PERFORMANCE OF MULBERRY SILKWORM RACES AND HYBRIDS IN KERALA

By

GEORGE THOMAS

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1995

DECLARATION

I hereby declare that this thesis entitled "Performance of mulberry silkworm races and hybrids in Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma, associateship, fellowship or other similar title of any other University or Society.

GEORGE THOMAS

Vellayani,
16.06.1995

APPROVED BY :

CHAIRMAN

Dr. D. DALE ,

Professor ,

Department of Agricultural Entomology ,

College of Agriculture , Vellayani.

MEMBERS

Dr. K. JOHN KURIYAN

Dr. K. SASIDHARAN PILLAI

Dr. B. RAJAGOPALAN

EXTERNAL EXAMINER

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INTRODUCTION

INTRODUCTION

The silk is a fibrous protein of animal origin. The mulberry silkworm Bombyx mori Linnaeus produce more than ninety five per cent of the commercial silk (Ganga and Chetty, 1991). The silkworm races are categorised into univoltine, bivoltine and multivoltine based on physiological and ecological factors in nature. The sucess of silkworm rearing largely depend on the suitability of productivity of the race in the particular ecological situation.

Though sericulture was being practiced in the neighbouring state Karnataka for the last so many decades, in Kerala the practice of silkworm rearing dates back to the 70's only. An attempt made by the Central Silk Board to introduce sericulture in Wayanad, in the erstwhile Malabar District, neighboring Karnataka, could not be a sucessful venture due to lack of appropriate technology applicable for the particular conditions. The study conducted by Kerala Agricultural University in 1980 in the districts viz. Thiruvananthapuram, Idukki and Wayanad revealed that sericulture will be a feasible programme in the state. The cocoons obtained from Idukki were of high standards and Das and Pillai (1983) reported that the bivoltine race is well adapted to the high range situations like Idukki and Ambalavayal.

In Karnataka the multivoltine races were being reared continously for more than five decades, leading to the deterioration of the racial characters and cocoon quality. The bivoltine got popularity in India only by the 1970's. The bivoltine races reared in south India are namely KA, NB_7, NB_{18} and NB_4D_2.

The pioneering work of Toyama in 1905 on the hybridisation in silkworms in Japan, led to the introduction of hybrids for commercial rearing, resulting in marked improvement in productivity. Hybrids are superior to the parents in many quantitative characters (Hirobe, 1968). The bulk of the cocoons now produced are from multivoltine x bivoltine hybrids (Anonymous, 1989). Multivoltine x bivoltine hybrids has a better performance over its reciprocals in respect of most of commercial characters like hatching percentage, survival rate and cocoon characters (Benchamin _et al_., 1983).

Kerala is a pilot state where bivoltine rearing was directly taken up when the traditional states were reluctant to it. Most of the commercial rearers are now using multivoltine x bivoltine hybrids. But there is tremendous scope for rearing bivoltines in the state even to meet the seed requirement of entire south India. For this, identifying the most suitable race for the different agro climatic conditions is of prime importance. In this context the present study was undertaken with the following objectives;

1. To identify the most suitable bivoltine race and cross breed among some of the popular races for the southern districts of Kerala.

2. To study the influence of the seasons on the cocoon productivity of same popular silkworm races.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The review of literature related to the characters under study are presented here under.

The superiority of hybrid races under new breeding and management techniques have been well demonstrated with regard to egg laying capacity (Sidhu, 1967), hatchability, (Krishnaswami et al., 1964), greater survival rate and larger size of caterpillars (Kovalev, 1965; and Sidhu, 1967), shortened feeding period and increased vitality (Bekirov, 1960; Golanski, 1959; and Sidhu, 1973), higher silk percentage (Krishnaswami et al., 1964), greater filament length (Krishnaswami, 1979), better adaptibility to climatic conditions (Sidhu, 1973) and better vigour and quality product (Tirelli, 1973).

2.1. Larval characters

2.1.1. Larval duration

Krishnaswami et al. (1971) reported that Pure mysore had the highest larval duration of 30 days : 17 hours, to that of other races, irrespective of seasons. The NB_4D_2 has the total larval duration of 23 days: 20 hrs and KA has the total larval duration of 22 days : 05 hrs (Anonymous, 1983a). According to another report NB_4D_2, NB_{18}, NB_7, and KA have the total larval duration of 25 days : 09 hrs, 25 days 10 hrs, 24 days : 15 hrs, and 24 days: 15 hrs respectively (Anonymous, 1987b).

Viswantha (1987) found that cross breeds viz., PM x NB_4D_2 and PM x NB_{18} have a shorter larval duration than NB_4D_2 and NB_{18} and Pure Mysore.

Mathur et al. (1988) reported that KA, NB_7, NB_4D_2 and NB_{18} had the total larval duration of 23.9, 27.4, 27.9 and 27.9 days respectively in the southern agro climatic conditions of Rajasthan.

Thangavelu and Raja Kumar (1988) studied the performance of Pure Mysore, NB_4D_2, NB_{18}, and the cross breeds viz. PM x NB_4D_2 and PM x NB_{18}, in tropical conditions of Tamil Nadu. They found that larval duration in the Pure Mysore was always longer than in bivoltine pure races and cross breeds. On an average, the cross breeds were shorter by 3.35 days per crop, and the bivoltines were shorter by 2.85 days.

2.1.2 Leaf consumption

The food intake is related to growth rate (Kaufman and Bayers, 1972; and Rogers *et al.*, 1977).

In *Bombyx mori* growth is heterogenic and varies according to its races, quality and quantity of food intake (Krishnaswami *et al.*, 1971) and climatic conditions (Vijay, 1985).

The food consumption of bivoltine races viz., NB_4D_2 and KA was two times more than larvae of the Pure Mysore (Prakash *et al.*, 1987). Kuribayashi *et al.* (1990) reported that in the old races, the dry matter digested by the larvae in the fifth instar was fourty per cent lower than that of newly bred races.

2.1.3 Larval weight and length

Pure Mysore has the lowest larval weight of 1.80 g, less than those of the cross breeds and the bivoltines irrespective of the seasons (Jolly *et al.*, 1982). Pure Mysore had the lowest larval weight having 18.63 g for ten mature fifth instar larvae; NB_{18} having 44.33 g, NB_7 having 42.10 g, and NB_4D_2 having 41.2 g (Anonymous, 1987c). Devakumar (1987) reported that larva of Pure Mysore had the weight and length of 2.1360 g and 5.83 cm respectively for the fifth instar.

Viswanatha (1987) found out that the bivoltine race NB_4D_2 has the highest fifth instar larval weight of 3.4043, 3.4811, 3.5316 g during August-September 1985, December 1985 to January 1986 and May-June 1986 respectively than NB_{18} and the cross breeds PM x NB_4D_2 and PM x NB_{18}. Kenchuji Rao (1988) reported that ten larvae of Pure Mysore had the weight and length of and 20.98 g and 4.29 cm respectively during fifth instar. According to Manjunath (1988) ten larvae of NB_{18} has the weight and length of 41.36 g and 7.49 cm respectively during fifth instar.

Mathur _et al_. (1988) observed that among the four bivoltine races viz. NB_7, NB_{18}, KA and NB_4D_2, NB_4D_2 has the highest larval weight. Ten matured fifth instar larvae weighed 33.016 g, but NB_{18} had the lowest larval weight of 27.915g in southern agro-climatic conditions of Rajasthan.

Venugopala Pillai and Krishnaswami (1989) found that in the fifth instar, KA have higher larval weight than NB_4D_2.

2.2. Cocoon characters

2.2.1. Cocoon yield potentialities

Devaiah (1973) observed more cocoon formation in case of multivoltine C. Nichi compared to the cross breeds and bivoltine races.

Benchamin et al. (1976) noticed that the cocoon yield of, NB_4D_2 was higher than that of KA and NN_6D, with 24015, 19970 and 20625 cocoons per 100 layings respectively.

Ganesh et al. (1976) observed that the bivoltine hybrids registered a better yield of 37.00 kg per 100 layings, compared to hybrids of KA and NN_6D, which yielded 34.0 kg per 100 layings. The other cross breed KA x NB_3C recorded a maximum cocoon yield of 51.0 kg per 100 layings. Similarly Narasimhanna et al. (1976) found out that the bivoltine hybrid, NB_4D_2 x KA yielded 42.0 kg as against 32.0 kg for KA x NN_6D per 100 layings.

The cross breeds viz. PM x NB_4D_2, PM x NB_{18}, PM x KA, PM x NB_7 gave yields of 35.4, 35.8, 37.4 and 40.1 kg per 100 layings respectively (Anonymous, 1981a).

Chandrashekharaiah <u>et al</u>. (1981) stated that the performance of bivoltine was superior to multi-bihybrid in Kolar and Bangalore districts. Hybrid of PM x NB_4D_2 yielded 50.1 kg/100 layings, while bivoltine hybrid NB_{18} x KA and NB_4D_2 yielded 45.3 and 43.6 kg cocoons per 100 layings respectively.

Siddappaji <u>et al</u>. (1983) noticed the cocoon yield of Pure Mysore, NB_{18} and NB_4D_2, and the cross breeds PM x NB_{18} and PM x NB_4D_2 and they found that cocoon yield of the three types showed a wide range of diversity.

The cocoon yield study of four bivoltine races showed the following yields per 100 layings: NB_4D_2 -77.3 kg, NB_{18} - 75.0 kg, NB_7 - 76.4 kg and KA - 76.4 kg (Anonymous, 1986b).

Study of Siddappaji <u>et al</u>. (1987) revealed that the cross breed PM x NB_4D_2 gave better yield than PM x NB_{18}.

Datta and Pershad (1988) in their study noticed that the crosses Nistari and Diazo multivoltine with NB_7 and Hosa Mysore with NB_4D_2 bivoltine were better specific combainers for cocoon yield and pupation rate.

Rao et al. (1989) stated that there are three methods open to silkworm breeder for improving the rate of response to selection in pupation, one is by increasing the heritability, second is by reducing the proportion selected and so increasing the intensity of selection and lastly by choosing the correct parents at the beginning of the experiment.

2.2.2. Cocoon weight, shell weight and shell ratio

Viswanath and Nagaraju (1975) observed that the variation in single cocoon weight, shell weight and shell ratio varied very much and ranged from 1.250 to 1.430 g, 0.200 to 0.250 g and 15 to 18 per cent for KA x NN_6D, respectively.

The study conducted with ten lines of NB series showed that the races, NB_4D_2, NB_4B, NB_2C_1, NB_3D_1 and NB_4D_1 showed better single cocoon weight with an average of 2.1 g with 0.420 g to 0.431 g shell weight and an average of 21-22 per cent silk content (Anonymous, 1981b).

Jolly <u>et al</u>. (1982) on cocoon weight and shell weight revealed that the Pure Mysore had a lower value than the bivoltine races, KA, NB_7, and NB_{18} and the cross breeds, PM x NB_{18} and hybrid NB_{18} x NB_7.

Study of Pillai and Raju (1982) revealed that NB_{18} had a cocoon weight, shell weight, and shell ratio of 2.328 g, 0.516 g, 22.2 per cent while NB_4D_2 had of 2.024 g, 0.464 g and 22.9 per cent respectively during September-October 1981 rearing compared to that of November-December 1981 and December 1981-January 1982. rearings.

A study on KA, NB_7, NB_4D_2, NB_{18}, NB_1C and NB_3D_1 showed that the cocoon weight was lowest in NB_1C with 1.816 g and highest in KA with 1.949 g (Anonymous, 1984a).

A study with NB_7, NB_{18}, NB_4D_2 and KA showed that they were having a cocoon and shell weight of 1.624 g and 0.356 g, 1.773 g and 0.400 g, 1.608 g and 0.347 g, 1.582 g and 0.331 gf respectively (Anonymous, 1986a).

Ravi (1986) noticed that the cocoon weight and shell weight of PM x NB_4D_2 were higher than that of PM x NB_{18}.

The multivoltine Pure Mysore had a cocoon weight of 0,841 g and shell weight of 0.093 g, while the bivoltines viz. NB_7, NB_{18}, and KA have a cocoon and shell weight of 1.654 and 0.330 g, 1.641 and 0.352 g, 1.718 and 0.325 g respectively (Anonymous, 1987a).

Raman <u>et al</u>. (1993) in their study noticed that among the tropical silkworms, PM x NB_4D_2 was very efficient in utilizing dry matter for body growth, cocoon and shell production.

2.2.3. Cocoon size and reelability

Jolly <u>et al</u>. (1981) observed that the average reelability of bivoltine cocoons are 67 per cent, while that of multivoltine are 59 per cent.

Guoliang Shou (1991) reported that reelability percentage is a characteristic parameter of cocoons.

Krishnaswami *et al*. (1991a) noticed that the number of cocoons varied between 100-150 per litre in bivoltine races and considerably more with multivoltine race.

Liug - X and Hes - M (1991) in their study reported that a positive relationship between reelability and tenacity and elongation, the tenacity of F1 hybrids was higher than that of the parents.

2.3. Pest and disease incidence

Jameson (1922) stated that pebrine caused considerable damage to the silk industry.

According to Aruga and Watanabe (1964), the F1 generation of silkworm hybrids were resistant to the infection of cytoplasmic polyhedrosis virus compared to their parents.

Liu Shi Xian (1964) noticed that the different races of silkworm showed variation in their susceptibility to various diseases.

Chowdary (1967) studied the relative incidence of different diseases viz. perbrine, grasserie, flacherie and muscardine of silkworm and found that pebrine was the major problem.

Jayaramaiah and Kuberappa (1978) stated that no race is immune to diseases.

The percentages of loss due to diseases viz. grasserie and flacherie in silkworm were 60.25, 50.375, 56.25 and 49.37 for NB_7, NB_{18}, NB_4D_2 and KA respectively (Anonymous, 1983b). Similarly another study of Dwarakinath and Chandrakanth (1983) revealed that KA had higher survival rate than NB_7, NB_4D_2 and NB_{18}.

Chinnaswamy and Devaiah (1984) reported high resistance of Pure Mysore over bivoltine races to aspergillosis infection.

The study on the early crop losses in NB_4D_2, KA, NB_7, NB_{18}, NB_4B, NB_3C_1 and $2C_1SS$ revealed that the loss were 8.14, 8.54, 8.49, 12.77, 16.12, 10.19 and 7.67 per cents respectively (Anonymous, 1985).

Narayanaswamy <u>et al</u>. (1985) noticed that Pure Mysore was more susceptible to kenchu virus infection than NB_7, NB_{18}, and NB_4D_2.

According to the research report of Rajanna <u>et al</u>. (1986), cross breeds of KA with Pure Mysore as male parent had higher resistance than KA. Moreover marginal improvement in fecundity and hatchability was also noted.

The Pure Mysore had 8 per cent incidence of grasserie and flacherie while NB_4D_2, NB_{18}, and NB_7 showed 25.50, 18.33, and 23.83 per cents respectively (Anonymous, 1987c).

Bhaskar <u>et al</u> (1987) found that PM X NB_4D_2 was less sensitive to kenchu virus infection. Another experiment conducted by Baig <u>et al</u>. (1988) revealed that there was significant difference between the multivoltine and bivoltine races towards disease incidence.

Ragahavaiah and Jayaramaiah (1990) observed that the cross breeds of multivoltine x bivoltine were less susceptible than the bivoltines towards the white muscardine infection. Among the bivoltines, NB_4D_2 was less susceptible than NB_{18} and NB_7 while among the cross breeds PM x NB_{18} was highly susceptible and PM x KA and PM x NB_4D_2 were less susceptible to the diseases. Similarly Bhaskar et al. (1991) noticed the lesser susceptibility of the cross breed PM x NB_7 towards kenchu virus infection than the female parent Pure Mysore and the male parent NB_7.

2.4. Adult characters

2.4.1. Fecundity

Egg laying capacity of various silkworm breeds of Bombyx mori was reported to vary even under identical nutritional atmospheric, mating and laying conditions (Hassanien and El-Sharawwy, 1960, 1962, Narayanan et al., 1964, Jolly et al., 1966; Ito, 1967; Sidhu et al., 1967; Kovalev, 1970; Nakasone, 1970; Sengupta et al., 1973; Horie 1978; Jadhav and Gajare, 1978; Pillai, 1979; Pillai and Krishnaswami, 1980; and Rahman et al., 1980).

The egg production efficiencies of NB_4D_2, KA, NB_3C_1, NB_7, $2C_1SS$, NB_{18} and NB_4B were 566, 563, 556, 550, 560, 532 and 503 respectively (Anonymous, 1985). In another study NB_7, KA, NB_{18} and NB_4D_2 had a fecundity of 569, 562, 559, and 547 eggs respectively (Anonymous, 1986b). According to another research report Pure Mysore had a egg laying efficiency of 444 per moth, while NB_7, NB_{18}, KA had of 580, 567, and 557 respectively (Anonymous, 1987a).

According to Nahar et al. (1989) the egg laying capacity of different breeds of silkworm was different.

Pillai and Krishnaswami (1989) studied the developmental difference and egg production capacity in silkworm breeds of different eco-geographic origin and found that KA, NB_4D_2, and J_{122} breeds exibited comparatively higher vigour and growth rates. KA had fecundity of 530 eggs and NB_4D_2 had 522.

According to Gupta et al. (1991) maximum fecundity was exhibited by bivoltines which was followed by bi-multivoltine, multi-bivoltine moths.

2.4.2. Female pupal weight

The number of eggs laid by female moths increased with increase in pupal weight (Jayaswal et. al., 1991). NB_4D_2 and NB_{18} had more pupal weight than Pure Mysore (Viswanatha, 1987).

2.5. Seasonal influence on cocoon productivity

In an experiment with different races of silkworm, Krishnaswami (1971) noticed that the polyvoltine races were having high resistance to adverse climatic conditions.

It was reported by Capniera <u>et al</u>. (1981) that the growth rate of insect was influenced by the changes in the climatic factors.

An experiment conducted by Parthasarathi and Ananthanarayan (1981) revealed that in case of bivoltine hybrids in January 1981, average yield per 100 layings in June 1980 varied from 34.8 kg - 17.05 kg.

Saheb (1981) assessed the cocoon productivity of the KA, NB_7, NB_{18}, and NB_4D_2 and found that it was better during the early summer season than monsoon seasons. The yields were 35.21, 30.55, 31.54 and 34.13 kg per 100 layings during summer and the figures for monsoon season were only 9.37, 7.01, 7.12, and 12.62 kg per 100 layings, respectively.

Vijay (1985) noticed a change in climatic conditions like temperature and humidity cause a change in growth habit of silkworm.

In Ramanagaram (Karnataka) Gowda et al. (1988) found that the field scale performance of hybrids viz., PM x NB_4D_2, PM x NB_{18} and PM x C. Nichi. in terms of cocoon yield per 100 layings through fortnightly observations was best during first fortnight of December (40.356 kg) second fortnight of January (35.919 kg) and second fortnight of December (28.711 kg). But the performance was the least during second fortnight of May (12.40, 11.680, and 10.680 kg cocoons respectively).

According to Pillai (1988), in March-April growth rate, cocoon output and fecundity were low in black cotton and rainfed areas.

In an experiment with NB_4D_2, KA, NB_7 and NB_{18}. Bhat et al. (1989) noticed that the higher yield was during the winter season, lowest in rainy season, and a moderate yield was in summer season. Similarly Rao et al. (1990) also found that during summer season when temperature rises, the percentage of dead pupae increased by 10 per cent, the lowest percentage of dead pupae was observed during the winter season. According to Gangawar and Somasundaram (1991), the months with cooler atmospheric temperature enhanced larval duration and cocoon yield, but relative humidity had its influence on larval duration only.

MATERIALS AND METHODS

MATERIALS AND METHODS

An investigation was undertaken to identify the mulberry silkworm races and cross breeds suitable under southern Kerala conditions.

The experiment was conducted in the silkworm rearing house of the sericulture section attached to Department of Agricultural Entomology, College of Agriculture, Vellayani, and Instructional farm of the College of agriculture, Vellayani.

Mulberry variety Kanva-2 was raised in 0.2 hectare area alloted in the instructional farm for the leaves required for feeding the silkworms. The mulberry cultivation was conducted according to the practices prescribed by Rangaswami et al. (1991).

3.1. Materials

3.1.1. Silkworm eggs (layings)

Before starting the experiment, the silkworm layings of pure races viz. Pure Mysore, NB_4D_2, KA, NB_{18} and

NB_7 were obtained from Silkworm Seed Production Centre, Palghat, an institute under Central Silk Board and the layings of pure races and hybrids of multivoltine x bivoltine for the experiments were prepared in the silkworm rearing house. Layings for second rearing were prepared from the first rearing, and layings for third rearing were prepared from the second rearing. The eggs of second and third rearings were obtained from the first and second rearings respectively.

3.1.2. Equipment for silkworm rearing

The rearing was conducted in the silkworm rearing house having required facilities. Rearing equipments used were rearing stand, rearing trays, chowky trays, feeding stands, antwells, chandrikes, paraffin paper, foam rubber strips, chopsticks, feathers, chopping board, chopping knives, leaf chamber, cleaning nets, hygrometers, thermometers and knapsack sprayer. The chemicals used were formaldehyde (40%), bleaching powder, and Reshamkeet oushad (RKO) powder.

3.2. Methods

3.2.1. Details of experiment

The experiment was conducted to find the performance of different races and cross breeds of mulberry silkworm in southern Kerala conditions, and it was conducted in the silkworm rearing house of the sericulture section. The silkworm races and cross breeds listed below were used in the experiment.

(i) Multivoltine - Pure Mysore

(ii) Bivoltines (1) NB_4D_2

(2) KA

(3) NB_{18}

(4) NB_7

(iii) Crossbreeds : (1) PM x NB_4D_2

(2) PM x KA

(3) PM x NB_{18}

(4) PM x NB_7

Number of replications - 3

Design - Completely Randomized Design (CRD)

Seasons I - December 1993 - January 1994, II - February - March 1994, III - May - June 1994.

3.2.2. Rearing techniques

The rearing was conducted according to the methods suggested by Krishnaswami et. al (1991b).

3.2.2.1. Disinfection

The rearing house and the equipments were disinfected by spraying with 2% formaldehyde five days before starting of rearing.

3.2.2.2. Brushing of larvae

Four Disease Free Layings (DFLS) of each race and cross breed prepared in the rearing house, were incubated and on the day prior to hatching was sibjected to black boxing. The brushing of larvae was done at 10 am. After brushing slikworm bed war prepared and foam rubber strips were placed all around the rearing bed to maintain the required R.H. of 85%.

3.2.2.3. Box rearing

The first and second instar larvae were reared by box rearing method. Wooden chowky trays of size of 0.7m x 0.9m and having depth of 10cm were used. A paraffin sheet was placed at the bottom of the box. Strips of wet foam rubber were placed all around the rearing bed for getting to required RH, and the bed was covered with another paraffin paper. But during the moulting time, the paraffin sheet covering the bed and the strips of wet foam rubber were removed and the larvae were kept undistrubed for moulting. After the moulting RKO powder was sprinkled over the larvae, before half an hour of the next feed. This treatment was given to prevent the diseases infection. The rearing boxes were placed in the rearing stand.

The earlier instars were fed with young and soft leaves having sufficient moisture content. The leaves were cropped to size of 0.5 - 2 cm and 2.0 - 4.0 cm for the first and second instars respectively.

During first instar, one cleaning was given, at the end of the instar. During the second instar, two cleanings were given one just after the first moulting and another before setting for the next moult. A temperature of 26 - 28^{o}C and a relative humidity of 85% were maintained for the chowky rearing.

3.2.2.4. Feeding

Four feeds were given per day ie, at 6 am, 11 am, 3 pm and 8 pm (Plate I).

3.2.2.5. Bed cleaning

Bed cleaning was done with the help of nylon net. When bed cleaning was done after the moulting, RKO powder was sprinkled over the larvae when 75% of larvae moulted out. After half an hour, the net was spread over the bed and fresh leaves of particular stage were given over the net and one more feeding was given over the net (Plate II). After all of them have come over to the fresh leaves over the net they were transferred to a fresh tray.

Rearing of third, fourth and fifth instar silkworms were conducted in wooden trays of 0.7m x 0.9m size and having a depth of 10cm. A newspaper was placed at the bottom of the tray. Two hundred numbers of third instar larvae from each lot were counted and transferred to rearing trays. For rearing third instar larvae leaves cropping to a size 4-6 cm were used. For rearing the fourth and fifth instar larvae

Plate - 1. Feeding of silkworms with mulberry leaves

Plate - 2. Bed cleaning using nylon net

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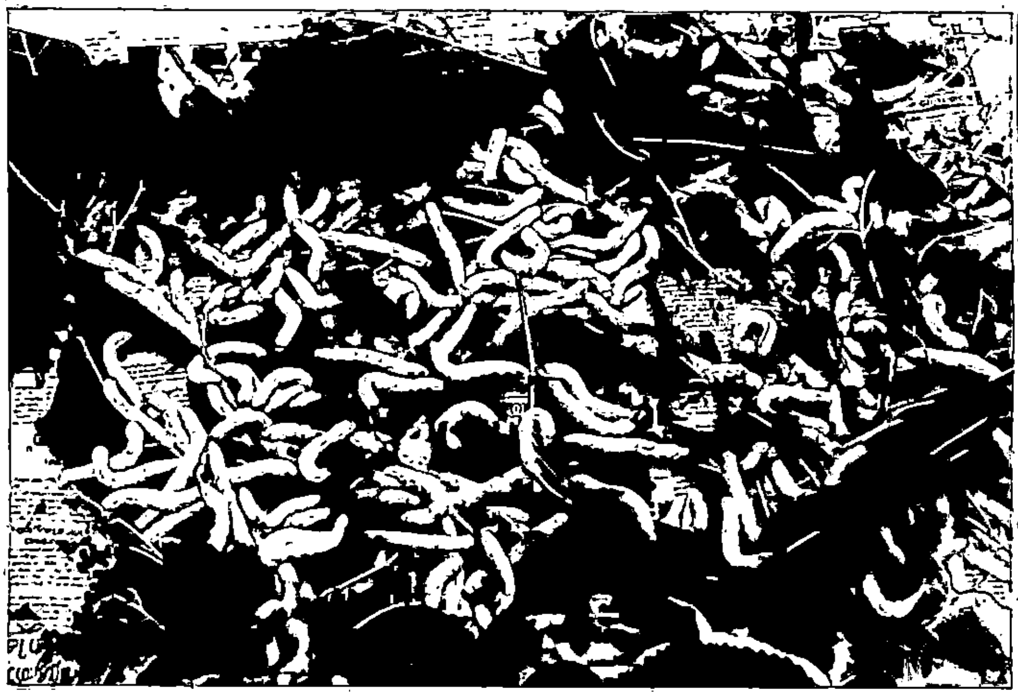

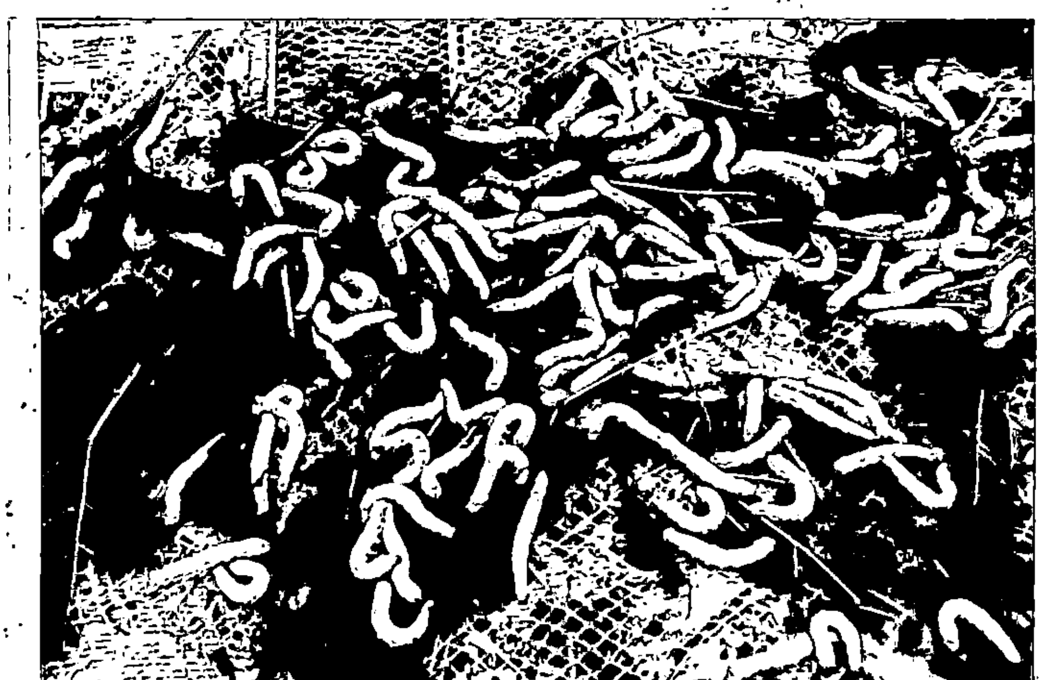

whole leaves were used. Number of bed cleaning given were; during third instar three cleanings, while during fourth and fifth instars, one cleaning per day. The temperature and humidity maintained for the later instar larvae were as follows.

Instar	Temperature (°C)	Relative humidity (%)
Third	24-26	80
Fourth	24-25	75
Fifth	23-24	70

3.2.2.6. Mounting of silkworms

Silkworms were mounted on chandrike on attaining maturity and stopped feeding. On the chandrike cocoons were spun in 48 hours and the silkworms transformed from larval stage into pupal stage (Plate III).

3.2.2.7. Harvesting of cocoons

Harvesting of cocoons were done on the sixth day after mounting of worms. After harvesting, total number of cocoons were counted, and their weight in grams also recorded.

Plate - 3. Cocoons formed on chandrike

3.2.2.8. Sex separation and moth emergence

By cutting open the cocoons and examining the pupal posterior segments, the female and male pupae of pure races were isolated. They were taken and spread out in thin layer over newspaper in separate trays. The preservation room was well ventilated to drive away gases such as CO_2 given out by the live pupae. Moth emergence took place ten day after mounting.

3.2.2.9. Copulation and oviposition

The fecundity and for maintaining the next generation of the pure races, selfing was allowed. But for producing the F1 generation of cross breeds ie, multivoltine x bivoltine cross breeds, crossing was allowed. For this male and female pupae of Pure Mysore were seperated. After the adult emergence females were taken out and males of each bivoltine race were allowed to mate with them in a separate tray. They were allowed to mate for four hours, the females were then separated from males and kept in a cellule over an egg card for egg laying.

3.2.2.10. Mother moth examination

Twenty four hours, after setting for egglaying, the mother moths were removed and examined for disease infection. Each moth was put into a mortar to which small quantity of two per cent caustic potash was added and ground with a pestle. The crushed juice was spread on a glass slide, covered with a cover slip and examined under a microscope with a magnification of X 600 for protozoan spores.

3.2.2.11. Washing of silkworm eggs

Eggs were soaked firm in two per cent formaldehyde solution for about an hour and afterwards, egg cards were washed in running cold water to wash the eggs free of traces of formaldehyde. Later they were dried in shade.

3.2.2.12. Cold acid treatment

The acid treatment with HCl was done to break the diapause of bivoltine eggs. About 15-20 hours after oviposition the eggs were dipped in HCl, 1.108 specific gravity at 15°C (about 20% concentration) for fifty minutes. After that the eggs were washed 10-12 times in cold water.

3.2.2.13. Incubation

The eggs were incubated after the acid treatment at 80-85% relative humidity and 24-25°C temperature. Towards the end of incubation period at the blue spot or eye spot stage, the eggs were subjected to black boxing. The experiment was conducted in three seasons.

3.2.3. Observations recorded

3.2.3.1. Percentage of missing larvae during early instars

At the start of third instar, number of larvae were counted and the missing larvae from the time of brushing upto the start of third instar were counted out. From this percentage of loss in case of early instars was found out.

3.2.3.2. Larval duration

The feeding and moulting durations in case of each instar and the total larval duration was found out.

3.2.3.3. Leaf consumption

The total consumption of leaves by the larvae during third, fourth and fifth stadia was found out. Leaf consumption was expressed as g of leaves eaten by 100 larvae.

3.2.3.4. Weight and length of larva

The larvae were weighed and measured twelve hours before spinning. Mean weight expressed in grams and mean length in centimeters. Ten larvae were taken at random for study. Weight and length of the larva were recorded during the fifth stadium.

3.2.3.5. Growth index

Ten larvae of fifth instar were taken at random and mean growth index was recorded according to the following formula:

$$\text{Growth index} = \frac{\text{Weight of larva at particular age} - \text{Weight of larva at hatching}}{\text{Weight of larva at hatching}}$$

3.2.3.6. Pest and disease incidence

The number of larvae removed as a result of disease incidence, out of 200 larvae reared from the start of third instar was counted.

3.2.3.7. Number of cocoons

The total number of cocoons harvested from the 200 larvae reared from the start of third stadium was recorded, and count was taken at sixth day of spinning.

3.2.3.8. Yield of cocoons

The yield of cocoons harvested was expressed in grams.

3.2.3.9. Percentage of spinning

The percentage of cocoons spinned from the 200 larvae reared from the start of third stadium was recorded.

3.2.3.10. Size of cocoons

Size of cocoons was expressed as number of cocoons per litre.

3.2.3.11. Single cocoon weight

Ten cocoons were selected randomly and mean single cocoon weight was recorded.

3.2.3.12. Shell weight

The cocoons were cut after measuring the cocoon weight, pupae removed and the mean weight of the ten shells was expressed in grams.

3.2.3.13. Shell ratio

Mean shell ratio of ten cocoons were expressed in percentage according to the following formula (Krishnaswami et al., 1991a).

$$\text{Shell ratio} = \frac{\text{Weight of shell} \times 100}{\text{Weight of cocoon}}$$

3.2.3.14. Reelability

The cocoons obtained were reeled in the silk reeling machine attached to the reeling unit of National Sericulture Project of Central Silk Board at Palghat. The reeling test was conducted according to Krishnaswami et al. (1991a). One hundred cocoons were taken at random from a lot of reeling cocoons and they were air stifled. After the cocoons were first boiled in the Central Boiling Machine. Preliminary examination was carried out for irregular, deformed cocoons or cocoons with dead pupae inside. According to the standard method of cooking in use, the cocoons reached a satisfactory sunken stage in 11 minutes. The boiled cocoons were then passed on to the test reeling section. The equipment used was six ends automatic reeling machine. There were 3 meters mounted on the machine at appropriate places to record the length of reeled silk on a reel, number of droppings and number of cocoons at each end in the reeling platform of six ends. The reeling was continued until more than 90 cocoons were completely reeled. At the end of reeling, the unreeled cocoons in different stages: half reeled, more than 75 per cent reeled etc. were taken into consideration and equated to full unused cocoons after applying the correction factor as detailed below;

half reeled : 0.5, 75% reeled :0.25.

The reelability of the 100 cocoons was found out by applying the formula;

$$\text{Reelability (\%)} = \frac{\text{Reeled out cocoons} \times 100}{\text{Number of castings}}$$

3.2.3.15. Fecundity

Eggs laid by ten moths were counted after selfing. The fecundity was not found out in case of cross breeds, and four replications of pure races were maintained to find the fecundity. Mean fecundity was expressed as number of eggs per laying. The observation was conducted in moths which emerged during the first three days.

3.2.3.16. Female pupal weight

Female pupal weight of pure races was found at time of harvesting and mean value was expressed in grams. Four replications of ten pupae were used.

3.2.3.17. Weather parameters

Maximum temperature, minimum temperature, relative humidity and rainfall outside the rearing house on each day was observed in the meteorological observatory attached to the Department of Agronomy. The temperature and relative humidity inside the rearing house were recorded at the time of each feeding during the entire rearing period ie, from hatching till adult emergence.

3.2.3.18. Statistical analysis

Data relating to each parameter were analysed statistically. Pooled analysis were also conducted. Wherever error variances were found to be heterogeneous, the genotype x season interaction was tested by applying weighted analysis and if interaction was absent, data left unpooled. 'F' test was done by analysis of variance. Correlation coefficients of temperature and relative humidity with biological characters were worked out. Significant results were compared on the basis of critical differences (Panse and Sukhatme, 1989).

RESULTS

RESULTS

The bivoltine race NB_7 was heavily infected by diseases during the rearing of stock material and hence NB_7 and PM x NB_7 were excluded from further rearings and observations. The data on the observations of the remaining seven lines were statistically analysed and the results are given below.

4.1. Larval characters

4.1.1. Metamorphic characters of larvae

4.1.1.1. Percentage of missing larvae during early instars

The percentages of larvae missed during the first two instars in the three seasons were computed and the pooled data are presented in Table 1.

During first and second seasons percentage of missing larvae in Pure Mysore was on par with bivoltines and in the case of bivoltines, they were on par during three seasons reared. The cross breeds were also on par among themselves during these seasons and the percentage of missing larvae was significantly lesser than pure races.

Table 1. Percentage of missing larvae during early instars

	S_1			S_2			S_3			Mean		Pooled
	No. of larvae brushed	No. of larvae missed	Missing percentage	No. of larvae brushed	No. of larvae missed	Missing percentage	No. of larvae brushed	No. of larvae missed	Missing percentage	No. of larvae brushed	No. of larvae missed	Missing percentage
PM	537.00	120.23	22.39	537.33	117.13	21.80	489.67	61.68	12.60	521.33	99.68	18.92
NB_4D_2	522.33	135.28	25.90	675.33	148.57	22.00	581.33	120.91	20.80	592.99	134.92	22.90
KA	478.67	116.46	24.33	492.67	111.68	22.67	574.67	110.64	21.47	515.33	112.93	22.82
NB_{18}	479.33	128.46	26.80	459.33	98.61	21.47	580.33	109.21	21.57	506.33	112.09	23.28
PM x NB_4D_2	373.67	44.39	11.88	544.00	61.33	11.27	579.67	54.31	9.37	499.11	53.33	10.84
PM x KA	488.00	58.80	12.05	395	45.42	11.50	398.67	37.35	9.37	427.22	47.19	10.97
PM x NB_{18}	477.67	60.23	12.61	419	50.57	12.07	367.33	38.67	10.53	421.33	49.82	11.73
$F(6,14)S$ $F(6,12)P$			17.05**			72.14**			96.06**			13.89**
SE			1.657			0.654			0.600			1.597
CD (0.05)			5.025			1.956			1.820			4.923

** Significant at 0.01 level

The third season showed a different pattern. During this time, Pure Mysore lost 12.60% larvae which was significantly lesser than the three bivoltines.

The pooled data showed that all the pure races viz. Pure Mysore, NB_4D_2, KA and NB_{18} were on par in relation to missing larvae (18.92 to 23.28%). Cross breeds lost least number of larvae (10.84 to 11.73%) and were on par.

4.1.1.2. Larval duration

No statistical analysis was done where no difference in the data was observed.

4.1.1.2.1. First instar

The data showing the duration of first instar is presented in Table 2(a).

In first season all races and cross breeds had larval duration of 60 hours. In second season pure races recorded 60 hours while cross breeds recorded 55 hours only. During the third season duration of the pure races was longer and on par. The cross breeds were on par but with a significantly lower larval duration.

Table 2(a). Duration of first instar (hours)

	S_1	S_2	S_3	Mean
PM	60.00	60.00	66.33	62.11
NB_4D_2	60.00	60.00	66.33	62.11
KA	60.00	60.00	66.33	62.11
NB_{18}	60.00	60.00	67.00	62.33
PM x NB_4D_2	60.00	55.00	55.00	56.67
PM x KA	60.00	55.00	55.00	56.67
PM x NB_{18}	60.00	55.00	56.67	57.22
F(6,14)	^	^	58.90**	
SE	--	--	0.766	
CD(0.05)	--	--	2.325	

Table 2(b). Duration of first moulting (hours)

	S_1	S_2	S_3	Mean
PM	24.00	19.00	23.33	22.11
NB_4D_2	19.00	15.00	22.67	18.89
KA	24.00	17.67	22.67	21.47
NB_{18}	24.00	15.67	22.67	20.78
PM x NB_4D_2	24.00	20.00	22.67	22.22
PM x KA	24.00	20.00	24.00	22.67
PM x NB_{18}	24.00	20.00	24.00	22.67
F(6,14)	^	14.33**	0.45(NS)	
SE	--	0.563	0.943	
CD(0.05)	--	1.709	--	--

Table 2(c). Duration of second instar (hours)

	S_1	S_2	S_3	Mean
PM	60.00	56.33	67.33	61.22
NB_4D_2	84.00	51.00	69.67	68.22
KA	63.00	59.00	65.67	62.56
NB_{18}	63.00	59.00	65.67	62.57
PM x NB_4D_2	63.00	49.33	63.00	58.44
PM x KA	63.00	49.33	64.00	58.78
PM x NB_{18}	63.00	51.33	66.63	60.22
F(6,14)	^	5.22**	2.34(NS)	
SE	--	1.856	1.425	
CD(0.05)	--	5.630	--	

Table 2(d). Duration of second moulting (hours)

	S_1	S_2	S_3	Mean
PM	24.00	20.67	22.67	22.47
NB_4D_2	16.00	14.33	20.00	16.77
KA	16.00	14.33	18.00	16.11
NB_{18}	16.00	18.00	22.67	18.89
PM x NB_4D_2	24.00	14.67	22.67	20.47
PM x KA	24.00	14.67	22.67	20.47
PM x NB_{18}	24.00	16.33	22.67	21.00
F(6,14)	^	4.52**	1.63(NS)	
SE	--	1.134	1.475	
CD(0.05)	--	3.440	--	

** Significant at 0.01 level

^ No ANOVA

NS Not Significant

Table 2(e). Duration of third instar (hours)

	S_1	S_2	S_3	Mean
PM	72.00	112.00	112.00	98.67
NB_4D_2	72.00	81.00	100.00	84.33
KA	72.00	83.33	101.67	85.67
NB_{18}	72.00	82.33	104.33	86.22
PM x NB_4D_2	60.00	77.33	79.33	72.22
PM x KA	52.00	86.00	79.33	72.44
PM x NB_{18}	52.00	74.67	71.33	66.00
F(6,14)	^	18.81^{**}	26.57^{**}	
SE	--	2.856	3.021	
CD(0.05)		8.665	9.164	

Table 2(f). Duration of third moulting (hours)

	S_1	S_2	S_3	Mean
PM	36.00	33.67	25.33	32.33
NB_4D_2	24.00	19.00	22.67	21.89
KA	36.00	17.67	25.00	26.22
NB_{18}	36.00	19.00	26.00	27.00
PM x NB_4D_2	24.00	16.00	22.33	20.77
PM x KA	24.00	17.00	25.00	22.00
PM x NB_{18}	24.00	18.00	26.67	22.89
F(6,14)	^	33.01^{**}	1.46(NS)	
SE	--	1.062	1.579	
CD(0.05)	--	3.220	--	

Table 2(g). Duration of fourth instar (hours)

	S_1	S_2	S_3	Pooled
PM	134.00	169.33	135.33	142.89
NB_4D_2	94.00	136.67	101.67	110.78
KA	104.00	148.00	109.00	120.33
NB_{18}	101.00	146.33	104.00	116.78
PM x NB_4D_2	96.67	133.00	102.33	110.67
PM x KA	111.67	140.67	110.00	120.78
PM x NB_{18}	108.00	138.33	106.67	117.67
F(6,14)S F(6,12)P	20.33^{**}	8.71^{**}	21.97^{**}	19.68^{**}
SE	2.965	2.981	2.491	2.456
CD(0.05)	8.995	9.044	7.557	7.570

Table 2(h). Duration of fourth moulting (hours)

	S_1	S_2	S_3	Pooled
PM	36.00	49.00	35.67	40.22
NB_4D_2	36.00	45.67	32.67	38.11
KA	32.00	46.67	34.33	37.67
NB_{18}	31.00	48.00	34.33	37.78
PM x NB_4D_2	28.00	35.67	26.00	29.89
PM x KA	30.67	38.00	28.33	32.33
PM x NB_{18}	36.00	40.33	35.00	37.11
F(6,14)S F(6,12)P	1.86(NS)	8.66^{**}	5.38^{**}	6.76^{**}
SE	2.364	1.791	1.599	1.405
CD(0.05)	--	5.432	4.849	4.330

** Significant at 0.01 level NS Not Significant

^ No ANOVA

Table 2(i). Duration of fifth instar (hours)

	S_1	S_2	S_3	Mean
PM	254.00	248.67	269.33	257.33
NB_4D_2	200.00	216.33	201.33	205.89
KA	208.00	221.33	210.67	213.33
NB_{18}	214.00	224.00	212.00	216.67
PM x NB_4D_2	204.00	204.00	197.67	201.89
PM x KA	204.00	206.67	205.33	205.33
PM x NB_{18}	204.00	214.00	209.33	209.11
F(6,14)	154.42**	18.82**	107.47**	
SE	1.512	3.418	2.360	
CD(0.05)	4.586	10.369	7.160	

Table 2(j). Total larval duration (days)

	S_1	S_2	S_3	Mean
PM	29.17	31.61	31.64	30.81
NB_4D_2	25.20	26.62	26.54	26.12
KA	25.62	27.83	27.22	26.89
NB_{18}	25.71	27.97	27.44	27.04
PM x NB_4D_2	24.32	25.21	24.62	24.72
PM x KA	24.72	26.14	25.56	25.47
PM x NB_{18}	24.79	26.16	25.77	25.57
F(6,14)	276.26**	138.53**	139.53**	
SE	0.098	0.179	0.193	
CD(0.05)	0.298	0.544	0.585	

** Significant at 0.01 level

4.1.1.2.2. First moulting

The data showing the duration of first moulting is presented in Table 2(b).

The data of moulting duration of only second season was statistically different. During this season the three cross breeds were on par, and had longer duration than the bivoltines. KA recorded a longer duration than NB_4D_2 and NB_{18}, while it was on par with Pure Mysore which was also on par with cross breeds.

4.1.1.2.3. Second instar

The data showing the duration of second instar is presented in Table 2(c).

During the second season, Pure Mysore was on par with bivoltines and PM x NB_{18}, but recorded longer larval duration than others. NB_4D_2 was significantly shorter in duration than KA and NB_{18}, but was on par with cross breeds. KA and NB_{18} showed significantly longer duration than cross breeds. The cross breeds had no statistical difference among themselves. The third season showed no statistical difference.

4.1.1.2.4. Second moulting

The data representing the duration of second moulting is presented in Table 2(d).

During the moulting period of second experimental season, Pure Mysore recorded a duration of 20.67 hours which was significantly longer than NB_4D_2, KA, and cross breeds but was on par with NB_{18}. The stadial duration of NB_4D_2 and KA was significantly shorter than NB_{18}, while NB_{18} was on par with the cross breeds. The cross breeds did not show any statistical variation. The third season showed no significant difference.

4.1.1.2.5. Third instar

The data showing the duration of third stadium is presented in Table 2(e).

Second season recorded a statistical difference in stadial duration between pure races and cross breeds. Pure Mysore recorded the longest duration of 112 hours NB_4D_2, KA and NB_{18}, PM x NB_4D_2 and PM x NB_{18} were on par. PM x KA was significantly longer in duration than the other two cross breeds.

The third season also indicated that Pure Mysore had the longest larval duration than others except NB_{18}. Bivoltines were on par. Cross breeds were on par but had a significantly shorter duration than bivoltines.

4.1.1.2.6. Third moulting

The data showing the duration of third moulting is presented in Table 2(f).

In second season, Pure Mysore recorded a significantly longer moulting duration than others, while others were on par. No statistical difference during third season.

4.1.1.2.7. Fourth instar

The data of duration of fourth stadium during three seasons and pooled values are presented in Table 2(g).

During the three seasons Pure Mysore recorded longest stadial duration. During first season NB_4D_2 was on par with NB_{13} and PM x NB_4D_2, but was with a shorter duration than KA, PM x KA and PM x NB_{18}. KA was on par with NB_{18} and the three cross breeds. NB_{18} was on par with PM x NB_4D_2 and PM x NB_{18}, but was significantly shorter in duartion than PM x KA. PM x NB_4D_2 was significantly shorter in duration than PM x KA and PM x NB_{18}; PM x KA and PM x NB_{18} were on par.

During second season NB_4D_2 recorded significantly shorter duration than KA but was on par with NB_{18}, PM x NB_4D_2, PM x KA and PM x NB_{18}. KA was on par with NB_{18} and PM x KA but recorded a significantly longer duration than PM x NB_4D_2 and PM x NB_{18}. NB_{18} was significantly longer in stadial duration than PM x NB_4D_2, but was on par with other two cross breeds. The three cross breeds were on par.

During third season NB_4D_2 was on par with KA, NB_{18}, PM x NB_4D_2 and PM x NB_{18}, but was significantly shorter in duration than PM x KA. KA and NB_{18} were on par with the cross breeds. Among the cross breeds the PM x NB_4D_2 was significantly shorter than PM x KA, but was on par with PM x NB_{18}. PM x KA and PM x NB_{18} were on par.

The pooled data showed that Pure Mysore performed the longest larval duration of 142.89 hours. NB_4D_2 was on par with NB_{18}, PM x NB_4D_2, and PM x NB_{18}, but was significantly shorter in duration than than KA and PM x KA. KA was on par with NB_{18}, PM x KA and PM x NB_{18}, but recorded longer duration than PM x NB_4D_2. NB_{18} was on par with other cross breeds. PM x NB_4D_2 was significantly shorter in duration than PM x KA, but was on par with PM x NB_{18}. PM x KA and PM x NB_{18} were on par.

4.1.1.2.8. Fourth moulting

The data representing the duration of moulting in different seasons and their pooled values are presented in Table 2(h).

The first season rearing revealed no significant difference in moulting duration

During second and third seasons, Pure Mysore was on par with bivoltines, and bivoltines were on par with themselves in case of moulting duration. During second season, Pure Mysore recorded significantly longer moulting duration than cross breeds, and bivoltines also were significantly longer than cross breeds. NB_4D_2 performed with higher value than PM x NB_4D_2 and PM x KA but was on par with PM x NB_{18}. KA and NB_{18} were significantly longer in moulting duration than cross breeds. Cross breeds were on par.

The third season rearing indicated that Pure Mysore was on par with PM x NB_{18} but was significantly longer in moulting duration than PM x NB_4D_2 and PM x KA. NB_4D_2 was on par with PM x KA and PM x NB_{18}, but was significantly longer in duration than PM x NB_4D_2. KA and NB_{18} were significantly longer than PM x NB_4D_2 and PM x KA, but was on par with PM x NB_{18}. PM x NB_4D_2 and PM x KA were significantly shorter in value than PM x NB_{18}. But PM x NB_4D_2 and PM x KA were on par.

The pooled data showed that Pure Mysore had a moulting duration of 40.22 hours, which was on par with NB_4D_2, KA, NB_{18} and PM x NB_{18}, but was significantly longer than that of PM x NB_4D_2 and PM x KA. Bivoltines and PM x NB_{18} were on par but were significantly longer than that of PM x NB_4D_2 and PM x KA. PM x NB_4D_2 and PM x KA were on par.

4.1.1.2.9. Fifth instar

The data representing the duration of fifth instar are presented in the Table 2(i).

During the three seasons, Pure Mysore recorded the longest stadial duration. During first season, NB_4D_2 was shorter in duration than KA and NB_{18} but was on par with cross breeds. KA was on par with the three cross breeds, but was shorter than that of NB_{18}. NB_{18} showed longer duration than cross breeds. Cross breeds were on par.

During second season NB_4D_2 was on par with KA, NB_{18}, PM x KA and PM x NB_{18}, but was significantly longer in stadial duration than PM x NB_4D_2. KA, NB_{18} and PM x NB_{18} were on par, but KA and NB_{18} were longer in duration than PM x NB_4D_2 and PM x KA. Cross breeds were on par.

At the third rearing season NB_4D_2 was statistically shorter in duration than KA, NB_{18} and PM x NB_{18}, but was on par with PM x NB_4D_2 and PM x KA. KA and NB_{18} were on par. KA and NB_{18} had longer instar duration than PM x NB_4D_2, but were on par with

PM x KA and PM x NB_{18}. . PM x NB_4D_2 was statistically shorter in duration than all others except NB_4D_2. PM x KA was on par with PM x NB_{18}. and PM x KA but was statistically shorter than others. PM x KA was on par woth PM xNB_{18}.

4.1.1.2.10. Total larval duration

The data of total larval duration in different seasons is presented in Table 2(j).

Pure Mysore recorded a significantly longer duration of 29.17, 31.61 and 31.64 days during first, second and third seasons respectively, while PM x NB_4D_2 recorded the shorter duration of 24.32, 25.21 and 24.64 days respectively during these occassions.

During the three seasons, NB_4D_2 was shorter in larval duration than KA and NB_{18}; KA and NB_{18} were on par but were longer in duration than cross breeds, and PM x KA and PM x NB_{18} that were on par.

During first and third seasons, NB_4D_2 recorded longer larval duration than cross breeds. But during second season, NB_4D_2 recorded significantly longer larval duration than PM x NB_4D_2, but was on par with PM x KA and PM x NB_{18}.

4.1.2. Leaf consumption

The data of total leaf consumption of one hundred larvae from the start of third instar in three seasons are presented in Table 3.

During the first and third experimental seasons, Pure Mysore consumed the least food while NB_4D_2 consumed the maximum during the three seasons. During first seasons KA was higher in consumption than NB_{18}. Cross breeds recorded lesser consumption than bivoltines. PM x NB_4D_2 recorded higher value than other two cross breeds. PM x KA was higher in consumption than PM x NB_{18}.

During second season Pure Mysore was lesser in feeding than NB_4D_2, KA and PM x NB_4D_2 but was on par with PM x KA and PM x NB_{18}. KA was higher in consumption than NB_{18} and cross breeds. NB_{18} was on par with PM x NB_4D_2 but was higher than PM x KA and PM x NB_{18}. PM x NB_4D_2 recorded higher than the other two cross breeds, which in turn were on par between themselves.

During third season, KA was higher food consumer than NB_{18} and cross breeds. NB_{18} was also higher in food consumption than cross breeds. PM x NB_4D_2 was on par with

Table 3. Leaf consumption (g/100 larvae)

	S_1	S_2	S_3	Mean
PM	903.47	882.19	930.30	905.32
NB_4D_2	1573.53	1411.40	1871.05	1618.67
KA	1454.33	1271.77	1736.70	1487.6
NB_{18}	1247.07	1123.43	1582.47	1317.66
PM x NB_4D_2	1178.70	1090.99	1419.33	1229.67
PM x KA	1048.90	951.22	1357.90	1119.34
PM x NB_{18}	995.07	913.18	1312.50	1073.85
F(6,14)	419.58**	36.33**	99.28**	
SE	11.952	31.067	32.544	
CD(0.05)	36.257	98.721	94.241	

** Significant at 0.01 level

PM x KA but recorded higher feeding rate than PM x NB_{18}. PM x KA and PM x NB_{18} were on par.

4.1.3. Weight of larva

The data representing the weight of fifth instar larva during three seasons and their pooled values are presented in Table 4.

During the three seasons, Pure Mysore recorded the lowest larval weight (1.40, 1.21 and 1.44g respectively). In case of first experimental season, NB_4D_2 was on par with KA and NB_{18}, but was significantly heavier than cross breeds. KA was also on par with NB_{18}, but was significantly higher in larval weight than the cross breeds. NB_{18} also exhibited a similar performance towards the cross breeds. PM x NB_4D_2 was on par with PM x KA, but was statistically heavier than PM x NB_{18}. PM x KA and PM x NB_{18} were on par.

At the second season NB_4D_2 (2.87g) was significantly higher in larval weight than others. KA was on par with NB_{18}, but recorded significantly higher value than the cross breeds, NB_{18} was superior to the cross breeds. The three cross breeds were on par.

Table 4. Weight of fifth instar larva (g)

	S_1	S_2	S_3	Pooled
PM	1.40	1.21	1.44	1.35
NB_4D_2	3.33	2.87	4.17	3.46
KA	3.30	2.74	4.05	3.36
NB_{18}	3.27	2.66	3.81	3.25
PM x NB_4D_2	3.04	2.49	3.74	3.09
PM x KA	2.96	2.42	3.34	2.90
PM x NB_{18}	2.93	2.40	3.32	2.89
F(6,14)S F(6,12)P	479.41**	174.17**	2917.34**	37.69**
SE	0.031	0.042	0.017	0.117
CD(0.05)	0.094	0.126	0.052	0.360

** Significant at 0.01 level

In case of third season also NB_4D_2 (4.17 g) recorded superior value than others. KA was also heavier than NB_{18} and the cross breeds. NB_{18} performed with higher larval weight than the cross breeds. Among the cross breeds, PM x NB_4D_2 was significantly heavier than PM x KA and PM x NB_{18}, but PM x KA and PM x NB_{18} were on par.

The pooled data showed that Pure Mysore recorded the lowest larval weight of 1.35g, NB_4D_2 was on par with KA and NB_{18} but was heavier than cross breeds. KA was on par with PM x NB_4D_2 but was heavier than other two cross breeds. NB_{18} was on par with the cross breeds. The three cross breeds were on par.

4.1.4. Length of larva

The data representing the length of fifth instar larva during the three seasonsand the pooled values are given in Table 5.

Pure Mysore recorded a shortest length of 4.27, 3.93 and 4.27cm during the first, second and third seasons respectively. During first time NB_4D_2 (5.47 cm) was

Table 5. Length of fifth instar larva (cm)

	S_1	S_2	S_3	Pooled
PM	4.27	3.93	4.27	4.16
NB_4D_2	5.47	5.27	6.23	5.66
KA	5.33	5.07	6.13	5.51
NB_{18}	5.27	4.97	6.10	5.44
PM x NB_4D_2	5.03	4.70	6.03	5.26
PM x KA	5.00	4.67	5.90	5.19
PM x NB_{18}	4.97	4.63	5.83	5.14
F(6,14)S F(6,12)P	161.81**	128.89**	367.96**	19.49**
SE	0.031	0.038	0.036	0.115
CD(0.05)	0.094	0.115	0.108	0.344

** Significant at 0.01 level.

significantly longer than others. KA was longer than cross breeds. NB_{18} was also longer than cross breeds. KA and NB_{18} were on par. The cross breeds were on par.

In case of second season, NB_4D_2 (5.27cm) was longer than KA, NB_{18}, PM x NB_4D_2, PM x KA and PM x NB_{18}. KA was on par with NB_{18} but was longer than cross breeds. NB_{18} was also significantly longer than cross breeds. The three cross breeds were on par.

The third season showed that NB_4D_2 was on par with KA, but was significantly longer than NB_{18} and cross breeds KA and NB_{18} were on par with PM x NB_4D_2 but were longer than PM x KA and PM x NB_{18}. PM x NB_4D_2 was longer than other two cross breeds; PM x KA and PM x NB_{18} were on par.

The pooled data showed that Pure Mysore recorded a significantly lower length of 4.16 cm. NB_4D_2 was on par with KA and NB_{18}, but was significantly longer than cross breeds. KA was on par with NB_{18}, PM x NB_4D_2, and PM x KA, but was significantly longer than PM x NB_{18}. NB_{18} and the three cross breeds were on par.

4.1.5. Growth index (GI)

The data showing growth index of fifth instar larva during three seasons and the pooled values are presented in Table 6.

The three seasons revealed that Pure Mysore got a significantly lower GI than others. During first season NB_4D_2 was on par with KA and NB_{18}, but was significantly higher in the value than cross breeds. But KA and NB_{18} were on par with PM x NB_4D_2, PM x KA and PM x NB_{18}.

The second season showed that NB_4D_2 was significantly higher in GI than others. KA and NB_{18} were on par, but both of them were significantly higher in the value than cross breeds. Cross breeds were on par.

The third season also showed that NB_4D_2 was on par with KA, but was significantly higher in GI than NB_{18} and cross breeds. KA was on par with NB_{18} but was higher than cross breeds. NB_{18} was also different from cross breeds. PM x NB_4D_2 was higher than PM x KA and PM x NB_{18}. PM x KA and PM x NB_{18} were on par.

Table 6. Growth index of fifth instar larva

	S_1	S_2	S_3	Pooled
PM	3154.01	2649.60	3435.44	3079.68
NB_4D_2	6241.72	5807.59	7227.76	6425.69
KA	6049.32	5528.47	7139.44	6239.08
NB_{18}	6015.53	5534.65	7037.13	6195.77
PM x NB_4D_2	5970.10	5330.62	6555.15	5951.96
PM x KA	5909.91	5253.61	6247.93	5803.82
PM x NB_{18}	5848.18	5181.95	6238.34	5756.16
F(6,14)S F(6,12)P	204.56**	409.67**	723.67**	107.30**
SE	75.864	53.123	48.911	111.320
CD(0.05)	230.134	161.149	148.374	343.043

** Significant at 0.01 level

Pooled data showed that Pure Mysore recorded the lowest GI. NB_4D_2 was on par with KA and NB_{18} but recorded significantly higher value than cross breeds. KA and NB_{18} were on par with PM x NB_4D_2, but both were significantly higher than PM x KA and PM x NB_{18}. Cross breeds were on par.

4.1.6. Number of diseased larvae

Pebrine, a protozoan disease (CO: Nosema bombycis), flacherie, a bacterial disease (COs: Streptcoccus bombycis and S. pastorianus), grasserie, a virus disease (CO: Borrelina virus) were recorded during the experimental seasons and the total number of diseased larvae out of two hundred larvae reared from the start of third instar was counted. The data showing the number of diseased larvae in three seasons and their pooled values are presented in Table 7.

During the first season, the number of diseased larvae in Pure Mysore was on par with NB_4D_2, PM x KA and PM x NB_{18}; significantly lower than KA and NB_{18}, but was significantly higher than PM x NB_4D_2. NB_4D_2 was on par with

Table 7. Number of diseased larvae

	S_1	S_2	S_3	Pooled	Percentage
PM	61.06 (7.88)	119.28 (10.97)	62.32 (7.96)	78.74 (8.93)	39.37
NB_4D_2	80.64 (9.04)	131.95 (11.53)	75.58 (8.75)	94.45 (9.77)	47.22
KA	100.59 (10.08)	151.98 (12.37)	101.31 (10.11)	116.72 (10.85)	58.36
NB_{18}	102.60 (10.18)	155.99 (12.53)	107.28 (10.41)	120.88 (11.04)	60.44
PM x NB_4D_2	18.71 (4.44)	74.66 (8.70)	18.29 (4.39)	33.11 (5.85)	16.55
PM x KA	65.35 (8.15)	110.28 (10.55)	45.00 (6.78)	71.25 (8.50)	35.62
PM x NB_{18}	50.16 (7.15)	99.28 (10.01)	41.78 (6.54)	61.41 (7.90)	30.70
F(6,14)S F(6,12)P	21.38**	100.94**	36.03**	41.22**	
SE	0.427	0.134	0.355	0.282	
CD(0.05)	1.296	0.408	1.078	0.868	

** Significant at 0.01 level

Figures in parentheses are $\sqrt{x+1}$ transformation

KA and NB_{18}. NB_4D_2 recorded higher number than PM x NB_4D_2 and PM x NB_{18}, but was on par with PM x KA.

During the three seasons, KA and NB_{18} were on par in larval mortality and were significantly higher than the cross breeds. PM x NB_4D_2 recorded a lesser value than other two cross breeds. But PM x KA and PM x NB_{18} were on par during first and third season only.

During second season disease infestation in Pure Mysore was significantly lesser than that of bivoltines but was higher than cross breeds. NB_4D_2 recorded lower value than KA and NB_{18}, but was higher than cross breeds. PM x KA recorded higher number than PM x NB_{18}.

Pure Mysore performed with a larval mortality which was on par with NB_4D_2, significantly lower than KA and NB_{18}, but was significantly higher than cross breeds. NB_4D_2 performed like the multivoltine.

The pooled data revealed that Pure Mysore was on par with NB_4D_2 and PM x KA in respect of the disease infestation, but it was significantly lower than KA and NB_{18}.

NB_4D_2 was lower than KA and NB_{18}, but was higher than the cross breeds. KA and NB_{18} were on par and both recorded higher value than the cross breeds. PM x NB_4D_2 was significantly lower than PM x KA and PM x NB_{18}, but the latter two were on par.

4.2. Cocoon characters

4.2.1. Number of cocoons

The data relating to the number of cocoons harvested out of two hundred larvae reared from the start of third instar in three seasons are presented in Table 8(a).

The data of the first season indicated that, in respect of number of cocoons harvested, Pure Mysore was higher than KA and NB_{18}, lesser than PM x NB_4D_2, but was on par with NB_4D_2, PM x KA and PM x NB_{18}. NB_4D_2 was significantly higher than NB_{18} and was lower than PM x NB_4D_2 and PM x NB_{18}, but was on par with KA and PM x KA. PM x KA and PM x NB_{18} were on par.

During the three seasons, KA and NB_{18} were on par and recorded a significantly lower number of cocoons, PM x NB_4D_2 recorded a significantly higher number of cocoons than others, with 181.00, 122.00 and 181.33 cocoons during first, second and third rearing respectively.

Table 8(a). Number of cocoons harvested

	S_1	S_2	S_3	Mean
PM	138.67	80.72	137.67	119.02
NB_4D_2	119.00	68.00	124.33	103.77
KA	99.33	48.00	98.64	81.99
NB_{18}	97.33	44.00	92.67	78.00
PM x NB_4D_2	181.00	122.00	181.33	161.43
PM x KA	134.33	89.67	154.33	126.11
PM x NB_{18}	148.67	100.67	157.67	135.67
F(6,14)	19.90**	90.76**	45.21**	
SE	6.574	2.957	4.716	
CD(0.05)	19.943	8.971	14.305	

Table 8(b). Yield of cocoons (g) harvested

	S_1	S_2	S_3	Mean
PM	114.00	60.00	119.33	97.78
NB_4D_2	139.33	76.67	143.67	119.56
KA	124.67	57.33	133.33	105.11
NB_{18}	120.00	63.33	109.67	96.33
PM x NB_4D_2	236.33	141.33	270.67	216.11
PM x KA	177.33	100.67	209.00	162.33
PM x NB_{18}	183.33	105.00	218.33	168.87
F(6,14)	25.14**	160.87**	73.32**	
SE	8.844	2.551	7.010	
CD(0.05)	26.829	7.739	21.265	

Table 8(c). Percentage of spinning

	S_1	S_2	S_3	Pooled
PM	69.33 (56.42)	40.33 (39.42)	68.83 (56.06)	59.76 (50.63)
NB_4D_2	59.50 (50.47)	34.00 (35.67)	62.17 (52.04)	51.84 (46.06)
KA	49.67 (44.81)	24.00 (29.33)	49.17 (44.52)	40.55 (39.55)
NB_{18}	48.67 (44.24)	28.67 (32.37)	46.33 (42.89)	40.83 (39.72)
PM x NB_4D_2	90.50 (72.05)	61.00 (51.35)	90.67 (72.21)	82.54 (65.31)
PM x KA	67.17 (55.04)	44.83 (42.03)	77.17 (61.44)	63.64 (52.99)
PM x NB_{18}	74.33 (59.56)	50.33 (45.19)	78.83 (62.16)	68.54 (55.88)
F(6,14)S F(6,12)P	17.65**	15.36**	38.07**	13.278**
SE	2.277	1.957	1.703	2.516
CD(0.05)	6.906	5.936	5.167	7.754

Table 8(d). Size of cocoons (Number/litre)

	S_1	S_2	S_3	Pooled
PM	297.00	312.00	288.00	299.00
NB_4D_2	104.00	110.00	98.33	104.11
KA	109.00	114.00	104.00	109.00
NB_{18}	111.00	114.00	106.00	110.33
PM x NB_4D_2	124.00	130.00	119.00	124.33
PM x KA	127.00	132.00	122.00	127.00
PM x NB_{18}	128.00	134.00	123.00	128.33
F(6,14)S F(6,12)P	457.89**	901.21**	500.81**	1905.73**
SE	3.207	2.441	3.002	1.589
CD(0.05)	9.729	7.312	9.108	4.896

** Significant at 0.01 level

Figures in parantheses are angular transformation

Table 8(e). Single cocoon weight (g)

	S_1	S_2	S_3	Pooled
PM	0.85	0.75	0.83	0.81
NB_4D_2	1.51	1.47	1.47	1.48
KA	1.60	1.54	1.52	1.55
NB_{18}	1.49	1.41	1.46	1.45
PM x NB_4D_2	1.36	1.31	1.45	1.37
PM x KA	1.47	1.39	1.51	1.46
PM x NB_{18}	1.35	1.30	1.44	1.36
F(6,14)S F(6,12)P	30.70**	715.90**	977.06**	47.34**
SE	0.044	0.010	0.008	0.036
CD(0.05)	0.135	0.030	0.024	0.111

Table 8(f). Shell weight (g)

	S_1	S_2	S_3	Pooled
PM	0.11	0.10	0.11	0.10
NB_4D_2	0.27	0.26	0.27	0.27
KA	0.26	0.25	0.27	0.26
NB_{18}	0.24	0.23	0.25	0.24
PM x NB_4D_2	0.22	0.21	0.25	0.23
PM x KA	0.21	0.20	0.24	0.21
PM x NB_{18}	0.20	0.20	0.24	0.21
F(6,14)S F(6,12)P	37.89**	638.19**	910.93*	53.49**
SE	0.009	0.002	0.002	0.007
CD(0.05)	0.027	0.007	0.006	0.023

Table 8(g) Shell ratio (percentage)

	S_1	S_2	S_3	Mean
PM	12.94	13.33	13.25	13.17
NB_4D_2	17.88	17.69	18.37	17.98
KA	16.25	16.23	17.76	16.75
NB_{18}	16.11	16.31	17.12	16.51
PM x NB_4D_2	16.18	16.03	17.24	16.48
PM x KA	14.28	14.39	15.89	14.85
PM x NB_{18}	14.81	15.38	16.67	15.62
F(6,14)S F(6,12)P	14.73**	60.16**	170.50**	
SE	0.419	0.183	0.128	
CD(0.05)	1.273	0.556	0.390	

Table 8(h). Reelability (percentage)

	S_1	S_2	S_3	Pooled
PM	39.51	43.36	42.33	41.73
NB_4D_2	58.65	64.77	73.94	65.79
KA	59.91	62.61	71.31	64.61
NB_{18}	55.58	60.16	67.10	60.95
PM x NB_4D_2	52.01	53.04	50.03	51.69
PM x KA	50.08	50.16	49.96	50.07
PM x NB_{18}	48.47	47.09	46.77	47.44
F(6,14)S F(6,12)P	9.72**	9.16**	32.08*	8.16**
SE	2.166	2.584	2.235	3.230
CD(0.05)	6.630	7.840	6.781	9.956

** Significant at 0.01 level

Second season showed that Pure Mysore recorded higher number of cocoons than bivoltines, and was lesser than PM x NB_4D_2 and PM x NB_{18}, but was on par with PM x KA. NB_4D_2 recorded a significantly higher number of cocoons than KA and NB_{18}, but recorded a lesser number than cross breeds. PM x KA recorded significantly lower number of cocoons than PM x NB_4D_2 and PM x NB_{18}.

It is evident from the table that during third season, the number of cocoons of Pure Mysore was significantly higher than those of KA and NB_{18}, but recorded lesser than those of cross breeds and was on par with NB_4D_2. NB_4D_2 was significantly higher than KA and NB_{18}, but was significantly lesser than cross breeds. But PM x KA and PM x NB_{18} were on par.

4.2.2. Yield of cocoons

The data representing the yield of cocoons (g) in three seasons out of two hundred larvae reared at start of third instar are presented in Table 8(b).

The first season showed that in case of yield of cocons, Pure Mysore was on par with the bivoltines, but was lesser than cross breads. Biovoltines were also lesser than cross breeds.

During first, second and third seasons, PM x NB_4D_2 performed with significantly higher yield of 236.33, 141.33 and 270.67 g respectively, but PM x KA and PM x NB_{18} were on par.

Pure Mysore was on par in yield with KA and NB_{18}, but was lower than others during the second season, Value of NB_4D_2 was higher than KA and NB_{18}; KA and NB_{18} were on par, and the three bivoltine were significantly lower than cross breeds.

During the third season also Pure Mysore was significantly lower in yield than NB_4D_2 and cross broads, but was on par with KA and NB_{18}. NB_4D_2 was on par with KA and was lower in yield than cross breeds but was higher than NB_{18}. KA was higher in value than NB_{18}, but was lower than cross breeds. NB_{18} was also lower than cross breeds.

4.2.3. Percentage of spinning

The data showing the percentage of spinning of cocoons out of two hundred larvae reared from the start of third instar during the three seasons and the pooled values are presented in Table 8(c).

In case of Pure Mysore it was on par in spinning percentage with NB_4D_2, PM x KA, and PM x NB_{18}, but was higher than KA and NB_{18}, and was lesser than PM x NB_4D_2, during the first and second seasons.

In the first season rearing NB_4D_2 was significantly lower in spinning percentage than PM x NB_4D_2 and PM x NB_{18}, but was on par with others.

KA and NB_{18} were on par in the values but was lesser than cross breeds during the three seasons.

PM x NB_4D_2 recorded the highest percentage of 72.05, 61.00, and 90.67 during the first, second and third seasons respectively, while PM x KA and PM x NB_{18} were on par.

The value of NB_4D_2 was higher than KA, but was lesser than cross breeds and was on par with NB_{18} during the second season.

At the third rearing time Pure Mysore was on par with spinning percentage with NB_4D_2, higher than KA and NB_{18}, but was lower than cross breeds. NB_4D_2 was higher in the value than KA and NB_{18}, but was lower than cross breeds.

The pooled values also showed that Pure Mysore was on par in spinning percentage with NB_4D_2, PM x KA and PM x NB_{18}, higher than that of KA and NB_{18}, but was lesser than that of PM x NB_4D_2. Value of NB_4D_2 was on par with KA, NB_{18}, and PM x KA, but was lesser than PM x NB_4D_2 and PM x NB_{18}. Values of KA and NB_{18} were on par with each other, and was lesser than cross breeds. PM x NB_4D_2 (82.54 percentage) recorded the highest value. PM x KA and PM x NB_{18} were on par.

4.2.4. Size of cocoons

The values represening the size pf cocoons (number per litre) during the three seasons and the pooled values are presented in Table 8(d).

The rearing during the three seasons indicated that Pure Mysore had the lowest size of cocoons. The three bivoltines were on par, and recorded the highest size. PM x NB_4D_2, PM x KA and PM x NB_{18} were on par and recorded lesser size than bivoltines.

The pooled data showed that Pure Mysore had the least size. NB_4D_2 was on par in size with KA but was higher than NB_{18} and cross breeds. Cross breeds were on par, but had a significantly lesser size than bivoltines.

4.2.5. Single cocoon weight

The single cocoon weight (g) in three seasons and the pooled values are presented in Table 8(e).

Pure Mysore recorded a significantly lower single cocoon weight during the three rearing seasons. During first season value of NB_4D_2 was on par with KA, NB_{18} and PM x KA, but was significantly higher than PM x NB_4D_2 and PM x NB_{18}. KA recorded the weight of 1.60 g which was on par with NB_{18}, PM x KA, but was significantly higher than PM x NB_4D_2, and PM x NB_{18}. NB_{18} was on par in the value with PM x NB_4D_2

and PM x KA, but was significantly higher than PM x NB_{18}. The three cross breeds were on par.

The second season study revealed that NB_4D_2 was significantly lesser in single cocoon weight than KA but was significantly higher than NB_{18} and the three cross breeds. KA recorded the highest single cocoon weight NB_{18} was significantly higher than PM x NB_4D_2 and PM x NB_{18}, but on par with PM x KA. PM x KA was higher than PM x NB_{18}.

The value of third rearing showed that NB_4D_2 was on par in single cocoon weight with NB_{18} and PM x NB_4D_2, and was significantly higher than PM x NB_{18}, but was significantly lower than KA and PM x KA. KA was on par with PM x KA, but was significantly higher than others. NB_{18} was on par with PM x NB_4D_2 and PM x NB_{18}. PM x NB_4D_2 and PM x NB_{18} were on par and they were was significantly lower than PM x KA.

The pooled data showed that Pure Mysore had the least single cocoon weight. Others were significantly higher than it. NB_4D_2 was on par with KA, NB_{18}, PM x NB_4D_2 and PM x KA, but was higher than PM x NB_{18}. KA was on par with NB_{18}, PM x KA, but was higher in value than PM x NB_4D_2 and PM x NB_{18}. NB_{18} was on par with cross breeds. Cross breeds were on par NB_{18}.

4.2.6. Shell weight

The data representing the shell weight (g) in three seasons and their pooled values are presented in Table 8(f).

A significantly lower shell weight was observed by Pure Mysore during the three experimental seasons, and PM x KA and PM x NB_{18} were on par. In case of first season value of NB_4D_2 was on par with KA, but was significantly higher than others. KA was on par with NB_{18}, but was significantly higher in value than cross breeds. NB_{18} was on par with PM x NB_4D_2, but was higher than PM x KA and PM x NB_{18}. PM x NB_4D_2 was on par with other two cross breeds.

NB_4D_2 recorded a significantly higher value than others, during the second season. KA performed better than NB_{18} cross breeds, and NB_{18} was also higher in shell weight than cross breeds PM x NB_4D_2 was higher than PM x KA and PM x NB_{18}.

Third rearing also indicated that NB_4D_2 and KA recorded the same weight (0.27g). This was significantly higher than NB_{18} and cross breeds. NB_{18} and PM x NB_4D_2 were on par. They were higher than PM x KA and PM x NB_{18}.

The pooled data showed that Pure Mysore recorded a shell weight of 0.10 g, which was significantly lower than those of others. NB_4D_2 was on par with KA, but was higher than others KA and NB_{18} were on par but they were higher than cross breeds. NB_{18} was on par with PM x NB_4D_2 and but was higher than PM x KA and PM x NB_{18}. The cross breeds were on par.

4.2.7. **Shell ratio**

The data representing the shell ratio (as percentage) is three seasons are presented in Table 8(g).

Pure Mysore reocorded the lowest values of 12.94, 13.33 and 13.33 percentage during the first, second and third seasons respectively, while NB_4D_2 recorded the highest values of 17.88, 17.69, and 18.37 percentage respectively during these occassions.

During first season KA was on par with NB_{18} and PM x NB_4D_2, but both were higher in shell ratio than PM x KA and PM x NB_{18}. NB_{18} was on par with PM x NB_4D_2, but was higher than PM x KA and PM x NB_{18}.

During the three seasons PM x NB_4D_2 was significantly higher in shell ratio than PM x KA and PM x NB_{18}.

The values of PM x KA and PM x NB_{18} were on par during first season.

KA and NB_{18} performed similarly like the first season during the second season also, and PM x KA was lower than PM x NB_{18}.

During the third time, value of KA was higher than NB_{18} and cross breeds. NB_{18} was on par with PM x NB_4D_2, but was higher than PM x KA on PM x NB_{18}. PM x KA was lower than PM x NB_{18}

4.2.8. Reelability

Table 8(h) represents the reelability (percentage) of cocoons in three seasons and their pooled values.

During the first season, Pure Mysore recorded a reelability of 39.51% which was significantly lower than others. Value of NB_4D_2 was on par with KA, and NB_{18}, but was higher than cross breeds. KA was on par with NB_{18}; but was significantly higher than cross breeds. NB_{18} was on par with PM x NB_4D_2, and PM x KA, but was higher than PM x NB_{18}.

The values of three cross breeds were on par during the three seasons.

During second season, reelability of Pure Mysore was on par with PM x KA and PM x NB_{18}, but was significantly lower than others. NB_4D_2 was on par with KA and NB_{18}, but was higher than others. KA was on par with NB_{18}, but was higher than cross breeds. The value of NB_{18} was on par with PM x NB_4D_2, but was hitgher than PM x KA and PM x NB_{18}.

Third season showed that the reelability of Pure Mysore was on par with PM x NB_{18}, but was lower than others. NB_4D_2 was on par with KA, but was higher than others. KA and NB_{18} were on par, and they were higher than cross breeds.

The pooled data showed that the reelability percentage of Pure Mysore was on par with PM x KA and PM x NB_{18} , but was significantly lower than others. NB_4D_2 was on par with KA and NB_{18}; but was significantly higher than cross breeds. KA was on par with NB_{18} and was higher than cross breeds. NB_{18} was on par with PM x NB_4D_2; but was higher than PM x KA and PM x NB_{18}. The three cross breeds were on par.

4.3. Adult characters

4.3.1. Fecundity

The data on the fecundities of moths in three seasons and their pooled values are presented in table 9(a).

During the three season, Pure Mysore reorded the lowest fecundity and NB_4D_2 was higher than it but was lower than KA and NB_{18} During first time KA recorded the highest fecundity than the other three pure races.

At the second and third experimental seasons, KA was on par with NB_{18} in respect of fecundity.

Table 9(a). Fecundity (no. of eggs/moth)

	S_1	S_2	S_3	Pooled
PM	403.00	399.00	403.00	401.67
NB_4D_2	465.00	448.00	469.00	460.67
KA	502.00	487.00	510.00	499.67
NB_{18}	493.00	480.00	499.00	490.67
F(3,12)S F(3,6)P	240.99**	241.24**	136.90**	70.32**
SE	2.879	2.582	4.107	5.278
CD(0.05)	8.873	7.956	12.659	18.265

Table 9(b). Female pupal weight (g)

	S_1	S_2	S_3	Pooled
PM	0.70	0.65	0.70	0.68
NB_4D_2	1.23	1.19	1.23	1.22
KA	1.35	1.29	1.36	1.33
NB_{18}	1.29	1.24	1.30	1.28
F(3,12)S F(3,6)P	121.30**	606.72**	141.07**	245.10**
SE	0.027	0.012	0.025	0.019
CD(0.05)	0.083	0.037	0.078	0.067

** Significant at 0.01 level

The pooled data showed that Pure Mysore was statistically lesser in fecundity than others. The value of NB_4D_2 was higher than Pure Mysore, but was lower than KA and NB_{18}. KA was on par with NB_{18}.

4.3.2. Female pupal weight

The data on the female pupal weight of pure races in three seasons and their pooled values are presented in Table 9(b).

During the three seasons, Pure Mysore had a significantly lower female pupal weight. During first season NB_4D_2 was on par with NB_{18}, but was significantly lower than that of KA, and KA and NB_{18} were on par.

During second seaso NB_4D_2 reconded significantly lower value than KA and NB_{18}. KA recorded highest weight. At the time of third rearing NB_4D_2 was on par with NB_{18}, but was lower than KA. KA and NB_{18} were on par.

Pooled values indicated the lowest female pupal weight for Pure Mysore. NB_4D_2 was on par with NB_{18} and was significantly lower than KA. But KA and NB_{18} were on par.

4.4. Correlation studies

Correlation studies were conducted between the weather parameters viz., temperature, and relative humidity (Appendices I II and III) with the various biological characters of the different races and cross breeds of silkworm.

4.4.1. Temperature

Results of correlation studies of temperature with biological parameters are presented in Table 10.

Temperature had no significant influence on the missing percentage of larvae during the early instars, total larval duration, and reelability.

In the case of duration of first instar and single cocoon weight, temperature in fact, showed a significant negative correlation in the three cross breeds but no significant influence on pure races. The duration of first moulting and shell weight had a significant negative correlation with all lines except with NB_4D_2. In the case of

Table 10. **Values of simple correlation coefficients of temperature with biological characters**

Temperature (ºC)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
S_1	28.12	28.00	27.87	28.04	28.75	28.72	28.75	28.66	29.10	28.90	28.65	28.65	28.90	28.90	28.90	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.72	28.60	28.60
S_2	29.50	29.50	29.75	29.75	29.75	30.15	30.18	29.20	30.78	30.50	29.95	29.95	30.50	30.50	30.50	29.95	29.95	29.95	29.95	29.95	29.95	29.95	29.95	30.40	30.15	30.15
S_3	28.06	28.66	28.50	27.99	26.75	26.81	27.75	27.15	26.05	28.08	27.65	27.65	28.08	28.08	28.08	27.65	27.65	27.65	27.65	27.65	27.65	27.65	27.65	28.91	27.98	27.98
Correlation coefficients																										
PM	0.62	-0.06	-0.94**	-0.70*	-0.07	-0.08	0.53	0.60	0.74*	-0.79*	0.06	-0.64	-0.75**	-0.90**	-0.97**	0.98**	-0.67*	-0.87**	-0.92**	0.84**	-0.54	-0.85**	0.20	0.38	-0.29	-0.35
NB_4D_2	-0.07	-0.06	-0.66	-0.78*	-0.73*	-0.71*	-0.68*	0.56	0.85**	0.79*	0.12	-0.91**	-0.94**	-0.87**	-0.91**	0.97**	-0.80**	-0.89**	-0.91**	0.74*	-0.05	-0.29	-0.40	-0.01	-0.83**	-0.67*
KA	0.01	-0.06	-0.86**	-0.78*	-0.74*	-0.67*	-0.48	0.61	0.59	0.73*	0.33	-0.95**	-0.96**	-0.89**	-0.92**	0.98**	-0.80**	-0.90**	-0.92**	0.93**	0.19	-0.72*	-0.71*	-0.16	-0.89**	-0.69*
NB_{18}	-0.11	-0.06	-0.93**	-0.78*	-0.85**	-0.71*	-0.49	0.65	0.62	0.81**	0.29	-0.93**	-0.98**	-0.90**	-0.91**	0.99**	-0.81**	-0.85**	-0.80**	0.73*	-0.52	-0.72*	-0.50	-0.01	-0.80**	-0.71*
PM x NB_4D_2	0.11	-0.82**	-0.83**	-0.97*	-0.35	-0.19	-0.75*	0.60	0.64	0.51	0.61	-0.90**	-0.97**	-0.89**	-0.98**	0.97**	-0.77**	-0.90**	-0.96**	0.79*	-0.80**	-0.89**	-0.73*	0.20		
PM x KA	0.12	-0.82**	-0.94**	-0.97**	-0.35	0.07	-0.90**	0.73*	0.78*	0.19	0.46	-0.90**	-0.99**	-0.90**	-0.98**	0.96**	-0.70*	-0.94**	-0.97**	0.78*	-0.84**	-0.90**	-0.67*	0.02		
PM x NB_{18}	0.15	-0.80**	-0.94**	-0.95**	-0.33	0.02	-0.83**	0.73*	0.76*	0.52	0.35	-0.89**	-0.99**	-0.91**	-0.73*	0.96**	-0.71*	-0.87**	-0.93**	0.75**	-0.84**	-0.88**	-0.57	-0.12		

* Significant at 0.05 level ** Significant at 0.01 level

1. % of early loss of larvae
2. Duration of first instar
3. Duration of first moulting
4. Duration of second instar
5. Duration of second moulting
6. Duration of third instar
7. Duration of third moulting
8. Duration o fourth instar
9. Duration of fourth moulting
10. Duration of fifth instar
11. Total larval duration
12. Leaf consumption
13. Weight of larvae
14. Length of larvae
15. Growth index
16. No. of diseased larvae
17. Percentage of spinning
18. No.of cocoons
19. Yield of cocoons
20. Size of cocoons
21. Single cocoon weight
22. Shell weight
23. Shell ratio
24. Reelability
25. Fecundity
26. Female pupal weight

NB_4D_2, no significant variation was observed. Duration of second instar, weight and growth index of larva during fifth instar, length of fifth instar larva percentage of spinning, number and yield of cocoons harvested were correlated negatively and significantly in all races and cross breeds.

The second moulting duration and duration of third instar showed a significant negative correlation in bivoltines, but no significant variation observed in others. Fecundity and female pupal weight were also showed a similar trend ie, no influence on Pure Mysore.

NB_4D_2, PM x NB_4D_2, PM x KA, and PM x NB_{18}. showed a significant negative correlation with temperature in third moulting. But there was no correlation in others. The duration of fourth instar revealed that only PM x KA and PM x NB_{18} showed a significant positive correlation, but others were insignificant. The duration of fourth moulting was significantly and positively correlated in Pure Mysore, NB_4D_2, PM x KA and PM X NB_{18}, but in KA, NB_{18} and PM x NB_4D_2 only an insignificant correlation was observed. In Pure Mysore significant and negative relationship was observed in the case of larval duration of fifth instar. In bivoltines a significant and positive correlation was noticed. In cross breeds, the relation was in significant.

The leaf consumption was negatively and significantly correlated with temperature in all silkworm lines except in Pure Mysore.

The numbers of diseased larvae was positively and significantly correlated in all races and cross breeds. The number of cocoons per litre increased in all lines which denoted a decrease in size.

Shell ratio showed an insignificant correlation in Pure Mysore, NB_4D_2, NB_{18} and PM x NB_{18}. In KA, PM x NB_4D_2 and PM x KA, a significant and negative correlation was noticed.

4.2.2. Relative humidity

The simple correlation coefficients of biological characters with relative humidity is presented in Table 11.

Table 11. Values of simple correlation coefficients of relative humidity with biological characters

RH (%)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
S_1	83.65	81.75	89.25	83.33	83.25	82.27	78.50	78.00	74.40	76.40	80.01	80.01	76.40	76.40	76.40	80.01	80.01	80.01	80.01	80.01	80.01	80.01	80.01	77.61	79.35	79.35
S_2	76.78	75.00	78.25	76.50	81.25	73.16	72.42	70.28	69.45	73.80	73.45	73.45	73.80	73.80	73.80	73.45	73.45	73.45	73.45	73.45	73.45	73.45	73.45	74.62	75.00	75.00
S_3	84.51	84.25	81.25	84.58	89.00	87.43	84.50	86.59	88.00	82.40	84.75	84.75	82.40	82.40	82.40	84.75	84.75	84.75	84.75	84.75	84.75	84.75	84.75	81.45	84.10	84.10
Correlation coefficients																										
PM	-0.57	0.69**	0.76*	0.77*	0.22	-0.15	-0.59	-0.74*	-0.68*	0.88**	-0.07	0.64	0.66	0.70*	0.90**	-0.96**	0.79*	0.88**	0.93**	-0.84**	0.54	0.85**	-0.21	-0.09	0.25	0.34
NB_4D_2	0.13	0.69*	0.28	0.70*	0.77*	0.52	0.62	-0.73*	-0.80**	-0.59	-0.13	0.91**	0.99**	0.98**	0.98**	-0.97**	0.81**	0.90**	0.91**	-0.74*	0.05	0.29	0.39	0.53	0.78*	0.53
KA	0.06	0.69*	0.72*	0.81**	0.81**	0.46	0.38	-0.77*	-0.51	-0.50	-0.35	0.95**	0.98**	0.99**	0.98**	-0.98**	0.82**	0.91**	0.93**	-0.73*	-0.18	0.72*	0.71*	0.65	0.88**	0.23
NB_{18}	0.17	0.70*	0.76*	0.81**	0.70*	0.52	0.39	-0.81**	-0.53	-0.69*	-0.30	0.93**	0.95**	0.99**	0.98**	-0.99**	0.83**	0.86**	0.81**	-0.73*	0.53	0.72*	0.49	0.58	0.77*	0.35
PM x NB_4D_2	-0.05	0.25	0.75*	0.96**	0.55	-0.05	0.69*	-0.73*	-0.59	-0.63	-0.60	0.90**	0.98**	0.99**	0.96**	-0.96**	0.77*	0.89**	0.96**	-0.79*	0.81**	0.89**	0.74*	-0.28		
PM x KA	-0.06	0.25	0.71*	0.97**	0.56	-0.32	0.86**	-0.84**	-0.73*	-0.08	-0.45	0.90**	0.93**	0.99**	0.90**	-0.96**	0.79*	0.94**	0.97**	-0.78*	0.84**	0.90**	0.68*	0.03		
PM x NB_{18}	-0.09	0.46	0.71*	0.97**	0.53	-0.27	0.81**	-0.84**	-0.67*	-0.22	-0.34	0.90**	0.94**	0.99**	0.59	-0.96**	0.76*	0.87**	0.93**	-0.75*	0.84**	0.89**	0.58	-0.07		

* Significant at 0.05 level ** Significant at 0.01 level

1. % of early loss of larvae
2. Duration of first instar
3. Duration of first moulting
4. Duration of second instar
5. Duration of second moulting
6. Duration of third instar
7. Duration of third moulting
8. Duration o fourth instar
9. Duration of fourth moulting
10. Duration of fifth instar
11. Total larval duration
12. Leaf consumption
13. Weight of larvae
14. Length of larvae
15. Growth index
16. No. of diseased larvae
17. Percentage of spinning
18. No.of cocoons
19. Yield of cocoons
20. Size of cocoons
21. Single cocoon weight
22. Shell weight
23. Shell ratio
24. Reelability
25. Fecundity
26. Female pupal weight

The percentage of missing larvae during the early instars duration of third instar, total larval duration, reelability and female pupal weight were insignificantly correlated with relative humidity

The duration of first instar was significantly and positively correlated with relative humidity in pure races only. In cross breeds an insignificant correlation was noticed. The duration of first moulting and shell weight were was significantly and positively correlated in all lines except in NE_4D_2. But the duration of second instar, length of fifth instar larva, percentage of spinning, number and yield of cocoons harvested were positively and significantly corrleated in all lines.

The duration of second moulting and fecundity showed a significant and positive correlation in bivoltines; and a non-significant correlation in others. The duration of third moulting and single cocoon weight showed an insignificant correlation with relative humidity in pure races, but in cross breeds a significant and positive correlation was observed. The duration of fourth instar, number of diseased larvae were negatively and significantly correlated with relative humidity in all races and cross breeds. Number of cocoons per litre was decreased in all lines which revealed an increase in cocoon size. In the case of fourth moulting,. the duration was negatively and significantly correlated in Pure Mysore, NB_4D_2, PM x KA and PM x NB_{18}. In others an insignificant correlation was observed. Duration of fifth instar was positively and significantly related in Pure Mysore, and negatively in NB_{18}. In others, an insignificant correlation was observed.

The leaf consumption showed an insignificant correlation in Pure Mysore, but a positve and significant correlation was observed in bivoltines and cross breeds.

In case of weight of fifth instar larva all affected positively and significantly.

The growth index of fifth instar larvae was showed positive and significant corelation in all lines except in PM x NB_{18}.

Shell ratio was positively and significantly correlated in KA, PM x NB_4D_2 and PM x KA.

DISCUSSION

DISCUSSION

The present investigation was done to evaluate the performance of popular bivoltine races viz. NB_4D_2, KA and NB_{18} and the cross breeds of multivoltine x bivoltine viz. PM x NB_4D_2, PM x KA and PM x NB_{18} and the multivoltine. Pure Mysore which was used as a check, with reference to cocoon yield, commercial qualities of cocoons and seasonal influence in order to identify a promising race suitable for the sericulture farmers in the southern districts of Kerala. Rearings were conducted in three seasons; during the cold season : December-January, summer season : February-March, rainy season : May-June in 1993-1994. The results obtained from the present investigation are discussed below.

In all the three seasons the percentage of missing larvae revealed a uniform pattern in case of bivoltines and cross breeds, but in case of Pure Mysore though the first two seasons were having similar effect to bivoltines, in the third season percentage was lesser than that of the bivoltines. This indicated that there was no significant genetical influence for the races in the earlier stages of the larvae even under different climatic conditions prevailed during the three seasons. But it may be noted that percentage was much higher ranging from 20.8 to 26.80 in different seasons. In case of feeding and moulting durations in early instars there was no significant variation between races. The cross breeds behaved almost in the same pattern in all the three seasons. The result obtained on the percentage of missing larvae were promising as the three bivoltine races performed alike in the early instars. Cross breeds have shown higher resistance to the climatic situations unlike the bivoltine races and this may be due to heterosis as referred by Baig et. al (1991). In respect of missing larval percentage, the cross breed can be identified as the suitable lines, for Kerala conditions.

The feeding and moulting durations recorded for the first and third instars indicated that the bivoltine races do not differ much among them. But during the fourth and fifth instars, the bivoltine races varied in their feeding durations and NB_4D_2 had a shorter duration in all seasons. Similar findings were reported by Krishnaswami et. al (1991b) who revealed that there was no significant difference in the durations of feeding and moulting periods for the bivoltine and multivoltine races during the first three stadia and difference were observed during the fourth and fifth instars. The statistical difference observed in early instars in case of second season may be due to the interaction of disease incidence and racial characters.

NB_4D_2 consumed more food during the three seasons. This race recorded shortest total larval duration than other bivoltines. Same observation was reported earlier (Annonymous, 1984b). This higher rate of consumption and shorter larval duration have not reflected in the larval weight during fifth instar or in single cocoon weight. Larval character of NB_4D_2 coming to earlier maturity than KA and NB_{18} is advantageous, for the easy rearing of the larvae without any loss in yield.

Of the cross breeds, PM x NB_4D_2 had shorter larval duration during the fourth and fifth instars, irrespective of the seasons. The racial character of early maturity had expressed in the cross breeds. The other two cross breeds were of the same duration. All the cross breeds had a lesser larval duration compared to their parents. Results of same nature was reported by Iyengar <u>et</u> <u>al</u>. (1983), and suggested as due to the hybrid vigour of the F1 generation. Pure

Mysore had the longest larval duration which is well accounted for its racial character. De (1976) had reported that it may be due to the degeneration of the race. But whether it is a deterioration or a fixed genetic make up is to be confirmed.

The leaf consumption which is an indication of the performance of the silkworm race with respect of productivity, is an important parameter for the efficient conversion of food into cocoons. The genetic make up of the particular race, combined with the quality of the leaf and climatic conditions, usually decide the rate of consumption. Though NB_4D_2 ranked first in leaf consumption, the single cocoon weight of this race was on par or less than KA. But the shell weight and shell ratio were higher in NB_4D_2. This indicate that the conversion of food into silk is more efficient in this race than the others. Pillai and Raju (1982) also found that NB_4D_2 had higher shell ratio than NB_{18}. KA was ranked next to NB_4D_2 in leaf consumption and for single cocoon weight it was ranked above NB_4D_2. This race also is having efficient rate of conversion of food into cocoon. NB_{18} ranked only last among the three in food consumption, single cocoon weight and shell weight. According to Penkov and Long (1987) cocoon weight, shell weight and silkiness were genetically conditioned. Another report stated that KA had the highest cocoon weight than NB_4D_2 and NB_{18} (Anonymous, 1984a).

The cross breeds were inferior to their male parent, bivoltines in leaf consumption, in all the three seasons. The single cocoon weight was correspondingly lesser for the first and second seasons, but during the third seasons they were on par with the corresponding bivoltine parent eventhough they consumed only lesser quantity of food. During this season, the average temperature remained low 27.65°C and relative humidity was higher (84.75 per cent). The rate of consumption was also higher during this season, and climatic conditions might have favoured for the efficient utilization of food which had resulted in higher larval weight and proportionate cocoon weight (Kaufman and Bayers, 1972). Of the cross breeds PM x NB_4D_2 was superior to other cross breeds in food consumption but in case of single cocoon weight, the character of the bivoltine parent has reflected as the PM x KA combination ranked first in single cocoon weight. For the shell weight and shell ratio PM x NB_4D_2 remained superior to others. The efficient conversion of food for shell production in PM x NB_4D_2 was earlier recorded by Raman et. al (1993).

Pure Mysore recorded the lowest food consumption than bivoltines (Prakesh et. al., 1987), lowest larval weight and cocoon weight (Jolly et. al., 1982), and minimum shell weight (Sonwalkar, 1992) and significantly lower shell ratio (Viswantha, 1987) as expected.

The reelability of bivoltines were on par during the first two seasons, but during the third time NB_4D_2 was superior to NB_{18}. Reelability is related to the shell weight and NB_4D_2 was having higher shell weight and shell ratio compared to the others. The temperature was not having influence in the reelability and hence high reelability expressed by NB_4D_2 is a racial character and can be accepted as a race suitable under the existing conditions. The size of cocoons of cross breeds were on par and were smaller than bivoltines. The racial quality of NB_4D_2 was reflected in the hybrid also. PM x NB_4D_2 was better than other cross breeds in shell weight and shell ratio, but the reelability was on par and this may be due to the characters of multivoltine which is having low reelability as its racial character, and it is not amenable to modern realing techniques. Similarly Jolly et al (1981) reported that multivoltine has lower reelability than bivoltines, and

Sonwalker (1992) revealed that lower reeling performance of multivoltine cocoons than bivoltine cocoons was because automatic reeling technique was meant for bivoltine cocoons, but multivoltine cocoons being flossy/flimsy with short filament cause loss in yield.

There were having incidence of diseases in the bivoltine races, NB_7 race has completely failed during the initial rearing itself which was taken in November-December 1993 and hence it could not be continued for the rest of the experiments. Jayaramaiah and Kuberappa (1978) has reported that no race is immune to disease and during the present investigation also the pure races and cross breeds were affected by mild pebrine grasserie and flacherie. The disease incidence was more in second season probably due to the high temperature prevailed in the range of 28.75 - 31.75°C. Of the bivoltines NB_4D_2 was superior to KA and NB_{18}. In the cross breeds PM x NB_4D_2 PM x NB_{18} and PM x KA were ranked in order. The percentage of spinning was more in NB_4D_2 among the bivoltines as the rate of disease incidence was lesser. Among the cross breeds also the combination with NB_4D_2 was ranked first in disease incidence, percentage of spinning and yield of cocoons. The better performance of

NB_4D_2 with respect to disease incidence percentage of spinning and cocoon yield were reported earlier by Benchamin et al (1976). The variation between the seasons was due to the climatic conditions prevailed in different seasons (Viswanatha, 1987).

In case of cross breeds, each cross breed was superior to its corresponding bivoltine parent in respect of disease resistance and cocoon productivity. This was due to the incorporation of the tolerant multivoltine character and superiority of the cross breed was due to the heterobeltiosis ie, F1 hybrid exhibited hybrid vigour which was superior to the better parental value (Singh, 1983). The superiority of PM x NB_4D_2 to other cross breeds in respect of cocoon productivity was reported earlier by Viswantha (1987) and Siddappaji et al (1987).

Pure Mysore was superior to bivoltines in disease incidence during the second season but during first and third seasons, it was similar to NB_4D_2. With respect to percentage of spinning, it was similar to NB_4D_2 irrespective of seasons but was higher than KA and NB_{18}. Devaiah (1973) reported that multivoltine recorded higher number of cocoons than bivoltines. In the present study also NB_4D_2 has been performing well as a pure race next to Pure Mysore.

Fecundity was highest in KA during first season, and during next two seasons is on par with NB_{18} but both were superior to NB_4D_2 and Pure Mysore. Similarly according to a study report KA, NB_{18} and NB_4D_2 recorded the fecundities of 562, 559 and 547 egg respectively (Anonymous, 1987a).

In the present study the female pupal weight was higher in races with high fecundities. This was earlier reported by Jayaswal et al (1991). Since KA recorded a higher single cocoon weight and a lower shell weight which have resulted in a higher female pupal weight and thus it reflected in higher fecundity.

The climate during the three seasons had no influence on the percentage of missing larvae during early instars and the climate itself has not varied much, except a rise in temperature in second season. Since the larval duration increases with decrease in atmospheric temperature (Gangawar and Somasundaram, 1991), it was found from the present study that hot and less humid rearing season reduced the feeding and moulting durations of first three intars though all lines were not affected by climate in a uniform pattern. In fourth and fifth stadia, different lines performed differently because of the disease incidence which has resulted a differential metabolic rate in the diseased larvae.

The reduction in growth characters during the hot and less humid season was due to the influence of climatic conditions (Adikson, 1965), and reduction in fecundity in summer seasons in bivoltines was also due to the influence of climate (Jayaswal et al., 1991).

Since the temperature was positively correlated with death of larvae (Rao et al., 1990) in the present study also number of diseased larvae increased in the second (summer) season. This was reflected in percentage of spinning and yield of cocoons harvested. Cocoon productivity was lesser in hot and less humid season. Similar findings were reported by Bhat et al. (1989) who noticed that cocoon yield was higher during winter season when compared to the summer season.

When bivoltine and cross breed were compared from the result obtained is evident that NB_4D_2 among the bivoltines, and PM x NB_4D_2 among the cross breeds have performed better than others. Though the bivoltine races were superior to cross breeds, qualitatively, the farmer's is to rear the race which give him a higher cocoon yield and profit. In order to ascertain the most productive line under the existing conditions, a comparison of the identified bivoltine race and cross breed is necessary. The cross breed PM x NB_4D_2 has been superior to its male parent NB_4D_2 with regard to the percentage of missing larvae, larval duration, disease incidence, percentage of spinning and effective rate of rearing. But the economic characters like single cocoon weight, shell weight, shell ratio and reelability were more in NB_4D_2 than its cross breeds. NB_4D_2 consumed more food than its cross breeds and resulted in a higher larval weight which reflected, in the economic characters.

Taking into consideration the higher spinning rate the reduction in the single cocoon weight, shell and reelability have been compensated by the total yield, produced by the cross breed PM x NB_4D_2 as the mean yield obtained was 119.56 g in NB_4D_2 and 216.11 g in PM x NB_4D_2. A higher productivity combined with good economic traits is the optimum requirement for the better performence of the programme. The present findings point out the lack of a race, which can yield the optimum quality and quantity. The research is to be oriented towards the identification of such a race suitable to southern districts of Kerala.

In brief, among the bivoltines NB_4D_2 and in cross breeds PM x NB_4D_2 was superior to others. For commercial rearings the cross breed PM x NB_4D_2 will be the suitable line in view of the productivity till a perfect race containing the optimum quality and quantity is identified.

SUMMARY

SUMMARY

The present investigation was carried to evaluate some of the popular bivoltine races and multivoltine x bivoltine hybrids of Bombyx mori Linnaeus in comparison with multivoltine race with reference to yield and quality of cocoons and seasonal influence, in order to identify a promising race for the benefit of the sericulture farmers in the southern districts of Kerala.

The bivoltine races used were NB_4D_2, KA and NB_{18} and the multivoltine x bivoltine cross breeds used were PM x NB_4D_2, PM x KA and PM x NB_{18} and multivoltine Pure Mysore used as check. Rearings were done in the silkworm rearing house of the sericulture section in the Department of Agricultural Entomology, College of Agriculture, Vellayani during the three seasons in 1993-94.

1. Cold season : months of December - January
2. Summer season : months of February - March
3. Rainy season : months of May - June

Observations were recorded during rearings to assess the performance of the races in respect of the percentage of missing larvae during first and second seasons, durations of larval instars and moulting durations, leaf consumption, weight, size and growth index of fifth instar larva, disease incidence, number of cocoons and yield of cocoons harvested, spinning percentage, size of cocoons, single cocoon weight, shell weight, shell ratio, reelability, fecundity and female pupal weight. The biological characters were correlated with the temperature and relative humidity during the periods.

The percentage of missing larvae during first and second instars ranged from 9.37 to 26.80%. The bivoltine races were on par and cross breeds were on par among themselves. The cross breeds were superior to bivoltines and multivoltines.

With regard to the total duration, NB_4D_2 was having shorter duration than KA and NB_{18}. PM x NB_4D_2 was shorter than other cross breeds. The cross breeds of Pure Mysore with NB_4D_2 was superior to NB_4D_2 in respect of total larval duration irrespective of the seasons.

Food consumption was more in case of NB_4D_2 than other bivoltine races and cross breeds during the three seasons. higher food consumption resulted in better larval growth with a higher growth index.

Among cross breeds PM x NB_4D_2 consumed more food than other cross breeds during first two seasons, and the weight of fifth instar larva was also higher than that of other cross breeds.

With respect to the number and yield of cocoons harvested, percentage of spinning and size of cocoons, among bivoltines NB_4D_2 ranked first and among the cross breeds PM x NB_4D_2 faired best except in the cocoon size.

The single cocoon weight was higher in KA among bivoltines and it was highest in PM x KA among the cross breeds. But the quality parameters viz. shell weight and shell ratio, NB_4D_2 was ranked first. Among cross breeds PM x NB_4D_2 was the best.

In general bivoltine cocoons were superior to the cross breeds and Pure Mysore especially in reelability percentage.

NB_4D_2 had only a lesser disease incidence than other bivoltines during the last two seasons, but during the first time they were on par. Among the cross breeds PM x NB_4D_2 was superior to others.

All the cross breed combinations were superior to NB_4D_2 during the three seasons in respect of cocoon yield, but in respect of disease incidence and spinning percentage the cross breeds were superior to NB_4D_2 with an exception in case of PM x KA during first season and PM x NB_4D_2 ranked first of the whole lot.

The fecundity was higher in KA than NB_4D_2 but did not vary significantly from NB_{18}. Weight of female pupa also exibited the same pattern.

Pure Mysore used as check was inferior to all bivoltines and cross breeds in case of total larval duration, weight size and growth index of fifth instar larva, single cocoon weight, shell weight and shell ratio. The fecundity and female pupal weight was less in Pure Mysore than bivoltines. But in case of food consumption Pure Mysore was on par with PM x KA and PM x NB_{18} during the second season.

The lowest reelability percentage exibited by Pure Mysore has contributed for a lower reelability in the cross breeds.

Climate had no significant influence on the percentage of missing larvae during early instars, total larval duration and reelability. Hot and less humid season reduced the weight of fifth instar larvae, percentage of spinning, cocoon yield and size of cocoons in all lines, but food consumption, fecundity and female pupal weight also were reduced in all lines except in Pure Mysore. Disease incidence was found to be more in summer season.

Future line of work

Research is to be concentrated to identify or breed pure races and hybrids which have high productivity and better quality of cocoons. The performance of different bivoltine hybrids are also to be studies under the conditions existing in Kerala.

REFERENCES

REFERENCES

Adikson, P.L. 1965. Action of light in controlling insect growth and development. *Proc. Cong. Electromagn. Rad. Agric.* New York. pp. 30-33.

Anantha Raman, K.V., Benchamin, K.V., Magadum, S.B., Rema Devi, O.K. and Datta, R.K. 1993. Studies on the nutritional efficiency in silkworm, *Bombyx mori* L. *Indian J. Seric.* 32 : 43-49.

Anonymous 1981a. Performance of Multivoltine hybrids in the field. *Annual Report*, CST and TI, Mysore. pp. 199-201.

Anonymous 1981b. Studies on the performance of various silkworm breeds and methods to improve yield and cocoon characters. Ibid., 161-162.

Anonymous 1983a. Breeding for shorted larval period. *Ibid.*, 11-14.

Anonymous 1983b. Studies on viral diseases of silkworm, *Bombyx mori*. *Ibid.*, 121-127.

Anonymous 1984a. Maintenance of basic stock of popular silkworm breeds. *Ibid.*, 92.

Anonymous 1984b. Foundation hybrids of approved races. *Ibid.*, 27.

Anonymous 1985. Screening of seven bivoltine races for egg production efficiency. *Ibid.*, 40-41.

Anonymous 1986a. Evaluation of commercially important characters of multivoltine and bivoltine breeds and their hybrids. *Ibid.*, 12-13.

Anonymous 1986b. Rearing of P_4 races. Ibid., 2.

Anonymous 1987a. Biochemical genetic studies in multivoltine and bivoltine silkworms. Ibid., 22-24.

Anonymous 1987b. Maintenance of breeders stock KA, NB_7, NB_{18}, NB_4D_2. Ibid., 7.

Anonymous 1987c. Screening of races of silkworm for their relative susceptibility to different diseases. Ibid., 60.

Anonymous 1989. Sericulture development in Asia, F.A.O., United Nations Regional office for the Asia and the Pacific, Bangkok, Thailand. p. 25.

*
Aruga, H. and Watanabe, H 1964. Resistance to per os infection with cytoplasmic polyhedrosis virus in the silkworm, Bombyx mori (Linnaeus). J. Insect Pathol. : 387-394.

Baig, M., Sharma, S.D., Balavenkatasubbaiah, M., Samson, M.V. and Sasidharan, T.O. 1988. Relative susceptibility of different races of silkworm. Bombyx mori L. of nuclear polyhedrosis under natural and induced conditions. Sericologia,

Baig, M., Sharma, S.D., Balavenkatasubbaiah, M., Samson, M.V., Sasidharan, T.O. and Noamani, M.K.R. 1991. Relative susceptibility of different races of silkworm, Bombyx mori L. to nuclear polyhedrosis under natural and induced conditions. Sericologia, 31 : 417-420.

*
Bekirov, A.G. 1960. Vnutriporodonoe Skreshchivanie belokonnykh porod tutovogo shelkopryada (Inter specific cross breeding of the white cocoon mulberry silkworm). Agrobiologiya, 6 : 80-83.

Benchamin, K.V., Jolly, M.S. and Benjamin, D.A.I. 1983. Study of the reciprocal crosses of multivoltine x bivoltine with special reference to use of bivoltine hybrid as a parent. Natl. Semi. Silk Res. Dev., C.S.B., Bangalore. Abst., pp. 27-30.

Benchamin, K.V., Veeraiah, T.M. and Thyagarajan, B.S. 1976. Establishment of seed areas and performance of bivoltine pure race Annual Report, CSR and TI, Mysore. p. 155.

Bhaskar, R.N., Govindan, R. and Devaiah, M.C. 1987. Sensitiveness of some breeds of silkworm. Bombyx mori L. to kenchu virus disease based on extent of cocooning, Entomon. 12 : 321-323.

Bhaskar, R.N., Govindan, R., Devaiah, M.C. and Munirajappa, R. 1991. Influencing of kenchu virus infection in some strains of silkworm, Bombyx mori L., on deterioration of cocoon parameters. Sericlogia, 31 : 713-716.

*
Capinera, J.L., Narango, S.E. and Ranaud, A.R. 1981. Alfalfa web worm : larval development in response to diet and temperature. South West Entomol. 6 : 6-17.

Chandrasekharaiah, Suryanarayana setty and Srinivasa Babu, G.K. 1981. Study on the performance of bivoltine hybrids in the field. Annual Report, CSR and TI, Mysore. pp. 197-200.

Chinnaswamy, K.P. and Devaiah, M.C. 1984. Susceptibility of different races of silkworm, Bombyx mori Linneus to Aspergillosis caused by Aspergillus tamarrikata. sericolgoia, 24 : 513-517.

Chowdary, S.N 1967. The silkworm and its culture, Mysore, Printing and Publishing house, Mysore, India. p. 76.

Datta, R.K. and Pershad, G.D. 1988. Combining ability among multivoltine x bivoltine silkworm (Bombyx mori L.). Sericologia, 28 : 21-29.

De, M. N. 1976. The pusa experiments on the improvements of mulberry silkworms. Proc. Third Ent. Meet. pp. 800-802.

Devakumar, H.J. 1987. A project report on post graduate diploma in sericulture, Department of Sericulture, U.A.S, Bangalore. p. 77.

Devaiah, M.C. 1973. Pathological and ecological studies on the pebrine desease of the silkworm, Bombyx mori L. Ph.D. Thesis, U.A.S., Bangalore. p. 175.

Divakar Bhat, Noamani, M.K.R., Venugopala Pillai, S., Nagaraj, C.S. and Rama Mohanna Rao, 1989. Preliminary assessment of four popular bivoltine breeds of silkworm Bombyx mori L. Indian J. Seric. 28 : 261-262.

Dwarakinath and Chandrakanth, 1983. Behaviour of the bivoltine races at basic seeds station of National Silkworm Seed Project. National Seminar on Silk Research and Development, C.S.B., Bangalore. Abst., p. 83.

Ganesh, N.K., Benchamin, K.V. and Raje Urs, S. 1976. Study on the field trials of new bivoltine hybrids. Annual Report, CSR and TI, Mysore. p. 154.

Ganga, G. and Sulochana Chetty 1991. An introduction to sericulture. Oxford and IBH Publishing Co. Pvt. Ltd, pp. 1-140.

Gangawar, S.K. and Somasundaram, P. 1991. Influence of abiotic factors on larval duration and cocoon yield of silkworm Bombyx mori L. A search for suitable rearing house. Entomon. 16 : 209-212.

*

Golanski, K. 1959. Selection of polish silkworm races (Bombyx mori. L.).. I. The polish white race. II. The polish yellow races I, II and III. The molva white and yellow races IV. The Woroclaw white and yellow races. Rev. Veri. and Socie. 11 : 119-133.

*

Guoliang Shou. 1991. Estimation of reelability percentage I. Estimation based on the number of unexpected droppings ends of cocoons. J. Seric. Sci. Jpn. 60 : 6-12.

Gupta, B.K., Sinha, A.K. and Pad, B.C. 1991. Studies on egg yielding capacity of different races of silkworm Bombyx mori L. Geobios. 18 : 173-176.

*

Hassanien, H. and El-sharawwy, F. 1960. Biological studies on certain races of silkworm, Bombyx mori L. Silkworm IB (2) : 376-390.

*

Hassanien, H. and El-Sharawwy, F. 1962. The effect of feeding the silkworms, Bombyx mori with different varieties on the fecundity of moths. J. Silkworm. 14 : 163-170.

*

Hirobe, T. 1968. Evolution, differentiation and breeding of the silkworm, the silk Road, past and present, Genetics in Asian Countries XII Intl. Congr. Genet. pp. 25-36.

*

Horie, Y. 1978. Quantitative requirements of nutrients for growth of the silkworm Bombyx mori L. JARO 12 : 210-218.

*
Ito, T. 1967. Nutritional requirements of silkworm Bombyx mori L. Proc. Jap. Acad. 43 : 57-61.

Iyengar, M.N.S., Jolly, M.S., Datta, R.K. and Subramaniam, R.K. 1983. Relative silk productivity of different silkworm breeds and its use as breeding index. National Seminar on silk Research and Development, C.S.B., Bangalore. Abst., p. 12.

Jadhav, L.D. and Gajare, B.P. 1978. Studies on the effect of mating duration on the viability of silkworm, Bombyx mori eggs, Indian J. Seric. 27 : 28-31.

Jameson, A.P. 1922. Report on the diseases of silkworm in India. Superintendent Govt., Printing India, Calcutta. p. 165.

Jayaramaiah, M. and Kuberappa, G.C., 1978. Silkworm Mycoses U.A.S Technical Report U.A.S., Hebbal, Bangalore. 48 : 1-85.

Jayaswal, K.P., Singh, T. and Subba Rao, G. 1991. Indian. J. Seric. 30 : 141-143.

Jolly, M.S., Benchamin, K.V., Rathnasen and Saheb, N.M. 1982. Study on the weight relationship among various growth parameters in silkworms. Annual Report, CSR and TI, Mysore. pp. 108-112.

Jolly, M. S., Sonwalker, T.N. and Gopala Rao, M. 1981. Test reeling of bivoltine and multivoltine cocoons on multi end reeling machine, Annual Report, CSR and TI, Mysore. p. 146.

Jolly, M.S., Subba Rao, S. and Krishnaswami, S. 1966. Studies on the mating capacity of males of mulberry silkworm and the possibility of utilizing polygamy in sericulture. Indian J. Seric. 1 : 25-32.

Jyoti. P. Mathur, Tyagi, H.R. and Verma, M.B. 1988. Performance of some pure and hybrids races of Bombyx mori in Rajasthan (Udaipur). Proceedings of the International Congress on Tropical Sericulture Practices. February, 18-23, 1988, C.S.B., Bangalore. 31-35.

*

Kaufman, G.A. and Bayers, R.J. 1972. Relationship of weight, length and body consumption in the Medola oryzes latipes. Amer. Medd. Natl. 88 : 239-245.

Kenchoji Rao, K. 1988. A project report on post graduate diploma in Sericulture, U.A.S., Bangalore. p. 83.

Kovalev, P.A. 1965. Silkworm Breeding Stocks. Indian Silk, 3 : 27-36.

Kovalev, P.A. 1970. Silkworm Breeding Stocks (Russian). English translation by C.S.B. pp. 45-57.

Krishnaswami, S. 1971. A new strategy for producing high grade raw silk in Mysore. Indian Silk, 10 : 7-11.

Krishnaswami, S. 1979. The first decade of bivoltine revolution. Indian Silk, 18 : 7-11.

Krishnaswami, S., Jolly, M.S. and Subha Rao, S. 1964. Diallel analysis of quantitative characters in multivoltine races of silkworm. Indian J. Genet. Pl. Breed. 24 : 213-222.

Krishnaswami, S., Kumara Raj, S., Vijayaraghavan, K. and Kasiviswanathan, K. 1971. Silkworm feeding trials for evaluating the quality of mulberry leaves as influenced by variety, spacing and nitrogen fertilization. Indian J. Seric. 10 : 70-80.

Krishnaswami, S., Madhava Rao, N.R. and Suryanarayan, S.K., Sundaramurthy, T.S. 1991a. Sericulture Manual - 3, Silk Reeling. F.A.O, Rome. pp. 7-81.

Krishnaswami, S., Narasimhanna, M.N., Suryanarayan, S.K. and Kumara raj, S. 1991b. Sericulture Mannual-2 Silkworm Rearing. F.A.O., Rome. pp. 28-129.

*
Kuribayashi, S., Sudha, Y. and Koosaka, I. 1990. Studies on the food utilization efficiency in the silkworm, Bombyx mori L. reared on mulberry leaves. Bull. Natl. Seric. Entomol. Sci. : 81-102.

Liu Shi Xian, 1964. Identification on the resistance of silkworm (Bombyx mori) races to six types of silkworm diseases. Sericologia, 24 : 377-382.

*
Liug-X. and Res.M. 1991. Studies on the efficiency of selection for improving technological characters of cocoon filament of Bombyx mori L. Canye Kaxue, 17 : 75-79.

Manjunath, M. 1988. A project report on post graduate diploma in sericulture, U.A.S., Bangalore, p. 111.

Mohan Das, N. and Sasidharan Pillai, K. 1983. Adaptability of sericulture in Kerala. National Seminar on Silk Research and Development, C.S.B., Bangalore. Abst, pp. 10-13.

Nahar, K. V., Dhuri, A.V. and Dumbre, R.B. 1989. Performance of hybrids of mulberry silkworm, Bombyx mori L. in Konkan. Indian. J. Seric., 28 : 145-149.

*
Nakasone, S. 1970. Effect of fatty acids on the cocoon formation, egg production and hatchability of eggs in the silkworm, Bombyx mori. J. Sericult. Sci. Japn. 39 : 261.

Narasimhanna, M.N., Iyengar, M.N., Muneer, N. and Prabha, G. 1976. Evaluation of superior bivoltine breeds suitable for Karnataka. Annual Report, CSR and TI, Mysore. pp. 54-55.

Narayanan, E.S., Prahalada Rao, L.S. and Nagaraja Rao, H.A. 1964. Studies on the correlation between the duration of mating and the number of viable eggs laid by the silk moth, Bombyx mori L. Indian. J. Seric. 3 : 1-10.

Narayanaswamy, T.K., Shyamala, M.B. and Govindan, R. 1985. Reaction of difference breeds of silkworm Bombyx mori L. to Kenchu virus. Indian. J. Seric. 24 : 66-73.

Panse, V.G. and Sukhatne, P.V. 1989. Statistical Methods for Agricultural Workers, I.C.A.R., New Delhi. pp. 1-35.

Parthasarti, B.S. and Ananthanarayanan, S. 1981. Month wise harvest data of bivoltine hybrids issued by CSR and TI, Extension Centre, Chamarajanagar. Annual Report, CSR and TI, Mysore. pp. 235-237.

*
Penkov, N. and Long, N.V. 1987. Breeding and genetic studies of some silkworm (Bombyx mori L.) breeds reared at high temperature and moisture. II. Inheritance of quantitative characters. Genet. Sel. 20 : 348-354.

Prakash, R., Naik and Dolvi, M.R. 1987. Food utilization in different races of silkworm Bombyx mori L. XVI International Sericultural Congress, Abst., p. 12.

Raghavaiah, G. and Jayaramaiah, M. 1990. Susceptibility of some races of the silkworm, Bombyx mori to white muscardine disease. Indian. J. Seric. 29 : 304-307.

Rahman, M., Khale Quizzaman, N.M. and Rahman, Sowdagar Mohfuzer, 1980. Studies on the oviposition and hatchability by some multivoltine silkworm races of the silkworm B. mori L. Indian. J. Seric. 19 : 28-31.

Rajanna, C.S., Sreerama Reddy, G. and Krishna Murthy, N.B. 1986. Evolution of Hardy Bivoltine Race of Silkworm Bombyx mori L. for Tropics. National Seminar on Prospects and Problems of Sericulture in India. Abst., p. 25.

Rama Mohana Rao, P., Nagaraj, C.S., Basavaraj, H.K. and Bhardwaj, N.G. 1989. Observations on selection pressure on pupation in four bivoltine breeds of the silkworm Bombyx mori L. Indian. J. Seric. 28 : 281-283.

Rama Mohana Rao, P., Noamani, M.K.R. and Basavaraj, H.K., 1990. Observations on the melting in bivoltine breeds of the silkworm, Bombyx mori L. Sericologia, 30 : 87-89.

Rangaswami, G., Narasimhanna, M.N., Kasiviswanathan, K., Sastry, C.R. and Manjeet, S. Jolly, 1991. Sericulture Manual - 1, Mulberry Cultivation, F.A.O, Rome. pp. 1-82.

Ravi, S.R. 1986. Field performance and variation in cocoon parameters of commercial hybrids of silkworm Bombyx mori L. in Karnataka. MSc (Agri.) Thesis, U.A.S., Bangalore. p. 106.

*

Rogers, L.E., Buschworm, R.L. and Watson, C.R. 1977. Length weight relationship of shrub steep invertebrates, Ann. Ent. Soc. Amm. 70 : 51-53.

Saheb, M. N. 1981. Behaviour of different bivoltine races. Annual Report, CSR and TI, Mysore. pp. 226-229.

Sengupta, K., Datta, R.K. and Biswas, S.N. 1973. Effect of multiple crossing on the type of progeny recovered in silkworm Bombyx mori L. Indian J. Seric. 12 : 21-38.

Siddappaji, C., Vasundara, M. and Shankar, A.G. 1987. Field evaluation of mulberry silkworm races in Karnataka. Indian Silk 25 : 30-35.

Siddappaji, C., Vasundara, M., Shashider, H.G. and Shivashankar, T. 1983. Investigation on sericultural practices in Karnataka. National Seminar on Silk Research and Development, C.S.B., Bangalore. Abst., p. 39.

Sidhu, N.S. 1967. Multivoltine breeding silkworm (Bombyx mori L.) for tropics in evaluation. Indian J. Seric. 1 : 63-66.

Sidhu, N.S. 1973. New evolved multivoltine breeds of silkworm. SABRAO News. 5 : 101-105

Sidhu, N.S., Sreenivasan, R. and Shamachary, 1967. Fertility performance of femal moths depends on their male mates. Indian. J. Seri. 1 : 77-82.

Singh, B.D. 1983. Plant Breeding Principles and Methods, Kalyani Publishers, New Delhi, p. 181.

Sonwalkar, T.N. 1992. Review of research work in post cocoon harvest technology in India. Sericologia, 32 : 1-26.

Thangavelu, K. and Raja Kumar, S. 1988. Relative performance of pure races and cross breeds in tropical conditions of Tamil Nadu. Proceedings of the International Congress on Tropical Sericulture Practices. February, 18-23. C.S.B., Bangalore, pp.85-88.

*
Tirelli, M. 1973. Study on some physiological phenomenon in the hybrid eggs of the silkworm. Zool. Jb. (physical). 53 : 367-410.

*
Toyama, K. 1905. Sericulture in Siam. Dainihon sanshikaiho. pp. 24-26.

Venugopala Pillai, S. 1979. Growth studies in silkworm Bombyx mori L. with special reference to the economic characters. PhD. Thesis., University of Kerala. pp. 15-60.

Venugopala Pillai, S.V. 1988. Studies on the adaptability of silkworm breeds of Bombyx mori L. to black cotton soil and rainfed areas. Proceedings of the International Congress on Tropical Sericulture Practices. February 18-23, 1988, C.S.B., Bangalore. 37-47.

Venugopala Pillai, S. and Krishnaswami, S. 1980. Effect of high temperature on the survival rate, cocoon quality and fecundity of Bombyx mori L. Proc. Sericult. Seminar and Sympo. T.N.A.U. (Coimbatore). : pp. 141-148.

Venugopala Pillai, S. and Krishnaswami, S. 1989. Growth studies in silkworm Bombyx mori L. under tropical conditions, VI. An assessment on the fecundity of silkworm breeds in relation to their growth. Indian J. Seric. 28 : 44-52.

Venugopala Pillai, S. and Satyanarayan Raju, 1982. Performance of new bivoltine/P_3 stock. Annual Report, CSR and TI, Mysore. pp. 184-189.

Vijay, S.R. 1985. Bivoltine in tropics, sericologia, 25 : 219-227.

Viswanath, K., and Nagaraju, C.S. 1975. Behaviour of bivoltine hybrids in Channapatna division. Annual Report, C.S.R. and TI, Mysore. pp. 137-138.

Viswanatha, G.M. 1987. Performance of the selected races of mulberry silkworm (Bambyx mori L.) in the eastern dry zone of Karnataka. MSc. (Seric) Thesis, U.A.S., Bangalore. pp. 84-97.

Visweshwara Gowda, B.L., Ravi, S.R. and Narayanaswamy, T.K. 1988. Field performance of some of the commercial hybrids (PM x NB_4D_2, PM x NB_{18}, PM x C. Ninchi) in Karnataka. Proceedings of the International Congress on Tropical Sericulture Practices. February 18-23. 1988, C.S.B., Bangalore, pp. 48-55.

* Originals not seen

APPENDICES

APPENDIX - I

Weather data : Inside and outside the rearing house

First Season

Date	INSIDE HOUSE		OUTSIDE			
	Temper- ature (°C)	Relative humidity (%)	Temperature (°C) Max.	Temperature (°C) Min.	Rain fall (mm)	Relative humidity (%)
24-12-1993	28.00	84.50	30.60	22.00	—	78.50
25-12-1993	28.25	77.00	30.90	22.00	—	81.50
26-12-1993	27.75	83.75	30.90	22.50	—	88.00
27-12-1993	27.87	89.25	30.50	23.00	—	86.50
28-12-1993	27.62	82.00	30.25	23.00	—	78.00
29-12-1993	27.75	84.50	29.75	23.60	—	83.50
30-12-1993	29.00	85.00	29.75	23.00	—	88.50
31-12-1993	28.75	83.25	29.50	22.75	—	86.50
1-01-1994	28.50	83.00	31.00	23.50	—	87.00
2-01-1994	28.75	81.25	30.75	23.00	—	88.50
3-01-1994	29.25	79.75	30.75	23.00	—	57.00
4-01-1994	28.50	78.50	30.75	22.50	—	88.50
5-01-1994	28.75	79.75	30.50	22.75	—	87.00
6-01-1994	28.50	74.25	31.00	22.75	—	88.00
7-01-1994	28.75	76.75	31.25	23.25	—	87.00
8-01-1994	28.50	79.75	31.00	23.50	—	87.00
9-01-1994	28.50	79.25	30.75	23.00	—	88.00
10-01-1994	29.00	73.00	31.00	22.50	—	77.00
11-01-1994	28.00	79.25	31.00	22.00	—	78.50
12-01-1994	28.50	75.25	30.50	22.00	—	81.50
13-01-1994	29.25	72.00	30.50	22.50	—	81.50
14-01-1994	28.00	81.00	30.25	23.00	—	84.50
15-01-1994	29.00	78.50	30.50	23.25	—	95.50
16-01-1994	29.25	78.75	31.25	23.50	—	90.00
17-01-1994	29.25	77.50	31.50	23.00	—	81.00
18-01-1994	29.00	81.50	31.50	23.50	—	91.00
19-01-1994	29.75	81.50	31.50	24.00	—	79.00
20-01-1994	29.50	78.25	31.50	23.00	—	83.50
21-01-1994	29.00	77.00	31.25	22.75	—	85.00
22-01-1994	28.50	79.00	31.50	24.00	—	84.50
23-01-1994	29.00	75.25	31.25	23.00	—	81.00
24-01-1994	27.50	80.00	31.25	22.50	—	81.50
25-01-1994	28.50	80.00	30.25	21.00	—	86.00
26-01-1994	29.00	78.25	30.75	20.50	—	87.00
27-01-1994	27.00	78.50	30.75	20.00	—	77.50
28-01-1994	28.50	78.50	30.25	20.25	—	76.50
29-01-1994	29.00	76.25	30.50	21.75	—	70.50
30-01-1994	28.25	79.00	30.75	20.00	—	75.00
31-01-1994	28.25	81.25	30.75	20.25	—	70.00
1-02-1994	28.75	80.50	30.50	22.50	—	75.00

APPENDIX – II

Weather data : Inside and outside the rearing house – Second Season

Date	INSIDE HOUSE		OUTSIDE			
	Temperature (°C)	Relative humidity (%)	Temperature (°C) Max.	Temperature (°C) Min.	Rain fall (mm)	Relative humidity (%)
16-02-1994	28.50	73.50	30.60	24.00	—	79.75
17-02-1994	29.50	74.75	30.90	23.00	—	76.00
18-02-1994	29.50	76.75	31.00	24.00	—	75.00
19-02-1994	29.75	78.25	31.00	24.00	—	77.50
20-02-1994	29.75	74.75	31.50	24.00	—	76.50
21-02-1994	29.75	78.25	31.50	24.00	—	71.50
22-02-1994	28.75	81.25	30.90	24.00	—	70.50
23-02-1994	30.00	74.50	31.00	23.50	—	87.50
24-02-1994	30.00	72.50	31.20	22.60	—	81.00
25-02-1994	30.25	74.00	31.00	24.00	—	71.00
26-02-1994	29.25	70.00	31.00	22.60	—	79.50
27-02-1994	30.25	74.00	30.90	21.40	—	81.50
28-02-1994	29.25	72.25	30.60	19.80	—	61.00
1-03-1994	29.25	67.25	30.40	19.75	—	73.50
2-03-1994	29.00	65.00	30.65	19.50	—	72.50
3-03-1994	29.00	69.37	31.10	20.00	—	80.50
4-03-1994	28.75	74.50	31.15	20.60	—	63.00
5-03-1994	29.50	72.00	31.20	21.00	—	77.00
6-03-1994	30.75	38.25	31.50	21.50	—	70.50
7-03-1994	31.75	73.50	31.90	23.30	—	76.00
8-03-1994	31.00	73.00	32.40	23.50	—	72.00
9-03-1994	30.50	70.75	32.00	22.00	—	72.50
10-03-1994	29.87	70.25	32.10	20.00	—	73.00
11-03-1994	30.00	73.00	31.50	20.20	—	68.00
12-03-1994	30.25	75.00	31.75	20.20	—	81.00
13-03-1994	30.00	75.50	32.25	21.00	—	75.50
14-03-1994	30.62	74.25	32.45	21.20	—	75.50
15-03-1994	30.25	78.00	32.20	22.00	—	77.50
16-03-1994	30.00	75.25	32.00	24.00	—	75.50
17-03-1994	29.62	74.00	31.60	24.50	—	85.00
18-03-1994	30.00	73.50	32.50	24.50	—	75.75
19-03-1994	30.25	74.00	32.60	23.50	—	82.00
20-03-1994	31.00	74.75	32.25	23.00	—	81.50
21-03-1994	30.86	76.25	32.10	23.50	—	82.50
22-03-1994	30.87	76.00	32.30	25.00	—	82.50
23-03-1994	30.25	75.25	32.50	25.50	—	82.25
24-03-1994	31.00	75.50	32.55	26.00	—	82.00
25-03-1994	30.50	79.00	32.30	26.00	—	79.50
26-03-1994	30.37	75.25	32.00	26.00	—	82.00
27-03-1994	30.00	74.25	32.45	25.60	—	82.00
28-03-1994	29.75	77.25	32.50	26.20	—	91.00

APPENDIX - III

Weather data : Inside and outside the rearing house - Third Season

Date	INSIDE HOUSE		OUTSIDE			
	Temperature (°C)	Relative humidity (%)	Temperature (°C) Max.	Temperature (°C) Min.	Rain fall (mm)	Relative humidity (%)
23-05-1994	28.50	83.00	31.50	24.50	44.00	84.50
24-05-1994	28.50	84.75	30.50	20.50	6.80	84.00
25-05-1994	28.87	84.25	31.40	24.80	6.80	88.50
26-05-1994	28.50	82.00	31.30	24.40	4.00	94.50
27-05-1994	29.25	80.50	29.60	25.00	---	92.00
28-05-1994	27.00	85.00	30.20	23.00	42.00	96.00
29-05-1994	25.87	88.25	29.50	23.00	20.00	90.00
30-05-1994	26.75	89.00	29.20	23.20	13.00	95.25
31-05-1994	26.25	87.25	29.50	23.00	23.00	95.25
1-06-1994	26.50	87.25	29.00	22.60	17.60	85.00
2-06-1994	26.50	87.00	31.50	23.50	10.40	97.00
3-06-1994	27.25	87.00	30.50	23.00	20.60	82.50
4-06-1994	27.75	84.50	29.50	23.50	7.40	95.25
5-06-1994	27.12	90.00	30.00	23.50	22.80	93.00
6-06-1994	26.75	88.25	29.50	23.50	33.20	87.00
7-06-1994	27.00	85.75	29.00	24.00	15.80	85.00
8-06-1994	27.25	84.25	29.00	24.50	2.40	85.00
9-06-1994	27.25	84.00	29.00	23.50	8.40	85.00
10-06-1994	26.87	89.00	30.00	23.00	22.40	84.50
11-06-1994	26.87	86.00	29.00	23.00	19.00	87.00
12-06-1994	27.50	82.00	28.50	23.00	6.20	85.00
13-06-1994	28.75	77.25	30.50	23.00	---	96.50
14-06-1994	28.25	80.25	30.50	24.00	1.40	92.00
15-06-1994	28.37	81.75	31.60	23.50	4.20	96.50
16-06-1994	27.00	88.25	30.00	22.50	1.40	87.50
17-06-1994	28.25	81.50	29.80	23.50	23.00	90.00
18-06-1994	27.75	83.75	29.50	24.70	2.80	87.50
19-06-1994	29.75	81.37	30.20	25.40	---	84.00
20-06-1994	29.00	78.75	30.20	25.50	---	84.00
21-06-1994	28.50	83.25	30.00	24.70	---	86.00
22-06-1994	29.25	85.00	30.00	24.60	---	81.50
23-06-1994	28.75	83.37	30.40	24.50	---	82.00
24-06-1994	29.25	79.20	30.00	24.30	---	81.50
25-06-1994	28.75	80.75	30.00	24.00	---	78.50
26-06-1994	28.00	84.00	29.80	24.00	---	78.50
27-06-1994	28.50	79.25	30.50	25.00	1.20	83.00
28-06-1994	28.75	79.62	30.50	24.00	1.20	75.50
29-06-1994	28.50	83.25	30.50	23.80	1.20	80.00
30-06-1994	29.00	73.00	30.40	24.80	---	73.00
1-07-1994	29.62	74.25	30.50	24.60	---	74.00
2-07-1994	28.00	80.75	30.60	24.50	---	73.00

PERFORMANCE OF MULBERRY SILKWORM RACES AND HYBRIDS IN KERALA

By

GEORGE THOMAS

ABSTRACT OF THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE
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ABSTRACT

Silkworm rearing experiment was conducted in the rearing house of the sericulture section in the Department of Agricultural Entomology, College of Agriculture, Vellayani in 93-94 to identify a pure race and cross breed suitable for rearing in the southern districts of Kerala, with reference of productivity and commercial quality of cocoons.

The trial was conducted with completely randomized design and the treatments were replicated thrice. Four replications were used for studying the fecundities and female pupal weight of pure races. The experiment was repeated in three seasons viz. cold season during December-January, summer season February-March and rainy season during May-June.

The percentage of missing larvae during early instars was least in the cross breeds which were on par and pure races suffered heavy loss.

Cross breed PM x NB_4D_2 was superior to others in case of total larval duration, disease incidence, percentage

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of spinning and cocoons yield. Among the bivoltines NB_4D_2 performed best with shortest larval period, less disease incidence, higher percentage of spinning and higher cocoon yield. It was superior to other bivoltines during most seasons. It consumed maximum food had highest growth index and larval weight in all seasons. Cocoon characters viz. shell weight, shell ratio, cocoon size and reelability of cocoons were also higher. Single cocoon weight, fecundity and female pupal weight were higher in KA.

NB_7 was heavily infected with diseases in stock rearing itself.

Of the cross breeds, PM x NB_4D_2 was superior to other cross breeds in respect of all parameters during the different seasons except in single cocoon weight. In this case PM x KA performed well.

Leaf consumption, weight, length and growth index of fifth instar larva, percentage of spinning and yield of cocoons, size of cocoons, single cocoon weight, shell weight, shell ratio, fecundity and female pupal weight were reduced in summer season. But disease incidence was increased and missing percentage of larvae during early instars, total larval duration, and reelability were not affected by climate.