa* on the cocoon, pupa, shell weights (gm) and silk ratio percentage of female *A. mylitta* D.

Each mean value is the average from 80-100 worms and the vertical bars on the figures represent the standard error of the mean.

STUDIES ON THE EFFECTIVENESS OF BENGARD <sup>®</sup> IN CONTROLLING  
THE MICROSPORIDIAN DISEASE OF ANTHERAEA MYLITTA D.

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*Microsporidiosis in Antheraea mylitta D. often assumes a menacing proportion in the major tasar growing tracts. The disease, which is transovarially transmitted, affects emergence, reproductive potentials, viability and cocoon characters. The experiment on the effectiveness of Bengard, a systemic fungicide, in controlling the microsporidian disease was investigated at egg and larval stages of tasar silkworm. Administration of 2% Bengard was found suitable in egg as well as in larval stages, as it reduces the incidence of pebrine to a considerable extent. A significant improvement was also observed in the effective rate of rearing and silk ratio. The results were further supported by analysis of uric acid level in healthy, infected and infected but treated larvae and pupae.*

INTRODUCTION

The microsporidian, *Nosema* sp. is one of the most deadly pathogens infecting tasar silkworm, *Antheraea mylitta* D. causing the disease commonly known as Pebrine. The disease results not only in poor crop yield but also affects the emergence of moths and their reproductive potential. The disease is transmitted both by transovarial and per-oral modes and multiplies at a very fast rate. Further, the outdoor nature of rearing of the tasar silkworm enhances the possibility of the pathogen being disseminated among the common vectors making it extremely difficult to eradicate the disease. Several methods have been employed in suppression of the microsporidian infection in insects (Allen & Bruson, 1949; Katznelson & Jamieson, 1952; Bailey, 1953; Jamieson, 1955; Fox & Weiser, 1959; Weiser, 1961; Raun, 1961; Lewis & Lynch, 1970; Wilson, 1974; and Hamm *et al.*, 1977). However, the only dependable method has been the Pasteurian method involving the selection of eggs from disease

free mother moths. Although this technique works well in raising a disease free colony, the method becomes ineffective if one desires to salvage an already established colony showing symptoms of the disease. Attempts have been made to control microsporidiosis in silkworm by various methods, viz., surface sterilants (Kagawa, 1970), acid treatment of eggs (Fujiwara and Kagawa, 1984; and Liu *et al.*, 1984), thermic treatment (Bednyakova & Vereiskaya, 1959; Griyaghey *et al.*, 1976) and administration of various drugs and chemicals (Chandra & Sahakundu, 1982-83, Iwano & Ishihara, 1981).

Effects of some fungicides in controlling microsporidian disease have been investigated by several workers in insects i.e. Flint *et al.*, 1972; Hsiao & Hsiao, 1973; Harvey & Gaudet, 1977; and Brooks *et al.*, 1978. Considering the effectiveness of fungicides in controlling the microsporidian disease in different insects, an attempt has been made to control the *Nosema* sp. infection of *Antheraea mylitta* D. by using the fungicide Bengard, which is a systemic fungicide chemically known as Carbendazim 30% W P (containing 50% (W/W) 2-methoxycarbamoyl Benzimidazole).

## MATERIALS AND METHODS

Treatment with fungicide was conducted both at the egg and larval stages.

### a) Egg stage treatment:

*Nosema* sp. infected layings with 200 or more eggs were taken and each of the layings divided in two equal parts for treatment and control respectively. 1% and 2% solutions of Bengard were prepared in distilled water at room temperature and the eggs kept for treatment were smeared with the solutions. The control lots were also dipped in distilled water simultaneously. The eggs were dried and incubated at  $28 \pm 1^\circ\text{C}$ . After hatching larvae were reared in rearing huts for 72 hours under indoor conditions in bottles with twigs of Asan (*Terminalia tomentosa*) inserted in it. Outdoor rearing was also performed on Asan plants under identical conditions. Disease mortality was assessed by microscopic examination of dead larvae. The data were analysed by standard statistical methods.

### b) Worm stage treatment:

This experiment was carried out during first and second crop 1985-86. Treatment at the larval stage was done after the completion of the indoor rearing. While only two concentrations were considered for egg treatment, three concentrations of Bengard (1%, 2% and 3%) were considered for the treatments at larval stages. Each concentration was fed to hundred larvae and simultaneously equal numbers of larvae were maintained for control and replicated ten times. Further, the larvae were fed with the chemical in their respective dosage from II to V instar, 24 hours after moulting. Feeding of the chemical was continued for three days in each stage. Disease mortality was assessed by microscopic examination of dead larvae and the data were analysed by standard statistical methods.

In order to find out the effectiveness of the treatment, the treated, untreated and healthy lots were subjected to biochemical analysis. As a first step the levels of uric acid in all the three lots were estimated from III instar onwards. The estimation was conducted by following the method of Dresel and Moyle (1950).

## RESULTS AND DISCUSSION

The data given in Tables I-II with regard to the treatments at egg and larval stages respectively reveal that Bengard is highly effective ( $P < 0.001$ ) in reducing the pebrine mortality in tasar silkworm and thereby significantly increasing the effective rate of rearing in comparison to untreated (control) lots. Silk ratio has also registered a significant improvement in the treated lots as against their controls. Among the different concentrations used, the treatment at 2% had an edge over the other concentrations.

The larvae (healthy, infected and infected but treated) were simultaneously subjected to biochemical analysis for the estimation of uric acid. From the figures (Fig. 1-2), it is evident that quantities of uric acid present in the haemolymph of healthy and infected but treated larvae were lower than those in the untreated infected larvae. The trend of the biochemical analysis in regard to diapausing pupae from 30 days onwards is similar to those observed at the larval stage except to those where the estimation was done on the pupae which were upto 15 days old. This requires further studies.

It is evident from the results presented in Table I-II and Fig. 1-2 that Bengard is highly effective in containing microsporidian disease of tasar silkworm. Although higher concentrations of Bengard used during trial are found more effective in reducing the disease as compared to lower concentrations, their applicability becomes impracticable as they had adverse effects on the survivality of the worms, thereby reducing the E.R.R. Hsiao & Hsiao (1973) in an experiment tried Benomyl which is also a systemic fungicide for controlling the microsporidian disease of alfalfa weevil and reported complete elimination of microsporidian disease in the larvae fed with diet containing Benomyl. Shinholster (1974), Armstrong (1976) and Harvey & Gaudet (1977) also observed the effectiveness of Benomyl against microsporidian infection. These findings are very much in accordance with our results. Bollen & Fuchs (1970) explained the role of Benomyl as a selective fungicide and suggested that the chemical exerts its effectiveness on sporogenesis of fungi. A similar possibility was advocated by Hsiao & Hsiao (1973) in inhibiting the propagation of spores in alfalfa weevil. Bengard being systemic fungicide might have similar mode of action as Benomyl. McEwen & Stephenson (1979) reported that the active ingredient in Benlate (Benomyl) might be converted to several compounds in plant tissues, one of which is Carbendazim which acts by adsorption to spindle fibres during cell division. Therefore, the reduction in pebrine mortality may be due to suppression in sporogenesis of *Nosema* sp.

Analysis of haemolymph in *Nosema* infected, Bengard treated and healthy worms further supports the effectiveness of this treatment biochemically wherein the quantity of uric acid in the treated lots was found to be in between the healthy and infected lots. The intermediate value of uric acid in Bengard treated lots proves the effectiveness of the fungicide in reducing the level of uric acid.

The inhibition of spore-propagation by the treatment of Bengard resulted in decreased concentration of spores in infected worms which ultimately increased the vigour and viability of larvae enabling them to ensure better yield and silk content.

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| Concentration | Hatching (%) | Pebrine mortality (%) | E.R.R. (%)    | Silk ratio (%) |
|---------------|--------------|-----------------------|---------------|----------------|
| 1% treatment  | 76.70±10.04  | 29.56±0.13***         | 31.95±2.24*** | 13.41±0.006*** |
| control       | 73.80±9.88   | 61.73±1.76            | 7.68±1.54     | 11.49±0.33     |
| 2% treatment  | 81.50±1.25   | 26.61±0.30 ***        | 45.13±1.51*** | 13.77±0.09 *** |
| control       | 83.50±2.83   | 66.22±0.25            | 3.9±0.19      | 11.50±0.21     |

Notes : 1. Values expressed in mean± S.E.

2. \*, \*\*, \*\*\* denotes the values significant at  $P < 0.1$ ,  $0.01$  &  $0.001$ , respectively.

Table 1. Effect of Bengard on microsporidiosis in *A. mylitta* (egg stage treatment).

| Concentration | Ist CROP              |               |                | IInd CROP             |               |                |
|---------------|-----------------------|---------------|----------------|-----------------------|---------------|----------------|
|               | Pebrine mortality (%) | E.R.R. (%)    | Silk ratio (%) | Pebrine mortality (%) | E.R.R. (%)    | Silk ratio (%) |
| 1 %           | 32.20±0.51***         | 44.00±0.50*** | 14.48±0.18***  |                       |               |                |
| 2 %           | 25.10±0.15***         | 50.60±0.32*** | 13.98±0.09***  | 16.30±0.23***         | 53.90±0.73*** | 12.22±0.24**   |
| 3 %           | 24.60±0.53***         | 48.50±0.29*** | 14.67±0.07***  | 19.40±0.16***         | 48.20±0.40*** | 13.60±0.37***  |
| Control       | 58.70±0.16            | 24.70±0.25    | 10.39±0.21     | 62.90±0.27            | 5.80±0.95     | 11.05±0.13     |

Notes : 1. Values expressed in mean ± S.E.

2. \*, \*\*, \*\*\* denotes the values significant at  $P < 0.1$ ,  $0.01$  &  $0.001$  respectively.

Table II. Effect of Bengard on microsporidiosis in *A. mylitta* (worm stage treatment).

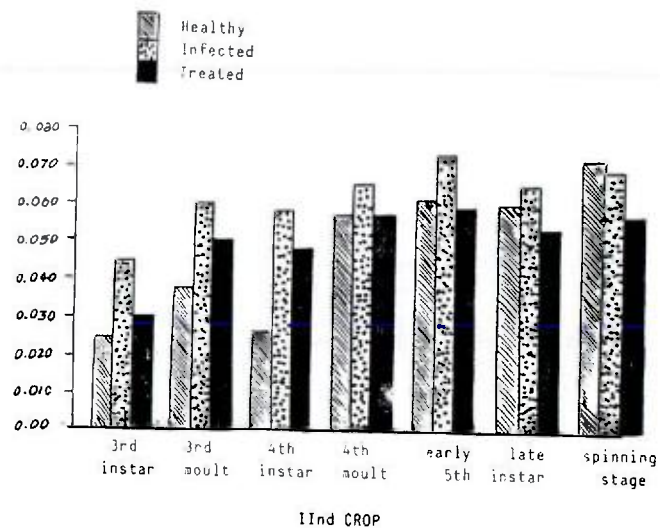
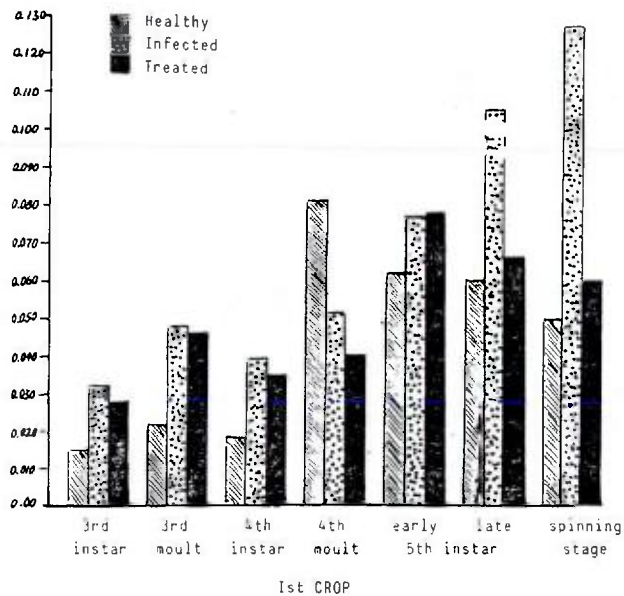


Fig. 1. Concentration of uric acid (mg/ml) in larvae of *Antheraea mylitta* D.

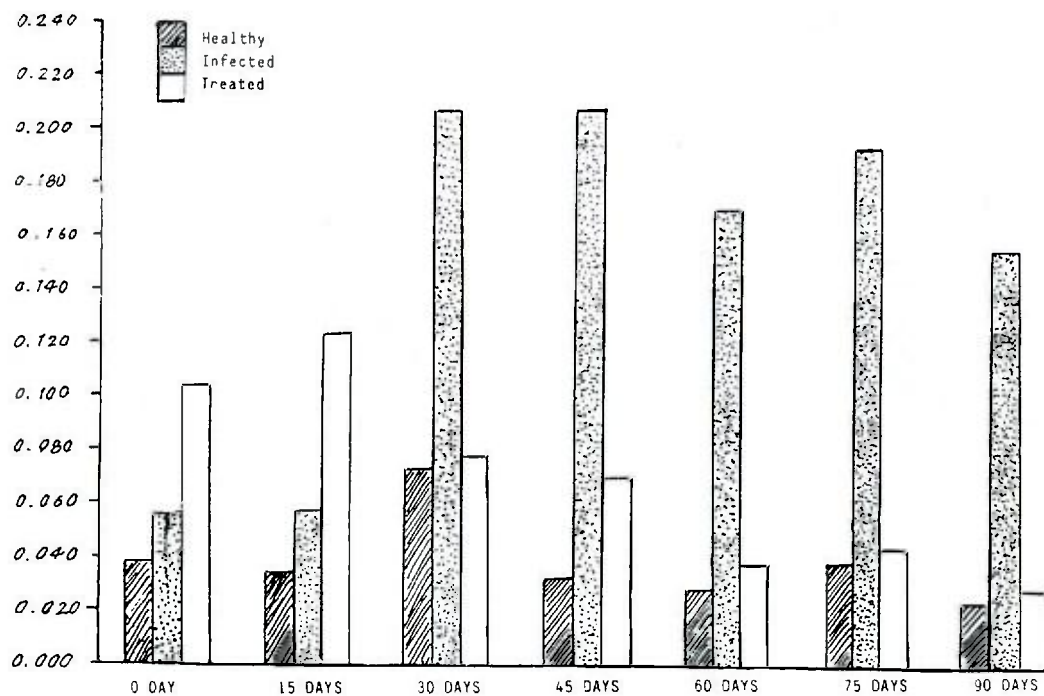


Fig. 2. Concentration of uric acid (mg/ml) in diapausing pupae of *Antheraea mylitta* D.

STUDIES ON THE BIOLOGY AND EXTENT OF DAMAGE TO TASAR FOOD PLANTS  
BY THE STEM BORER AEOLESTHES HOLOSERICEA FAB.  
(CERAMBYCIDAE : COLEOPTERA)

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An attempt has been made to study the biology, nature and extent of damage caused by Aeolesthes holosericea, the common bark beetle being a serious pest of primary tasar food plants viz., Terminalia arjuna and T. tomentosa. Oviposition occurs from April-September in the bark of dying or weakened tasar food plants. The number of eggs varies from 5-20. Hatching period varies from 14-18 days and the newly born larvae directly feed on the cortex of the main stem. The larval period ranges from 45-60 days. Pupation takes place inside the pupal chamber made by the larvae. Emergence starts from April onwards. Mating is observed during attack on the new host plants which occurs in June-September. Severe damage is caused by tunnelling under the bark by the larvae and feeding on the bark by the adults. The tunnels are filled with powdery borings and small pellets. The grubs are more destructive than adults. Its presence is indicated by the accumulation of granular frass and wet spots around the attack site.

INTRODUCTION

With the exception of brief descriptions given by Coulsen (1984) and Raske (1973) there is little published information on the biology of Aeolesthes holosericea, a common bark beetle of primary tasar food plants. Preliminary observations reported by Wickman (1968), Donley (1978) and Davidson (1964) indicated that Aeolesthes holosericea causes maximum injury to Shorea robusta. The beetle breeds in the weakened or dying tasar food plants. Infection of healthy food plants also takes place as a result of adult beetle feeding on them. Observation reported here are part of a detailed study on the biology, nature and extent of damage by the species on Terminalia arjuna and Terminalia tomentosa.

## MATERIALS AND METHODS

Field experiments were carried out at the Field Laboratory, Nagri, of Central Tasar Research & Training Institute, Ranchi. The experimental design was completely randomised having, split plots with blocks. 735 plants of *T. arjuna* and *T. tomentosa* were screened for pest infestation for two years. Parameters used for assessing borer attack were the presence of grubs or existence of holes or faecal matters on the trees. The total number of holes on each tree was counted.

For studying the oviposition process, barks of the plant were peeled during September-October preferably at main stem from where joints of the branches start. At each oviposition site eggs laid were counted. The thickness of the stem bearing the existing holes or grubs were measured. Infected stems were cut into small pieces (25 to 30 cm) and kept in jars covered with muslin cloth. The emerged adults from the jars were counted and their morphology and behaviour were studied. The grubs were collected and preserved in 70% alcohol for biometrical and other studies. The tunnels made by grubs were also studied. The shape, size, mode of galleries, depth and site of exit holes made by grubs were also studied.

## RESULTS AND DISCUSSION

Females deposit eggs singly in small slits cut into the bark of the tree. The eggs are long, oval in shape and measure 1.5 x 0.75 mm in size. Freshly laid eggs are whitish in colour. After 6 to 9 hours the colour of the eggs changes to brown. It may be due to light intensity. The number of eggs varies from 5 to 20.

The larvae normally called "round headed borers" are elongated, cylindrical, fleshy and white. Grubs are legless but thoracic and abdominal segments swell into distinct bulbs. The full grown grub varies from 40-45 mm with an average of 42 mm whereas breadth varies from 7-8 mm with an average of 7.5 mm.

The first, second and third instar grubs measure 6.3, 12.5 and 25.6 mm in length respectively. The larval period varies from 45-50 days. Larvae overwinter in third to fifth instar. With the onset of winter, generally from November-February, feeding ceases and the larvae construct galleries. It was observed that overwintering larvae exhibit cold hardiness. This ability is thought to be due to presence of glycerol in the larvae. Glycerol is commonly found in insects that exhibit cold hardiness and is known as cryoprotectant (Asahina, 1969). The concentration of glycerol has been similarly reported in the overwintering larvae of *Scolytus ratzeburgi* by Ring (1977). Larvae recommence feeding after overwintering until pupation which occurs in a cavity constructed by the prepupal larvae approximately 25 mm below the surface of the bark. During the following spring, larvae bore further into the sapwood and heartwood where they feed and later pupate. Pupation also occurs in the larval galleries in the xylem. The duration of the pupal stage is about 2-3 weeks. The length of the pupal chamber varies from 35 to 40 mm long, 18-20 mm broad and 10-15 mm towards the cortex of the stem.

Pupation takes place inside this chamber keeping the head upwards, adults emerge from pupal case within the pupal cavity and remain there while their untanned cuticle hardens. Adults generally emerge from the original oviposition sites by chewing oval exit holes through the bark.

Emergence starts generally from April onwards. The pattern of emergence of each sex is similar and the ratio of males to females is approximately 1:1. Adults are "long horned beetles" elongated and cylindrical with long antennae often larger than

the entire body. The size of males varies from 30-35 mm and width varies from 10 to 14 mm. The emerged adults feed on the bark of twigs of *Terminalia arjuna* and *T. tomentosa* but this feeding is not obligatory for sexual maturation. Twig feeding is however a crucial feature of the biology of cerambycids (Wickman, 1968). The period during which attacks are made on new breeding sites by *A. holosericea* extends from July-October but due to its earlier emergence sometimes attacks occur from May to October (Fig. 1). Beaver (1967) reported similar observation in *Scolythus intricatus*. Temperature and physiological changes brought about by flight activity may be a pre-requisite for response to new host and egg laying.

Both grubs and adults are injurious for primary tasar food plants. It is observed that grubs are more destructive than adults. Their presence is indicated by the accumulation of granular frass and discolouration i.e. "wet spots" caused by sap leakage that occurs around the attack site. The infected plant oozes sticky gums as well as the faecal matters, which cover the opening of the hole.

A severe damage is caused by tunneling under the bark by the larval stage and feeding on the bark by the adults. On cutting the infected stems, numerous tunnels are observed. These ramified tunnels reach the centre of the main stem, thus causing damage to phloem and the plant ultimately dies. Tunnels are filled with powdery borings and small frass pellets (Fig. 2). The nature and extent of damage to plants are influenced by the feeding behaviour of insects in relation to chemical composition of the host plant (Yates, 1984). Feeding behaviour of grubs reflects that grubs do not have fixed pattern of making galleries. The grubs remain concentrated at the height of 4'-6' in the main stem. Thus more exit holes are made in this region. Beaver (1967) and Kirby and Fairhurst (1983) reported that *S. multistriatus* construct maternal galleries in the cambial region of bark. In *Aeolesthes holosericea* it has been observed that those branches which get more sunlight have higher number of grubs and pupal chambers. This suggests that *Aeolesthes holosericea* may require higher temperature for oviposition and larval development. According to Sharma *et al.* (1963), borer confines its activity to the eastern half of the stem. The observation is well supported since more grubs have been observed on the branches which are exposed to sunlight.

In the present observation it has been observed that out of 735 plants of each variety, 24.49% are infected in *T. arjuna* and 34.69% in *T. tomentosa* (Table I). All the dead trees were examined and found having grubs and exit holes in large numbers. The trees become extremely weak due to irregular gallery formation and vulnerable to future attack. In case of severe attack, the trees die and attacked branches are broken. In dead branches deep cracks develop. The bark splits up and is separated from the wood, beneath. It can easily be removed and tunnels filled with yellowish brown frass can easily be seen (Fig. 3).

Lakra *et al.* (1980) reported the damage of peaches by peach borer. They reported the similar observation on *Sphenoptera lafertei*. The pest had preference for weaker but vigorous and healthy trees escaped the attack of the borer. Batra and Renghen (1950) observed that healthy trees were preferred. The observation made in the present study is contrary to the finding of Lakra *et al.* (1980) and supports the findings of Batra and Renghen (1950). In the beginning these trees do not show any symptoms but later on trees became weak and leaves fall out to give dry appearance and ultimately growth of the trees is stunted.

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| Type of plants      | No. of trees observed | % of infestation | % of trees having :             |                                 | No. of exit holes (cm) | Distance between the holes (cm) |
|---------------------|-----------------------|------------------|---------------------------------|---------------------------------|------------------------|---------------------------------|
|                     |                       |                  | No insect attack, only gummosis | Only insect attack, no gummosis |                        |                                 |
| <i>I. arjuna</i>    | 735                   | 24.49            | 15.65                           | 24.49                           | 5.0                    | 31.67                           |
| <i>I. tomentosa</i> | 735                   | 34.69            | 14.29                           | 38.78                           | 6.67                   | 35.67                           |

Table I. Incidence of *Aeolesthes holosericea* in primary tasar food plants.

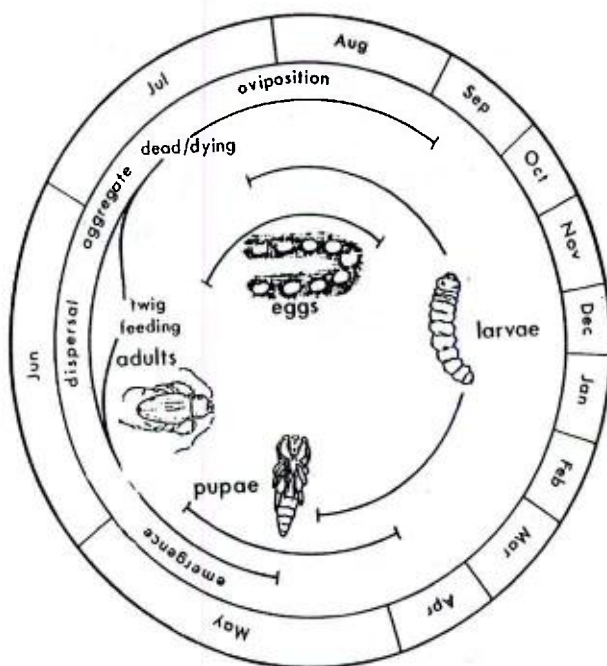


Fig. 1. The life cycle and seasonal history of *Aeolesthes holosericea* at Field Laboratory, Nagri, Ranchi.

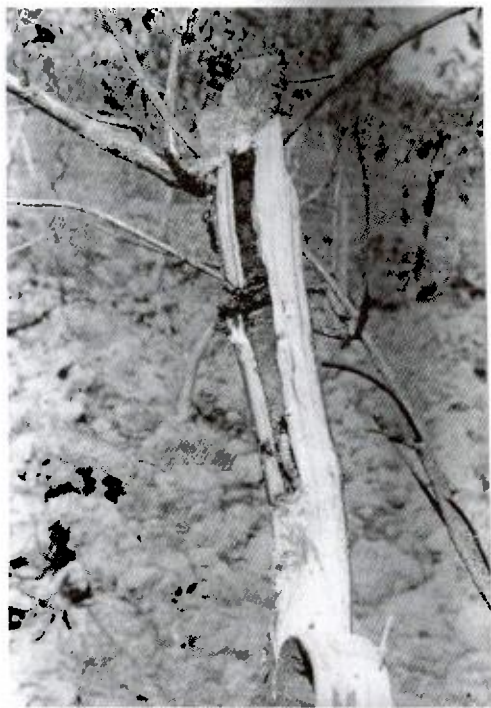


Figure 2.



Figure 3.

Fig. 2. *Aeolesthes holosericea* grub made vertical tunnel on *T. tomentosa* plant.

Fig. 3. Irregular galleries made by *Aeolesthes holosericea*.

EFFECT OF REFRIGERATION ON THE PRESERVATION OF MUGA SEED COCOONS,  
ANTHERAEA ASSAMENSIS W.

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Healthy male and female *Antheraea assamensis* seed cocoons were refrigerated at  $5^{\circ}\pm 1^{\circ}\text{C}$  temperature for periods ranging from 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, and 120 days, and the number of moths emerged, pairing, eggs laid and hatching percentage of worms, calculated. All the characters showed a gradual decrease with the increase in the duration of refrigeration period. The maximum number of moths emerged, pairing, eggs laid and hatching percentage were observed in the treatments ranging from 10-30 days refrigeration and the minimum results were recorded in 120 days of refrigeration.

The experiment was repeated during summer season with a temperature of  $5^{\circ}\pm 1^{\circ}\text{C}$  and upto 30 days of refrigeration. Moth emergence and pairing were found to improve.

INTRODUCTION

As muga seed crops suffer a lot during prolonged winter and adverse summer seasons, a forced postponement of moth emergence becomes inevitable for solving the problems associated with the seed production. Information regarding the proper preservation of muga seed cocoons is scanty. Attempts have been made to observe the effect of refrigeration of muga silkworms at  $5^{\circ}\pm 1^{\circ}\text{C}$  for 50 days (Sengupta and Singh, 1974). Bharali (1982) also studied the effect of refrigeration of muga cocoons by keeping 240 cocoons, ten days old, (Jathua crop) for 60 days. No healthy moths were found in the treated groups of moths emerged on the date of release which were unable to couple. Artificial pupal diapause in *P. ricini* was induced by gradual lowering of the temperature to  $5^{\circ}\text{C}$  (Ahmed, 1979). So, it was considered worthwhile to investigate once more the effect of refrigeration on the preservation of muga seed cocoons in order to work out a better seed production schedule.

## MATERIALS AND METHODS

Three thousand healthy seed cocoons, 6th day from the date of spinning (1500 males + 1500 females) were selected and subjected to refrigeration at  $5^{\circ}\pm 1^{\circ}\text{C}$  with a gradual step-down cooling process and a control was maintained with 250 cocoons separated from the same seed stock. The experiment involved 13 treatments (including control), each with five replications and each replication contained 50 cocoons (25 males + 25 females). A period of 10 days interval was maintained between the release of the seed cocoons from the refrigerator in successive 13 treatments upto 120 days of preservation and data were recorded in respect of moth emergence (sexwise), pairing, number of eggs laid and hatching percentage of worms. Cocoons were released in the late evening hours and kept at room temperature to recover from the effect of chilling and to ensure acclimatisation to room temperature slowly before they were used for the grainage purpose. The experiment was repeated during summer season and the seed cocoons were preserved at  $5^{\circ}\pm 1^{\circ}\text{C}$  temperature upto only 30 days to avoid hazardous seed crop ("Bhadia crop"). The data were statistically analysed by the method of "Analysis of Variance" and "Students t-test".

## RESULTS

### 1. Effect of refrigeration on winter seed cocoons of muga silkworms, *A. assamensis* W.

#### a) On male and female moth emergence (Fig. 1)

Observations reveal that the male and female moth emergence is higher in the treatments ranging from 0-60 days and 0-20 days respectively ( $P < 0.05$ ). The lowest value is found in the treatments ranging from 110-120 in male and 100-120 in female. No significant difference in moth emergence is observed among 0-60, 70-90 and 110-120 days in males and 0-20, 20-30, 30-40, 50-70, 70-80, 80-90, 90-100 and 110-120 days in females. It is also found in both sexes that the moth emergence gradually decreases with an increase in the refrigeration period. Moreover, the number of male moth emergence is found to be higher than the female except 0-20 days of refrigeration. At 5% level critical difference (CD) value calculated was 1.371 in male and 1.434 in female.

#### b) On the number of pairing (Fig. 1)

The maximum number of pairing is obtained from 0-30 days of refrigeration ( $P < 0.05$ ), after that the number of pairings decreases and the minimum value is recorded in the 120 days of refrigeration. It is also noted that there is no significant difference among 0-30, 40-50, 50-60 and 60-90, 70-100 and 110-120 days of refrigeration. At 5% level CD value calculated was 1.415.

#### c) On egg layings (Fig. 2)

The maximum number of eggs laid has been found in the treatment of 0-30 days of refrigeration ( $P < 0.05$ ) and minimum value is noted in 120 days. A steep down decrease in the number of eggs laid has been recorded after 30 days which continues upto 120 days of refrigeration period. Moreover, there is no significant difference in egg deposition among 0-30, 80-90 and 90-100 days of refrigeration duration. At 5% level CD value calculated was 3.108.

#### d) On hatching (Fig. 2)

Hatching percentage has been found to be higher in the treatment ranging from

0-30 ( $P < 0.05$ ) days of refrigeration followed by a gradual fall, the lowest value is found in the treatment of 120 days. There is no significant difference in the treatments of refrigeration among 0-30 and 50-70 days. At 5% level CD value calculated was 2.612.

## II. Effect of refrigeration on the summer seed cocoons of muga silkworms, *A. assamensis* W. (Table I)

Moth emergence and pairing are significantly higher in the refrigerated groups than that of the control, but no change has been observed in the number of eggs laid. Hatching percentage of the refrigerated groups indicates a decrease in comparison to that of the control groups.

## DISCUSSION

It is obvious from the results that all the characters viz., moth emergence, pairing, egg laying and hatching showed a gradual decrease with an increase in the refrigeration period. But the pattern of fall in different refrigeration duration was not identical. It is revealed from the observations that the male moth emergence declines after 60 days whereas female moth emergence declines after 20 days of refrigeration. Similarly, the number of moth pairing, eggs laid and hatching percentage show a gradual fall after 30 days of refrigeration duration. So, it may be taken note of that 30 days of refrigeration is most suitable for the economic preservation of muga seed cocoons. Sengupta and Singh (1974) observed 70-90% and 50-90% moth emergence after 35 and 50 days of refrigeration respectively at  $4 \pm 1^\circ\text{C}$  in *A. assamensis* W. And to prevent moth emergence,  $2^\circ\text{C}$  temperature is suitable for winter season in *A. proylei* (Sengupta, 1983). It has also been reported that the pupae of *P. ricini* can be preserved at  $5^\circ\text{--}10^\circ\text{C}$  for 25 days (Bharali, 1974; 1978; 1982).

The experiment was repeated in the summer season with  $5 \pm 1^\circ\text{C}$  temperature and only upto 30 days of refrigeration and good results were achieved.

Further experiments are needed to pin point the best method of preservation of seed cocoons at low temperature for proper moth emergence, pairing, egg layings and hatching supported by physiological and biochemical studies.

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| Character                     | Refrigerated<br>Mean $\pm$ SE | Control<br>Mean $\pm$ SE               |
|-------------------------------|-------------------------------|----------------------------------------|
| Number of seed cocoons        | 50x5=250                      | 50x5=250                               |
| Number of male moth emerged   | 24.31<br>$\pm 1.21$<br>A      | 20.77<br>$\pm 0.53$<br>A <sub>1</sub>  |
| Number of female moth emerged | 22.86<br>$\pm 0.59$<br>B      | 18.41<br>$\pm 0.62$<br>B <sub>1</sub>  |
| Number of pairings            | 19.79<br>$\pm 1.33$<br>C      | 13.43<br>$\pm 0.81$<br>C <sub>1</sub>  |
| Egg layings                   | 172.00<br>$\pm 5.00$<br>D     | 176.00<br>$\pm 7.00$<br>D <sub>1</sub> |
| Hatching percentage           | 65.55<br>$\pm 2.16$<br>E      | 88.69<br>$\pm 3.53$<br>E <sub>1</sub>  |

t-test probability differences between control and treated groups

A-A<sub>1</sub> = P<0.05

B-B<sub>1</sub> = P<0.02

C-C<sub>1</sub> = P<0.01

D-D<sub>1</sub> = NS

E-E<sub>1</sub> = P<0.01

SE = standard error;

NS = not significant

Table I. Results of refrigeration at  $5^{\circ}\pm 1^{\circ}\text{C}$  upto 30 days of 6 days old seed cocoons of muga silkworm, *A. assamensis* W. on male and female moth emergence, pairing, egg laying and hatching percentage during summer season.

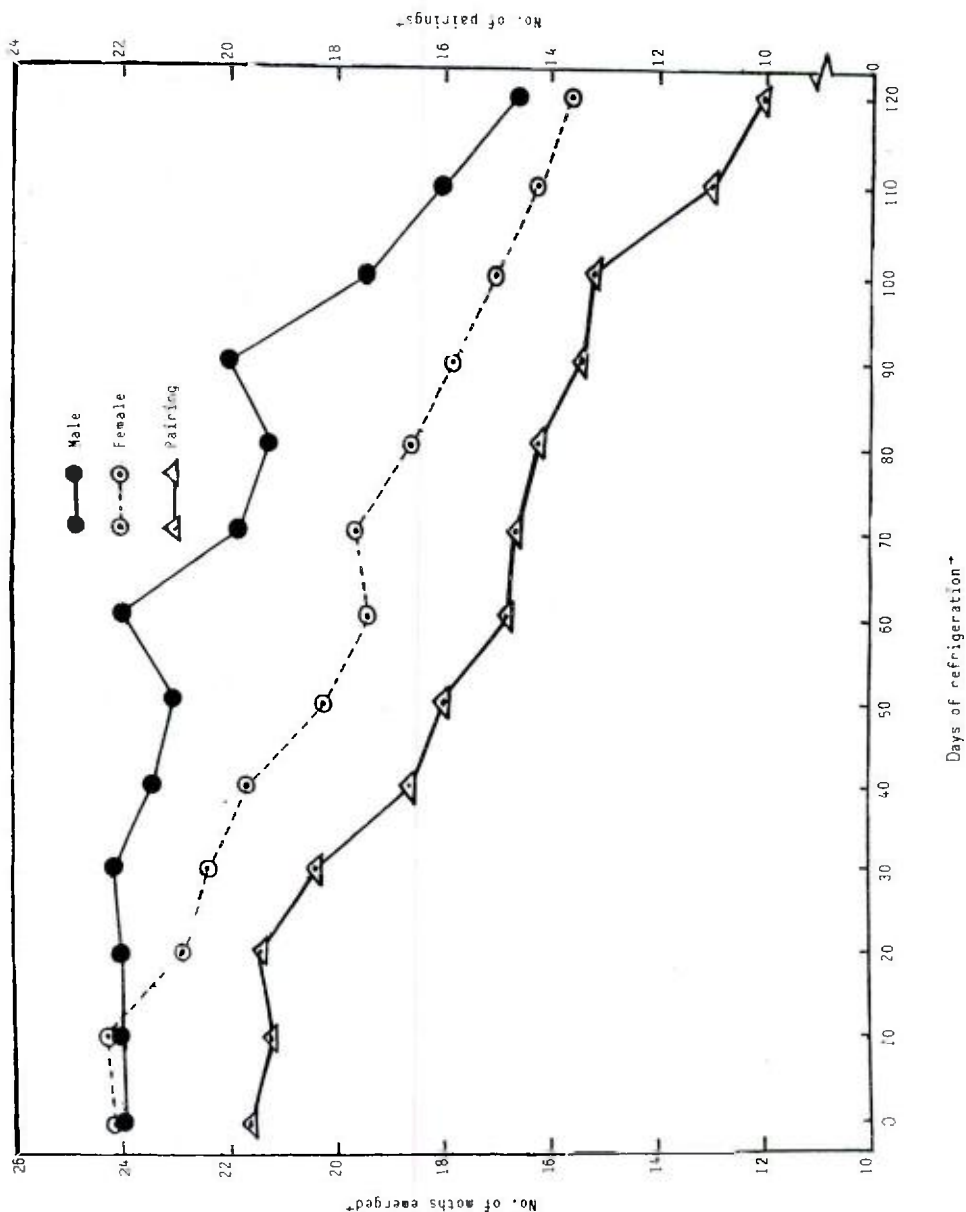


Fig. 1. Effect of different refrigeration durations (0-120 days) at  $50 \pm 1^{\circ}\text{C}$  on the male and female moth emergence and pairing of 6 day old cocoons of muga silkworm, *A. assanensis* W. during winter season.

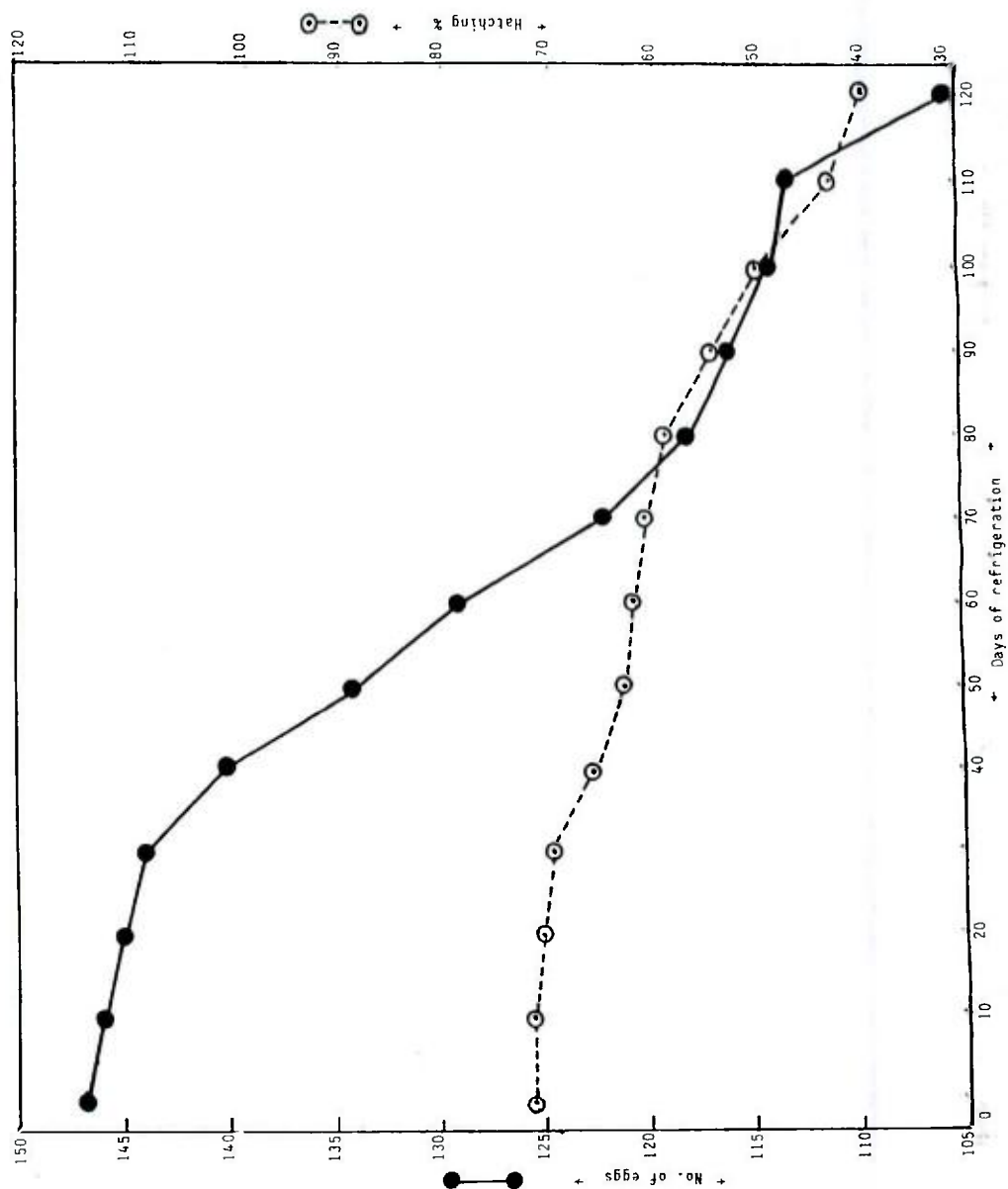


Fig. 2. Effect of different refrigeration durations (0-120 days) at  $50\pm 1^{\circ}\text{C}$  on the number of eggs laid and hatching percentage of 6 day old cocoons of muga silkworm, *A. assamensis* W. during winter season.

## SYNAPTONEMAL COMPLEX ANALYSIS IN INDIAN SILKWORMS AND THEIR HYBRIDS

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Meiotic prophase chromosome behaviours have been examined, using surface spreading and silver staining technique, in Indian eri silkworms *Philosamia ricini*, *P. cynthia* and their hybrids. Meiotic development, diploid chromosome numbers ( $2n=28$ ), morphology and pairing behaviours in all three cases resemble alike. At pachytene normal 14 complete synaptonemal complexes (SCs) are observed in both parents. In the species hybrid 14 SCs are also found to be composed of two homologous chromosomes of the parents, however, in some cases complete unpaired LEs of the univalent chromosomes are seen.

Similarly, oak feeding tasar silkworm, *Antheraea proylei* has 49 complete SCs at pachytene and 31 SCs are present in another species of *A. roylei*. Thirty to thirtyfive SCs with some tri-valents are seen in the F1 hybrid of these two *Antheraea* species.

DEVELOPMENT OF OAK SILKWORM (*ANTHERAEA PERNYI*) CULTIVATION  
IN THE CHILLY AREAS OF NORTHEAST CHINA

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According to ancient Chinese historical literature and local chronicles, it is considered that Chinese oak silkworm (*Antheraea pernyi*) was first found in what is Shondong Province now in Han dynasty more than 2000 years ago, and it was then introduced to Northeast China 1200 years later after its discovery. Northeast China has an abundance of oak resources of about 70 million hectares widely distributed over the whole district, including the eastern part of Nei Moggol Autonomous Region. The plenty of tasar food plant impells the development of tasar cultivation in this region and finally makes it the largest production base with an annual cocoon output estimated as 70% of the total amount produced in China.

As a matter of fact, tasar production in Northeast China has centred mainly in Liaodong Peninsula and never been successful beyond the geographic limits of 45° N or over an altitude of 500 metres above sea level before. It was also a truth that even within this limited area, rearing was found to be rather difficult in Heilongjiang or Giling Province either. Except for the lack of skilled workers, the chilly climate and unstable voltinism of worms were the main hindrance that ceased the further development of tasar cultivation in these areas.

In consideration of the vast wealth of tasar food plants of which nearly 90% remained unutilized, a series of experiments were carried out soon after the founding of People's Republic of China. Furthermore, a cooperative investigation was organised in the sixties between sericultural researchers from different provinces of the region as a joint effort to accelerate the exploitation. As a result of these, great success has been met with both on rearing technique and variety breeding, they are reported as follows:

### Rearing technique:

Chinese Tasar appears to be bivoltine in the Northeast while the climatic condition is relatively severe as compared with that of its native place. In general, a bivoltine breed of Chinese Tasar requires a mild weather with frost-free period of at least 145 days for its growth, as the geographical limitation, most areas of the region except the southern parts were found to be unsuitable for tasar rearing. For instance, in Tonghua, a major tasar production site which is located at 41° 43' N in Gilling Province, the natural temperature averaged in May and September respectively are 14.1°C and 15°C, and it is even more lower (11.3°C in May, 15°C in September) in Nenjian district lying by parallel of 49° N in Heilongjiang Province. The frost free period of this extensive area again varies from 130 to 110 days, leaving virtually no time to complete the second generation of the insect. Consequently special measures has to be adopted, a particular rearing technique was developed to accommodate the traditional rearing method to the rigorous circumstances. It is so-called the bivoltine breed once rearing or annual rearing for short.

Annual rearing has only one crop a year, it is based upon the principle of postponing the rearing season to a certain period during which the air temperature would be warm enough for larvae growing, and the photoperiod should be confined to enable the worms to alter their voltinism into univoltinism. Annual rearing has the same process as that of the second crop of bivoltine breed but one or two weeks earlier on schedule. Larvae usually hatch at the middle of July and spin cocoons at the beginning of September.

In order to start the rearing season on schedule time, preservation of activated pupae has to be prolonged under an adequate low temperature to prevent the proceeding of pupal development as the room temperature increases. Experimental finding showed that the overwintering pupae could be preserved safely until June at a constant temperature of -2° to 0°C and not to exceed 6°C by the end of May. There are several instruments designed to satisfy this purpose. The simplest equipment is a glaze jar buried underground, in which seed cocoons are previously preserved. Such an equipment eases the farmer but it is inconvenient and hazardous. Because the frozen mud in winter and early spring makes regular management impossible. The most popular installation nowadays is cellars of different types, partially or entirely underground, depending on the conditions of each locality. Cellar consumes no energy, it is easy to run and lower in investment.

### Variety breeding:

Annual rearing has been successful technically in the Northeast. It has promoted tasar cultivation in some areas like Tonghua, Mudanjiang, etc, yet it does not fit the whole region by using bivoltine races. The day length in August in most areas is still too long for pupal hibernation, particularly in the northernmost. In such case, moths emerge scatterly on various scale the same year while a number of pupae, being not truly in physiological diapause lie dormant by the inhibition of low temperature they face. Some of the pupae die during the resting stage, some others come to have various deformities with wrinkle wings, short legs, swollen abdomen, ruined in sexual system or weakness after dormancy. It leads to a heavy shortage of basic seed cocoon supply and makes multiplication rather difficult. Therefore, there is a problem of variety on the other hand.

In order to solve the problem mentioned above, attempt had been made initially to introduce univoltine races to these areas but it failed. All the breeds which had been confirmed to be univoltine converted their voltinism into bivoltinism, only little differences were found in diapause rate between the univoltine race and bivoltine race when they were reared in annual rearing season, for the farmer diapause

rate was a little higher in comparison with that of the latter. Besides, univoltine races from the southern part of China were of lower yield, perhaps it is due to the difference in area of adaptation.

Thus, a desirable race that can be reared whether earlier or later within the growing season and has no influence on its diapause rate is absolutely needed, a few breeds based on the selecting principle raised by Sericultural Research Institute however have already been created. These new breeds are generally smaller in size with yellowish blue body colour and a duration of larval stage of 45-48 days. The photoperiod threshold of the worms is about 16 hours with a diapause rate up to 99% throughout the region. Although the cocoon weight of these breeds is lighter than that of the bivoltine races, yet the rearing season may start at the beginning of July and complete by the end of August under a favourable weather condition, which raises the silk reeling efficiency, the same yield of silk can be obtained.

In addition to the plenty of food plants, tasar has less natural enemies in this region. The epidemic like jaundice that has severely threatened the worms in the South also hardly occurs. There is no doubt that tasar cultivation has a bright future in the chilly areas of the Northeast China.

STUDIES ON THE JUVENILE LARVA OF ERI SILKWORM,  
PHILOSAMIA CYNTHIA RICINI B. REARED ON FRESH CASTOR LEAVES  
INSERTED IN WATER IN SUMMER AND AUTUMN SEASON (1983)

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During seven seasons from 1979 to 1981, Philosamia cynthia ricini B. eri silkworms have been reared on fresh castor leaves inserted in water. The main results were as follows:

1. The juvenile larvae of this silkworm were fed on fresh castor leaves inserted in water and the elder larvae turned to feed on whole leaves bud of stork tree or cassava leaves. This rearing method is very suitable for half-feeding form varieties of eri silkworm in practice. This rearing method can develop the excellent character of poly-eating habit of this species. It reduces the expense of leaves of the oil plant. The harm of typhoon and the natural enemies may be avoided.

2. In our test, the development or moulting of each instar of the larva can be well managed on time. The man-made trouble which would make the silkworm excrete its digestive fluid may be decreased, so it is a benefit for high production of sericulture.

3. This rearing method would decrease the temperature of small circumstances and wet supplied in high temperature season. So it is suitable for the development of the larva and the moth and to strengthen its adverse-resistance character.

4. The total weight of the cocoon and the weight of the cocoon shell of ten thousands eri silkworm would increase by an average of 6.7-7.9%. The higher productive varieties in high temperature condition are "New 681", Guangsi-2, 684 and LC--1.

5. The number of eggs deposited by a female moth, as the results of our tests during the fore two years, would increase by an average of 16.3-30.1% in high temperature season. The rate of larvae hatched is high in practice. The quantitative ratio of eggs hatched among the varieties is in decreasing order "New

681", "Guangsi-2", "110 A", "684", "LC-1", respectively.

6. In juvenile larva stage the expense of fresh leaves may be decreased by 20% with this rearing method and the effect of man labour may be raised over double. So it is available for extension of common rearing of juvenile larva and group-rearing of elder larvae and the development of sericultural production.

ON THE EFFECT OF LOW TEMPERATURE ON EGG HATCH AND  
SUBSEQUENT DEVELOPMENT OF SAMIA CYNTHIA RICINI BOISDUVAL  
(LEPIDOPTERA : SATURNIIDAE)

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22 hour old eggs of Samia cynthia ricini Boisduval obtained from a stock bred purely on castor, Ricinus communis for three generations were subjected to storage for varied durations (5 to 30 days) and temperatures (0 to 15°C). Observation of eggs at 0°C revealed good hatchability (74 to 85.3%) when stored upto 15 days, beyond which egg mortality was high (57-73.2%). Eggs cold stored at 5°C showed 79 to 92.6% hatchability upto a period of 20 days. However, 15°C showed significantly low hatchability in all durations of storage. Further at none of the tested temperatures, the eggs could be stored for a period of 30 days since the mortality was very high (87.3 to 100%).

The time taken for egg hatch at each of the temperatures and durations showed significant variations. The maximum delay in egg hatch was 9.6 days but showed high percentage of mortality. Further, rearing of larvae from cold stored eggs, on castor leaves showed marked variation in larval weight, weight of green cocoon and shell weight. Storage of eggs at 5-10°C for 5-10 days recorded a higher effective rearing rate (E.R.R.) than all other treatments.

## GENERAL POSITION OF NON-MULBERRY SILK IN THAILAND

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The general position of non-mulberry silk in Thailand is in natural condition, as what we call wild silkworm is usually found in the forest. Four species are available in natural environment:

1. *Antheraea mylitta*
2. *Antheraea frithii*
3. *Antheraea roylei*
4. *Philosamia ricini*

There are many varieties of plants that can be used for rearing of non-mulberry silkworm in Thailand. They are as follows:

1. *Lagerstronemia flosreginae* R
2. *Lagerstronemia indica* L.
3. *Terminalia calappa* L.
4. *Terminalia alata*
5. *Ricinus communis*
6. *Heteropanax fragrans*
7. *Manihot utilissima*
8. *Ailanthus* sp.
9. *Carica papaya*

On December, 1974, P. Sepsawasdi, Department of Agriculture conducted a trial of rearing of *Philosamia ricini* Boisd. (1500 eggs) by feeding on *Ricinus communis* and *Manihot utilissima* at 24-25°C. The results were as follows:

Egg incubation : 8-10 days  
Amount of eggs : 242 eggs/batch

Larval duration : 26-31 days

Molting : 4 times

Pupal duration : 18-22 days

Male moth life duration : 5-6 days

Female moth life duration : 10-15 days

The life cycle is of 57-78 days. This is the general information on non-mulberry silk in Thailand.

OAK TASAR ANTHRAEA PROYLEI J. REARING IN HIMACHAL PRADESH (INDIA)

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Although oak tasar culture was started in Himachal Pradesh (India) in 1969 with a hybrid between *Antheraea roylei* and *Antheraea pernyi* named as *Antheraea proylei* J., it could not acquire a commercial status due to various reasons. Problems have been many like unsuitability of some variety of host plants like *Quercus incana* due to its quick maturing nature, unsuitability of the same variety of plants for rearing in different seasons, unstable and weak voltinism, low fecundity, hazards of outdoor rearing, etc.

By stages all these barriers have been broken and consequently oak tasar rearing has reached the threshold of success.

a) Rearing on *Q. incana* has been made successful by defoliation of the plants on which rearing has to be started leading to an early sprouting, followed by the late stage rearing on the normal undefoliated plants.

b) Use of the same variety for different seasons has been avoided by rearing the first crop at a low altitude on *Q. incana* followed by the rearing of the second crop at a higher altitude on *Q. semecarpifolia*.

c) Unstable and weak voltinism has been overcome by conducting the rearing at a higher altitude and isolating univoltine stocks which can be preserved from one year to another.

d) With the isolation of univoltine line, better cocoon weight, shell weight and fecundity have been achieved.

e) Outdoor rearing has been done away with the same being replaced by indoor and stall rearing.

Rearing results (quantitative and qualitative) of the Research Extension Centre of the Central Tasar Research and Training Institute, located at Bir, Himachal Pradesh, are given in Tables I and II.

| Year | FIRST CROP         |                          |                      | SECOND CROP        |                          |                      |
|------|--------------------|--------------------------|----------------------|--------------------|--------------------------|----------------------|
|      | No. of DFLs reared | No. of cocoons harvested | Yield of cocoon/DFLs | No. of DFLs reared | No. of cocoons harvested | Yield of cocoon/DFLs |
| 1980 | 1 124              | 10 727                   | 9.54                 | 676                | 24                       | 0.34                 |
| 1981 | 824                | 14 251                   | 16.68                | 1 725              | 2 500                    | 1.45                 |
| 1982 | 920                | 14 718                   | 16.06                | 999                | 22 030                   | 22.05                |
| 1983 | 1 689              | 10 087                   | 5.97                 | 1 959              | 66 262                   | 33.82                |
| 1984 | 5 735              | 75 401                   | 13.14                | 10 426             | 350 259                  | 33.59                |
| 1985 | 7 600              | 127 439                  | 16.77                | 19 389             | 372 230                  | 19.19                |

Figures represent results of multilocal trials in different villages.

Table I. Rearing results (quantitative) of C.T.R.&T.I., Research Extension Centre, Bir (Himachal Pradesh).

| Host plant               | Rearing place          | Type of brood | E.R.R. % | Cocoon weight (gm) | Shell weight (gm) | Shell ratio % |
|--------------------------|------------------------|---------------|----------|--------------------|-------------------|---------------|
| <u>Q. incana</u>         | Shahpur (823m ASL)     | First         | 51       | 5.65               | 0.60              | 10.61         |
| <u>Q. semecarpifolia</u> | Winch Camp (2432m ASL) | Second        | 90       | 7.63               | 0.85              | 11.14         |

The values are average of the rearings conducted during 1983-85.

Table II. Qualitative improvement of *A. proylei* cocoons at C.T.R.&T.I., Research Extension Centre, Bir (Himachal Pradesh).

## INDUCTION OF PUPAL DIAPAUSE IN OAK TASAR SILKWORM ANTHERAEA PROYLEI J.

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*Rearing of Antheraea proylei J. in the sub-Himalayan India at different altitudes on different Quercus species, led to the development of the present bivoltine strain. However, due to considerable erratic emergence in the bivoltine strain nearly half of the seed cocoons are wasted every year. An attempt was made in this study to induce diapause in the pupae of the present bivoltine strain by successive univoltine rearing in temperate area on Q. semecarpifolia Smith. The erratic emergence in the second successive rearing was noted to be 6.16% and in third year only 2.83% moths emerged out.*

### INTRODUCTION

The primary ecological factor responsible for the induction and termination of diapause in Antheraea pernyi is reported to be photoperiod (Tanaka, 1944; Williams *et al.*, 1965; Mc Daniel and Berry, 1967). Subsequently, temperature has been shown to affect and modify the photoperiodic response (Mansingh and Smallman, 1971). The induction of pupal diapause in A. proylei is reported in this paper.

### MATERIALS AND METHODS

The Indian oak tasar silkworm, Antheraea proylei was reared domestically as already reported (Bahl *et al.*, 1985). This work was conducted in temperate climatic conditions at an elevation of 2470 m ASL at Winch Camp in western sub-Himalayan region.

The worms were fed upon cut twigs of Quercus semecarpifolia Smith. The harvested cocoons were preserved in the form of garlands in ventilated rooms at the place of

rearing (Winch Camp) under natural temperature and relative humidity (Table I). The erratic emergence of moths was recorded at weekly intervals during nine months of storage between August of rearing season to April of next year.

## RESULTS AND DISCUSSION

Bahl *et al.* (1985) have shown that after conducting preponed first crop at low altitude (600-1000 m ASL) on *Quercus incana* Roxb., second crop rearing can be successfully conducted at high altitudes (2000-3000 m ASL) on *Q. semecarpifolia* Smith. However, due to weak voltinism of *A. proylei*, it has not been possible to check erratic emergence in the seed cocoons preserved either from first or second crop.

In this study, from second crop high altitude rearing at Winch Camp during the year 1982, a batch of 2500 cocoons had been preserved for repeated rearings on *Q. semecarpifolia*. Between August of 1982 and April of 1983, around 40% erratic emergence was recorded as a result of which only 311 disease free layings could be prepared for first consecutive rearing at Winch Camp on *Q. semecarpifolia*. A total of 18 333 cocoons were harvested out of 18 690 worms brushed. The erratic emergence recorded during the year was 30.52% (Table II). In 1984, second successive rearing was undertaken with 58 320 worms obtained from 1981 DFLs. The erratic emergence in the second year remained only 6.16%.

Again, in third year of successive rearing (1985), a total of 118 770 worms were reared from 8607 DFLs. It can be seen from Table II that only 2.83% erratic emergence was recorded between August 1985 and April 1986.

Thus, we have been able to induce almost complete diapause in the pupae of *A. proylei* by letting the larvae grow at high altitudes in relatively cool environment. The key point of transforming a bivoltine oak silkworm into univoltine strain was the cultivation of three successive generations in the temperate region. This has laid the foundation of univoltine self perpetuation of *A. proylei* in the western Himalayas.

Exactly how, temperate climate has been helpful in the induction of diapause in this study, is not known, but it is possible that low temperature extended help in reducing the emergence of moths from pupae. This seems to agree with eri silkworm where Tingyin (1984) has demonstrated role of low temperature in the induction of hibernation condition. The maintenance and termination of the diapause of pupae in saturniids appears to be a temperature dependent phenomenon.

## ACKNOWLEDGEMENT

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| 1983-85 | Temperature (°C) |      | Relative humidity (%) |
|---------|------------------|------|-----------------------|
|         | Max.             | Min. |                       |
| JAN     | 8.6              | 1.9  | 68.0                  |
| FEB     | 9.3              | 2.3  | 63.9                  |
| MAR     | 13.4             | 5.6  | 64.0                  |
| APR     | 15.5             | 10.3 | 62.8                  |
| MAY     | 18.8             | 11.1 | 60.4                  |
| JUN     | 23.5             | 16.7 | 57.3                  |
| JUL     | 24.8             | 15.7 | 89.8                  |
| AUG     | 23.0             | 16.0 | 81.7                  |
| SEP     | 21.9             | 11.7 | 80.0                  |
| OCT     | 18.8             | 11.8 | 74.8                  |
| NOV     | 16.0             | 8.4  | 64.1                  |
| DEC     | 12.0             | 3.1  | 76.4                  |

The values are average of daily record.

Table 1. Temperate hygrothermic conditions at 2470 m ASL (Winch Camp).

| Year     | Worms reared | Cocoons harvested | Cocoons preserved | Erratic moth emergence | % loss |
|----------|--------------|-------------------|-------------------|------------------------|--------|
| I 1983   | 18690        | 18333             | 18333             | 5597                   | 30.52  |
| II 1984  | 58320        | 56528             | 47803             | 2984                   | 06.16  |
| III 1985 | 118770       | 117415            | 115822            | 3280                   | 02.83  |

Values represent total number counted manually.

Table 11. Effect of successive rearing of *A. proylei* at high altitude (2470 m ASL).

EVALUATION OF DIFFERENT REARING METHODS FOR OAK TASAR  
SILKWORM ANTHRAEA PROYLEI J.

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*The larvae of Antheraea proylei J. were reared outdoor on Oak trees and by stall feeding under nylon net cover as well as under tarpauline tent cover by comparison with domestic floor feeding inside the rooms at high and low altitudes. It was observed that A. proylei can be easily reared by stall feeding under nylon net cover at high altitudes in temperate area on Quercus semecarpifolia Smith, thereby opening way for large scale mass rearing of A. proylei.*

INTRODUCTION

Jolly *et al.* (1975) advocates rearing first three instars of Indian Oak tasar silkworm (Antheraea proylei) on cut twigs rested in bottles with water. This method of bottle rearing is not economically useful because of the poor adaptability for mass production.

We have evaluated different rearing methods for A. proylei in north-western India with reference to mass rearing from commercial point of view.

## MATERIAL AND METHODS

This work was carried out in Himachal Pradesh at two places; Shahpur (low altitude - 823 m ASL) and Winch Camp (high altitude - 2470 m ASL). As reported earlier (Bahl *et al.*, 1985), *Quercus incana* Roxb. leaves were utilized for brushing in spring season at low altitude (Shahpur) and *Q. semecarpifolia* Smith leaves were utilized at high altitude (Winch Camp).

Disease free layings of *Antheraea proylei* J. were prepared from the hibernated cocoons according to the method of Jolly *et al.* (1975). Incubation of eggs was carried at  $27\pm 1^{\circ}\text{C}$  with 80% relative humidity. The worms were brushed on tender shoots bearing newly sprouted leaves and placed into box type trays with flat bottom as well as lid made of wire mesh (inner dimensions : 70x40x14 cm). These rearing trays contained upto 3000 newly hatched worms from nearly 75 DFLs. The trays were cleaned daily in the morning and the worms were fed upon tender shoots only. After the first instar rearing, worms were taken out of the tray and fed on the floor of the house. The temperature ( $27\pm 1^{\circ}\text{C}$ ) and relative humidity (80%) were maintained until the worms settled in second moult. After this chawki rearing when the worms were in third instar, a part of the worms was transferred outdoor and fed upon stalls made of oak twigs bearing leaves in the open ground under nylon net cover. Another part of the worms was reared similarly on stalls but covered by tarpauline tent of 10x12 m size. The results of this semi-outdoor stall feeding under nylon net cover were compared with indoor floor feeding of the remaining worms from the same batch.

## RESULTS AND DISCUSSION

*Antheraea proylei* is grown on coppiced *Quercus serrata* trees in north-eastern India. The recovery of cocoons per laying from such outdoor rearing on oak trees remains around 25% in spring season. In north-western India, *A. proylei* rearings are carried on *Q. incana*, *Q. dilatata* (syn. *Q. himalayana*) and *Q. semecarpifolia*. The average height of these trees in this region is nearly 15 to 30 meters. As a result, it becomes difficult to release the worms on nature grown oak trees in north-west sub-Himalayan India.

Bahl *et al.* (1985) reported 97% recovery of cocoons by indoor floor feeding of worms on cut shoots of *Q. semecarpifolia* at high altitudes in Himachal Pradesh. However, due to limited inhabitation in high altitude areas, semi-outdoor stall feeding on cut shoots was tried in this work by comparison with completely indoor floor feeding.

It can be seen from Table 1 that the recovery of cocoons in semi-outdoor stall feeding was equally good on *Q. semecarpifolia* at high altitudes (2470 m ASL). In this sub-Himalayan region, temperate climatic conditions prevail. There was no significant difference in the recovery of cocoons either under nylon net cover or under tarpauline tent. Both these prevented predators like birds, etc.

Semi-outdoor stall feeding on *Q. incana* at low altitudes was not successful. This might have been due to rapid fluctuations in sub-tropical hygrothermic conditions of low altitude. But indoor floor feeding under controlled hygrothermic conditions at Shahpur provided good recovery of cocoons from preponed brushings in spring season.

In this work, a total of 44 farmers were given chawki reared worms and twelve villages were covered. It has been observed that the rearers obtained 46.85% effective rate of rearing on *Q. incana* at low altitudes by indoor floor feeding. At high

altitudes, 78.99% E.R.R. was obtained by the rearers (Table II), when the farmers reared *A. proylei* on *Q. semecarpifolia* by indoor floor feeding as well as by semi-outdoor stall feeding. These results have opened way for large scale mass rearings of *A. proylei*.

#### ACKNOWLEDGEMENTS

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| Year 1985                   | Indoor<br>floor feeding | Semi-outdoor<br>stall feeding |
|-----------------------------|-------------------------|-------------------------------|
| Number of worms brushed     | 91 270                  | 27 500                        |
| Number of cocoons harvested | 87 940                  | 26 780                        |
| E.R.R. (%)                  | 96.35                   | 97.38                         |

Table 1. *A. proylei* rearing on *Q. semecarpifolia* at 2470 m ASL (Winch Camp).

| Village               | Number of<br>rearers involved | Number of<br>worms supplied | Number of<br>cocoons harvested | E.R.R.<br>(%) | Host plant               |
|-----------------------|-------------------------------|-----------------------------|--------------------------------|---------------|--------------------------|
| Manjgran              | 8                             | 90 000                      | 45 360                         | 50.4          | <u>Q. incana</u>         |
| Daman                 | 1                             | 10 000                      | 7 875                          | 78.75         | <u>Q. incana</u>         |
| Banai                 | 3                             | 25 000                      | 13 540                         | 54.16         | <u>Q. incana</u>         |
| Dhaloon               | 2                             | 15 000                      | 5 850                          | 39.0          | <u>Q. incana</u>         |
| Yol Camp              | Army unit                     | 15 000                      | 6 025                          | 40.1          | <u>Q. incana</u>         |
| Nalauta               | 9                             | 90 000                      | 73 767                         | 81.96         | <u>Q. semecarpifolia</u> |
| Kothi                 | 4                             | 40 000                      | 24 445                         | 61.11         | <u>Q. semecarpifolia</u> |
| Kothi Kohr            | 10                            | 100 000                     | 70 470                         | 70.47         | <u>Q. semecarpifolia</u> |
| Winch Camp            | 3                             | 48 200                      | 35 750                         | 74.17         | <u>Q. semecarpifolia</u> |
| Joginder Nagar (W.C.) | 1                             | 16 000                      | 15 500                         | 96.87         | <u>Q. semecarpifolia</u> |
| Darat Bangla          | 1                             | 16 000                      | 15 600                         | 97.50         | <u>Q. semecarpifolia</u> |
| Upper Banai (W.C.)    | 1                             | 18 000                      | 17 700                         | 98.33         | <u>Q. semecarpifolia</u> |

Table II. Rearing performance of *A. prgylei* with private rearers during the year 1985.

## PROSPECTS OF ANTHERAEA YAMAMAI REARING IN INDIA

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An attempt was made in this work to domestically rear Japanese Oak Tasar Silkworm, Antheraea yamamai Guérin-Ménéville on the leaves of three Indian Quercus species. Larvae were reared on cut shoots dipped in water in bottles. Although, survival (%) was not good on Q. incana Roxb. and Q. serrata Thunb., yellowish green cocoons (size 4.8 x 2.5 cm) were harvested from a rearing on Q. semecarpifolia Smith at a higher altitude (2470 m ASL). The emerged moths coupled and eggs laid were observed for their diapausing behaviour. Oak forests of Q. semecarpifolia thus, appeared to be suitable for A. yamamai rearing in India.

### INTRODUCTION

Antheraea yamamai G.M. is a native of Japanese islands. Kuribayashi (1985) has reported that this insect feeds on oak trees such as Kunugi (Quercus acutissima Carruth), Konara (Q. serrata Thunb.), Kashiwa (Q. dentata Thunb.) and Shirakashi (Q. myrsinaefolia Blume).

An experimental rearing of A. yamamai on three Indian Quercus (Oak) species is reported here.

### MATERIAL AND METHODS

The hibernating eggs of Antheraea yamamai G.M. were imported from Nagano Prefecture, Ariake district, Japan.

Experimental rearings were conducted at two different altitudes; 1678m ASL (Bir) and 2470m ASL (Winch Camp) in the sub-Himalayan region of north-west India. At 1678m

ASL, *Quercus incana* Roxb. and *Q. serrata* Thunb. were employed, whereas at 2470m ASL, *Q. semecarpifolia* Smith was utilized. These species are easily identified on the basis of leaf morphology (Hooker, 1883; Chowdhary and Wadha, 1984).

The diapause of the hibernating eggs was broken by low temperature (3-5°C) treatment. The eggs were withdrawn from refrigerator on the availability of newly sprouted leaves in April at 1678m ASL and in early May at 2470m ASL.

The larvae were brushed on tender, newly sprouted leaves and reared on cut shoots dipped in water filled bottles inside a room. The temperature and relative humidity of the room were maintained at  $27\pm 1^{\circ}\text{C}$  and 80%, respectively, until the larvae entered 3rd instar. Thereafter, the rearing was conducted at natural room temperature ( $23\pm 1^{\circ}\text{C}$ ) and relative humidity (70±2%). The harvested cocoons were also kept under natural conditions for eclosion, copulation and oviposition (Kato *et al.*, 1981).

## RESULTS AND DISCUSSION

The survival of *A. yamamai* larvae on three Indian *Quercus* species is shown in Figure 1. At Bir (1678m ASL), 80% larvae could grow upto 3rd instar on *Q. incana* but none could survive after 12 days of brushing. The survival was relatively better on *Q. serrata*, where mortality was noticed only after 5 days of growth. However, not even one cocoon was harvested either from *Q. incana* or *Q. serrata* at Bir. Microscopic examination of the deceased larvae revealed only polyhedral inclusions.

At Winch Camp (2470m ASL), interestingly not even single larva died on *Q. semecarpifolia*. The cocooning occurred after 40 days of feeding. The average weight of full grown larva was noted to be 18 gm. The pupation occurred 8 days after cocooning. While, the male pupa showed average weight of 5.5 gm, female had 7.6 gm. The male cocoon shell weight was 0.63 gm, and female cocoon shell weight was 0.68 gm with cocoon shell ratio 10.27 and 8.99% respectively. The cocoons had yellowish green colour and their size was around 4.8 x 2.5 cm.

The imagoes emerged around 50 days after pupation under natural temperature ( $23\pm 1^{\circ}\text{C}$ ) and relative humidity (70±2%). The imagoes were placed out in verandah in a bamboo basket under cool natural breeze for coupling. The females laid around 200 eggs within 4 days. These eggs did not hatch in the same year confirming univoltine diapausing nature.

An interspecific cross of female *A. yamamai* with bivoltine Indian oak silkworm, *A. proylei* (n=49) was also obtained. These eggs did not show diapause and 88% hatching of worms was obtained ten days after coupling. This result demonstrates male dependent genetic basis of egg diapause in *A. yamamai*.

In this study, the eggs obtained from self couplings of *A. yamamai* were preserved at Winch Camp for hibernation, where indoor winter temperature remained around 2-5°C. However, in next spring due to early rise in temperature and non availability of newly sprouted *Q. semecarpifolia* leaves at that time, this material was lost and further rearing of *A. yamamai* could not be continued by the authors.

The current price of *A. yamamai* silk is about 50 times higher than *Bombyx* silk. Only around 35-40 kg *A. yamamai* (tensan) silk is annually produced in Japan (Kuribayashi, 1985). As the tensan silk, mix woven with usual silk improves textile quality of clothes, demand for it is rapidly increasing in recent years. This report demonstrates a new area for *A. yamamai* rearing in India, which can boost tensan silk production. Nearly 38 thousand hectares of forest flora is under the cover of *Q. semecarpifolia* in various forest ranges of Himachal Pradesh alone as shown in Table

1. Other Indian states like Jammu and Kashmir, and western Uttar Pradesh also have considerable area under this oak. The present restraint is the non availability of *A. yamamai* in India.

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| Forest range | Area under <i>Q. semecarpifolia</i><br>(Ha.) |
|--------------|----------------------------------------------|
| Kangra       | 12 570                                       |
| Rohru        | 9 778                                        |
| Rajgarh      | 1 246                                        |
| Chopal       | 1 195                                        |
| Mandi        | 868                                          |
| Kulu         | 584                                          |
| Seraj        | 697                                          |
| Nachan       | 594                                          |
| Simla        | 800                                          |
| Kotgarh      | 6 151                                        |
| Dalhousie    | 2 296                                        |
| Chamba       | 1 320                                        |

Table 1. Distribution of *Quercus semecarpifolia* in Himachal Pradesh.

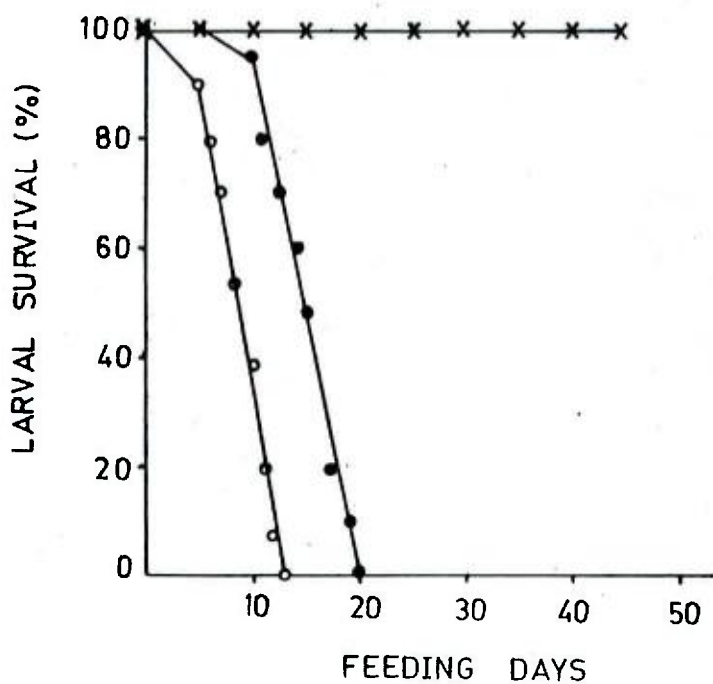


Fig. 1. Rearing of *A. yamamai* larvae on leaves of Indian *Quercus* species.

- : *Q. incana*
- : *Q. serrata*
- × : *Q. semecarpifolia*

## LIST OF PAPERS ACCEPTED FOR DOCUMENTATION

Effect of different periods of brushing on the rearing performance and cocoon quality of the oak tasar silkworm *A. proylei* J. reared on *Q. semicarpifolia* smith in U.P. hills.

MADAN BHAT, J. BHATTACHATYA, P.S. SINHA and K. SENGUPTA.

Change in total soluble proteins in the midgut epithelium, haemolymph and silk glands of tasar silkworm.

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Changes in free amino acids in the larval and pupal haemolymph of *A. Proylei* J.

A.K. SINHA, U.S.P. SINHA, A.K. SENGUPTA and K. SENGUPTA

Ascorbic acid content in the leaves of *Q. Serrata* Thunb and *Q. Dealbata* Carr., the common food plants of oak tasar silkworm *A. proylei* J.

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