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EVALUATION OF MULTI X BI BIVOLTINE HYBRIDS OF SILKWORM *Bombyx mori* L.

By

RAJENI NARAYANAN

THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
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DECLARATION

I hereby declare that the thesis entitled **'Evaluation of multi x bi and bivoltine hybrids of silkworm *Bombyx mori* L.'** 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, fellowship or other similar title, of any other University or Society.

Vellanikkara
21.8.98

RAJENI NARAYANAN

Dr.A.M. Ranjith
Associate Professor
Department of Agricultural Entomology
College of Horticulture

Vellanikkara

CERTIFICATE

Certified that the thesis entitled **'Evaluation of multi x bi and bivoltine hybrids of silkworm *Bombyx mori* L.'** is a record of research work done independently by **Mrs.Rajeni Narayanan**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellanikkara
26.8.98

A.M. Ranjith
Chairman, Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mrs.Rajeni Narayanan,** a candidate for the degree of **Master of Science in Agriculture** with major in **Agricultural Entomology**, agree that the thesis entitled **`Evaluation of multi x bi and bivoltine hybrids of silkworm *Bombyx mori* L.'** may be submitted by Mrs.Rajeni Narayanan in partial fulfilment of the requirement for the degree.

Dr.A.M.Ranjith
Associate Professor
Department of Agricultural Entomology
College of Horticulture
Vellanikkara

Dr.Jim Thomas
Associate Professor and Head
Department of Agricultural Entomology
College of Horticulture
Vellanikkara

Dr.M.V.Rajendran Pillai
Associate Professor
Department of Plant Pathology
College of Horticulture
Vellanikkara

Dr.C.C.Choudhuri
Deputy Director
Central Silk Research and Training Institute
Mysore

EXTERNAL EXAMINER

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RAJENI NARAYANAN

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

INTRODUCTION

Silk constitutes a romantic past of Indian history. In fact, milleniums before the utility of silkworm was discovered by a princess overland Himalayas, scriptures and epics are replete with references to silk in India, indicating that obtaining silk from nature was already known to pre-Aryan civilisation in the country.

To begin with, silk clothed only kings and queens and remained far away from the reaches of commoners. As the clientele was confined to a few, so was the industry.

It was perhaps only in the 20th century, that silk started reaching other people. As the demand expanded, the industry set on spreading. By the time India won freedom, sericulture had already rooted deep into the mass and milieu of rural India.

India is a vast country with varying climatic conditions in different agro-climatic zones. The precipitation rate, temperature and humidity vary from season to season and zone to zone. Among the different zones, tropical region experiences the highest temperature. The high rainfall areas and the coastal regions also experience high humidity and precipitation during summer and monsoon respectively.

Traditionally in India, sericulture was confined to Kashmir and U.P. in the north, West Bengal and Assam in the east, Karnataka, Andhra Pradesh and Tamil Nadu in the south. Of late, sericulture has been introduced in almost all the states.

In Kerala, sericulture was practised in small isolated pockets as far back as seventies. In the beginning, its development was very slow possibly due to the lack of enough technical guidance. However, during 1985-86, Central Silk Board, through its extension centres introduced and popularised sericulture in an organised way in parts of Palakkad and Idukki districts of Kerala (Anon, 1996).

The silkworm, *Bombyx mori* L. is an obligate feeder of mulberry leaves. It feeds continuously during five instars of larval period to spin the cocoon. Cocoon characters, both quantitative as well as qualitative depend largely on the quantity and quality of leaves (Koul, 1986, 1989; Koul *et al.*, 1979; Dar *et al.*, 1988). Quantity is purely a physical attribute largely dependant on the management of rearing. Leaf consumption directly affects the silk producing capacity of the silkworm (Muthukrishnan *et al.*, 1978). Sumioka *et al.* (1982) observed that leaf consumption influenced body weight which in turn affects the silk output.

The climatic conditions of Kerala are favourable for mulberry cultivation and silkworm rearing in all seasons. Still, sericulture remains only as a subsidiary occupation and is practised only as a sort of mixed crop or inter crop with other traditional cash crops. In Kerala, the labour cost is very high and labour availability uncertain. In this set up, sericulture, a labour intensive enterprise has some set back. High rainfall and humidity prevailing during major part of the year adversely affects cocoon quality especially the reeling parameters. High yielding mulberry varieties and superior silkworm races tolerant to high humidity conditions can become an effective tool for development of sericulture industry in Kerala. Much of the sericulture in Kerala is done using Kanva-2 (K-2) mulberry variety. Other varieties suited for the region have to be evaluated.

Traditionally in India, pure multivoltine races, were being reared. Of late, there has been a shift to bivoltine races, but there are still a lot of problems with respect to their adaptability. The stress now has to be on the F_1 hybrids of both multi x bi or bivoltine races to exploit hybrid vigour to the maximum. Since cocoon production is both season and region specific it is necessary to identify hybrids most suitable for every season.

So the present study was undertaken to

(i) identify the best season specific multi x bi and bivoltine races of silkworm suitable for Vellanikkara conditions

(ii) evaluate the cultivar S-36 of mulberry as against the conventional K-2.

Review of Literature

2. REVIEW OF LITERATURE

The review of literature pertaining to the characters under study are presented below:

Vijayaraghavan *et al.* (1987) found MYI, a new multivoltine race to hold promise. Gupta *et al.* (1992) carried out heterosis studies of commercial characters of bivoltine hybrids of six female (JD_6, SH_6, YS_3, SF_{19}, YS_5 and SF_4) and three male (NB_4D_2, C_{122} and KA) component races and found KA as the better male component. In Karnataka, PM x *C. nichi* is a very popular hybrid (Jayaswal *et al.*, 1992). NB_4D_2 x KA, KA x NB_4D_2 and KA x NB_7 were found to be the most superior in that order from among 12 bivoltine hybrids tested at Udaipur by Jyothi and Tyagi (1992). Gururaj *et al.* (1993) evaluated four yellow multivoltine races (RD_1, P_2D_1, AP_2 and PA_{11}) three white multivoltines (KW, KW_2 and GNP) along with the native strain (PM) in Tamil Nadu. All new multivoltines were superior in economic traits and they recommended production of hybrids using RD_1 and P_2D_1.

2.1 Larval characters

Viswantha (1987) reported that cross breeds namely PM x NB_4D_2 and PM x NB_{18} have shorter larval duration than NB_4D_2 and NB_{18} and Pure Mysore. He also observed that bivoltine race NB_4D_2 has the highest fifth instar larval weight of 3.4043, 3.4811 and 3.5316 g during August-September '85, December '85-January '86 and May-June '86 respectively than NB_{18} and the cross breeds PM x NB_4D_2 and PM x NB_{18}.

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

Raju *et al.* (1989) carried out a study to examine the performance of some single and 3-way cross hybrids of *Bombyx mori* involving *C. nichi* as one of the parental breeds. In general, bivoltine hybrids showed superiority for larval weight whereas multi x bivoltine and three way cross hybrids performed better for progression upto the fourth instar and shorter larval duration.

Rahman *et al.* (1991) evaluated the performance of six multivoltine races of *B. mori*, Nistari, Nistari-L, BSRI-85/1, BSRI-85/3, BR-84 and NN7B with respect to larval, pupal and cocoon characters during the chaita rearing season (March-April). When compared with Nistari-L, all races had increased mean larval weights, larval lengths and head capsule lengths.

Jayaswal *et al.* (1992) revealed that Multi x bivoltine hybrids exhibited significantly high superiority over multi x multi hybrids for larval weight.

In a study conducted to correlate the economic parameters of bivoltine and multivoltine hybrids (NB_4D_2 x KA and PM x NB_4D_2). Anantharaman *et al.* (1995) reported that larval weight was negatively correlated with cocoon and shell weights in bivoltine hybrids.

Larval weight had no significant correlation with cocoon, shell weight and nutritional parameters in multivoltine hybrids.

Singh *et al.* (1995) studied the relationship between larva, cocoon, pupa and fecundity in bivoltine females of *B. mori* and found that all parameters were positively correlated with each other.

In a study undertaken by Singh *et al.* (1996) the larval weight was seen to be positively correlated with both silk gland weight and shell weight.

In an attempt to identify new bivoltines for tropical conditions, Rao *et al.* (1997) identified four new bivoltine hybrid combinations namely NP_2 x KSO_1, SP_2 x KSO_1, KSO_1 x NP_2 and KSO_1 x SP_2 for commercial consideration. These hybrids had higher survival rate of 90-95 per cent and a larval duration which was shorter by one to two days.

2.2 Food consumption and utilisation by the larva

The food consumption by the larvae of bivoltine races namely NB_4D_2 and KA was two times more than that of PM as reported by Prakash and Delvi (1987).

Anantharaman *et al.* (1992) found that when multi x bivoltine hybrid PM x NB_4D_2 was reared on K-2 mulberry variety it was very efficient in utilising dry matter for body growth.

Anantharaman *et al.* (1995) in a correlation study on economic parameters of bivoltine and multivoltine hybrids of silkworm (viz., NB_4D_2 x KA and PM x NB_4D_2) found that there was significant positive correlation between larval weight and dry matter digested and approximate digestibility.

Chandramani (1997) reported that the efficiency of conversion of ingested food was maximum when *B. mori* was reared on S-36 mulberry variety.

2.3 Cocoon characteristics

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

Chandrashekaraiah *et al.*, (1981) stated that the performance of bivoltines was superior to multi x bivoltine hybrids in Bangalore and Kolar districts. Hybrids of PM x NB_4D_2 yielded 50.1 kg cocoons per 100 layings while bivoltine hybrids NB_{18} x KA and NB_4D_2 yielded 45.3 and 43.6 kg cocoons per 100 layings respectively.

Jolly *et al.* (1981) observed that the average reelability of bivoltine cocoons are 67 per cent while that of multivoltines are 59 per cent.

Siddappaji *et al.* (1983) noticed that cocoon yield of PM, NB_{18}, NB_4D_2 and the cross breed of PM x NB_{18} and PM x NB_4D_2 showed a wide range of diversity.

He and Oshiki (1984) suggested that it is preferable to use bivoltine females with multivoltine males in silkworm crosses.

The cocoon weight and shell weight of PM x NB_4D_2 were higher than that of PM x NB_{18} as reported by Ravi (1986).

In Marathwada, out of the twelve hybrids tested by Tayade (1986) PM x NB_4D_2 showed very high positive heterosis for single cocoon weight, shell weight, filament length and yield of cocoons.

Siddappaji *et al.* (1987) revealed in a study that cross breed PM x NB_4D_2 gave better yield than PM x NB_{18}.

Benchamin *et al.* (1988) opined that the cocoon weight was significantly higher in crosses using multivoltine as a female parent than in crosses using bivoltine as female parent.

An evaluation on the performance of some hybrids of mulberry silkworm *B. mori* L. in Konkan by Nahar *et al.* (1989) revealed that the hybrid races NB_7 x NB_{18} and CA_2 x NB_{18} were at par with each other in filament length, silk percentage, percentage reelability and hence superior to other hybrids viz., NB_4D_2 x PCN, CC1 x NB_{18} and MYS x NB_{18}.

Effective rate of rearing (ERR) was investigated in four breeds of *B. mori* viz., KA, NB_4D_2, NB_7 and NB_{18} using five varieties of mulbery viz., S-30, S-36, S-41, S-54 and K-2 by Giridhar and Reddy (1991). They reported that although different breeds performed differently on different mulberry varieties, all gave high ERRs on variety S-36 and lower ones on S-41. The silkworm breed NB_7 had highest ERR and KA the lowest. NB_4D_2 and NB_{18} were intermediate.

In a study by Basavaja and Datta (1992) involving six bivoltines (KA, NB_7, NB_{18}, NB_4D_2, CC_1 and CA_2) and their hybrids, it was found that CC_1 and CA_2 helped in improving shell ratio to 22 per cent from 20.8 per cent of the existing hybrids (KA x NB_4D_2 or NB_7 x NB_{18}). They also increased most of the qualitative traits.

Anantharaman *et al.* (1995) observed that cocoon weight was positively correlated with shell weight in both multi x bivoltine hybrids and bi x bivoltine hybrids.

Crosses in all possible combinations including reciprocals were made with five popular Indian bivoltine races of silkworm *B. mori* by Bhargava *et al.* (1995). The highest silk productivity was achieved with the cross CC_1 x NB_4D_2.

In yet another evaluation of traditional and new multi-bi hybrids of silkworm, *B. mori* across seasons, Raju and Krishnamoorthy (1995) reported that the new multi x bi hybrids viz., Pm x MG 511, PM x MG 521, PM x MG 512 and PM x MG 522 showed better cocoon weight, shell weight and cocoon shell percentage thus heralding increased yield by weight compared to the traditional multi-bi hybrids viz., PM x KA, PM x NB_7, PM x NB_{18} and PM x NB_4D_2 during all seasons of the year.

Test reeling performance of cross breed cocoons reared under National Sericulture Project, at Palakkad, Kerala gave the following results. The shell percentage ranged from 15.76 to 16.57. The average filament length from 504.17 to 611.13, denier from 1.98 to 2.51, reelability from 29.33 to 66.28 and renditta from 10.18 to 18.20. Test reeling performance of bivoltine cocoons under the same project showed that the shell percentage ranged from 18.55 to 20.70, average filament length from 657.45 to 894.78, denier from 1.98 to 3.17, reelability from 40.25 to 58.45 and renditta from 7.8 to 9.22 (Anon, 1996).

In a study conducted in Koraput district of Assam, it was found that multi x bi combinations of PM x JD_6 and N x JD_6 gave a higher cocoon yield than multi x multi (N x PM and S x KW_2) or Bi x Bi (K x NB_4D_2 and P_5 x JD_6) combinations throughout the year (Senapati *et al.*, 1996).

Rao *et al.* (1997) identified four new bivoltine hybrid combinations suited for tropical conditions namely NP_2 x KSO_1, SP_2 x KSO_1, KSO_1 x NP_2 and KSO_1 x SP_2. These had better cocoon weight (1.7 to 1.98), better cocoon-shell ratio (20-22 per cent), lesser melting percentage (3-4 per cent), better reelability and lower renditta (6.5-6.9).

2.4 Pupal characteristics

A significant correlation between female pupal weight and fecundity was established by workers like Shamachary and Krishnaswamy (1980) and Gowda *et al.* (1988).

A study on the influence of pupal weight on fecundity, rearing and post cocoon parameters in the *B. mori* bivoltine race NB_{18} indicated that moderate and heavy pupal weight greatly influence egg production potential as well as rearing and post cocoon parameters (Narayanaswamy and Gowda, 1989).

Shaheen *et al.* (1992) found out that there was a highly significant and positive correlation between the weight of female pupae and fecundity.

2.5 Varieties of mulberry

The feeding quality of mulberry leaf depends upon the variety and nutrients available in the leaf and this has also been stressed by Toshio and Arai (1963), Radha *et al.* (1978) and Pillai (1979).

Quite a lot of information is available on the growth and economic characters of silkworm (Narayanan *et al.*, 1966; Terkaraptyan *et al.*, 1966; Krishnaswami *et al.*, 1970; Shyamala *et al.*, 1978; Pillai and Jolly, 1985 and Sharma *et al.*, 1986).

In an attempt to isolate a good mulberry variety suitable for bivoltine *B. mori* L. Bheemanna *et al.* (1989) concluded that maximum progression upto fourth instar was achieved on NB_7 and NB_{18} with cultivar S-36.

An assessment of the response of silkworm hybrid NB_4D_2 x NB_2C_1 to seven mulberry varieties namely S-30, S-36, S-41, S-54, K-2, Assamabola x Philippines and English Black x Kosen during different seasons revealed that varieties S-30, S-36, S-54 and Assamabola x Philippines gave sufficiently higher single cocoon weight over local (Nataraju *et al.*, 1989).

In a study by Das and Vijayaraghavan (1990) using improved varieties of mulberry viz., S-36, S-41 and S-54 compared to K-2 it was found that the mean larval weight with variety S-36 was significantly increased over K-2. There was no effect of varieties on the larval duration. The cocoon weight was highest with variety S-41 and K-2. Variety S-36 was reported to be on par with S-41 and K-2 regarding cocoon weight. Highest single shell weight and shell percentage was obtained with S-41 and S-36 varieties.

Raju *et al.* (1990) conducted a study with four popular bivoltine silkworm breeds viz., NB_7, NB_{18}, NB_4D_2 and KA in order to evaluate their comparative performance when reared on 3 mulberry varieties in high altitude conditions of Nilgiris (Tamil Nadu). It was observed that breeds NB_7 and NB_{18} performed better than NB_4D_2 and KA. The nutritive quality of Kosen variety was found better than that of Kanva-2 and MR-2 varieties.

Bose *et al.* (1991) made a comparative biochemical evaluation of six popular mulberry varieties so as to spot out the most nutritive one. The results revealed that the percentage of reducing and non-reducing sugars, total sugars, starch, total carbohydrates, water soluble proteins and total free amino acids were maximum in S-41 variety. Of this, the water soluble protein and total free amino acid contents were equal to that of S-36 and K-2 varieties.

Gaur *et al.* (1991) reported that for rearing a bivoltine strain of *B. mori*, S-1 (Mandalay) was the best mulberry variety in Uttar Pradesh.

In a work undertaken to evaluate the effect of different mulberry varieties on the Effective Rate of Rearing (ERR) of silkworm *B. mori*, Giridhar and Reddy (1991) reported that of the varieties S-30, S-36, S-41, K-2 and S-54, S-36 gave higher ERR values for all the silkworm breeds.

A volumetric study was conducted in bivoltine silkworm *B. mori* by Giridhar *et al.* (1991) using different mulberry varieties. The breeds used were KA, NB_4D_2, NB_7 and NB_{18} and they were reared on S-30, S-36, S-41, S-54 and K-2 mulberry varieties. All the silkworm breeds registered minimum values for larval and silk gland volumes with S-41 mulberry variety. These values were more when reared on K-2 mulberry variety.

Chandramani (1997) in a work undertaken to study the nutritional indices of mulberry silkworm, *B. mori* reported that the variety S-36 had a high total mineral content and that it gave a higher growth rate in the silkworm.

2.6 Effect of seasons

Gowda and Ravi (1986) found PM x NB_4D_2, PM x NB_{18} and PM x *C. nichi* to perform in that order in Karnataka. The best season was December-January and the poorest yields were in May.

The biology of *B. mori* and yield and quality of silk was studied in the spring and autumn seasons in Punjab, India, by Harcharan Singh and Mavi (1986). Of the three spring crops and one autumn crop the quantity and quality of silk was best in the first spring crop followed by autumn crop.

It was found that seasons and races were significant for all characters valuable in silkworm breeding while interactions of races x seasons were significant for fecundity and pupation rate during all seasons (Pershad *et al.*, 1986).

The findings of Venkatagiriyappa *et al.* (1989) indicate that PM x NB_{18} was superior in whole cocoon weight (2.022 g) during rainy season compared to PM x NB_7 (1.2 g). However, they performed equally during summer season though significantly inferior compared to rainy season. A similar trend in racial and seasonal performance was observed for shell and pupal weight.

Das and Vijayaraghavan (1990) initiated a study to ascertain the feeding quality of three improved varieties of mulberry viz., S-36, S-41 and S-54 over K-2 in different seasons on the various economic characters of silkworm. The study indicate that seasonal changes have profound effect on the growth and quality of mulberry leaves which in turn affect silkworm health and cocoon crop production. The unfavourable rearing season was found to be April-May, while the best rearing season was from August to January.

The performance of seven sex limited races of bivoltine *B. mori* (G 109, G 153, G 118, G 113, G 105, G 128 and G 111) were evaluated for ERR per 10000 larvae brushed, single cocoon weight, single shell weight, shell ratio and filament length in spring, summer and autumn 1989-91. ERR and filament length varied slightly with race. All characters varied with season (Bhargava *et al.*, 1993).

Kerala Agricultural University conducted a project during 1980-83 to study the adaptability of sericulture in Kerala, in multi locational trial in the districts of Trivandrum, Idukki and Wynad and all the three districts were found to be suitable. It is also reported that bivoltine race is adapted to Trivandrum, Idukki and Ambalavayal (Anon, 1983).

In a study conducted to assess the performance of some hybrids of bivoltine silkworm *B. mori*, Chathopadhyay *et al.* (1994) reported that the percentage survival of all the hybrids was more than 80 during the favourable season, but in the unfavourable season it was below 60 per cent except in the case of KPG x NB_7.

During summer season, incidence of grasserie was more with NB_4D_2 than PM and cross breeds. In rainy season, bivoltine races were more susceptible to flatcherie and grasserie (Anon, 1994).

A study was undertaken to monitor the sex ratios, in culture of multivoltine (PM) and bivoltine (NB_4D_2) *B. mori* by Dwarakinath and Ramanjaneyulu (1995). They observed that there were fewer females than males in both races, and that there was little or no seasonal effect on sex ratio.

Prasad *et al.* (1996) conducted a study about the prospects of multi x bivoltine silkworm cross breeds in Assam during spring and summer crop. The multivoltine races studied were Sarupat (S), MY_1, MY_2 and Graces with four bivoltine races viz., NB_7, NB_{18}, KPG(B) and P_5. Rearings were conducted during March-April, May-June and July-August. The crosses S x P-5, MY_1 x NB_7, MY_1 x NB_{18}, S x NB_{18}, MY_2 x NB_{18}, G x KPG(B) and MY_2 x KPG(B) were found to be better for the region during the above mentioned seasons.

In Karnataka, the average yield/100 dfl's of multivoltine has always been higher when compared to bivoltine hybrids. However, bivoltine rearing has given a better yield during July and January-February. The environmental conditions, disease occurrence and cocoon yield reveal that two seasons, viz., July and January-February are favourable for bivoltine rearing (Rao *et al.*, 1997).

2.7 Disease and pest incidence

Studies in Maharashtra (Teli *et al.*, 1984) showed that though Mysore hybrids NB_7 x NB_{18} and NB_{18} x NB_7 were efficient than wai strains in converting mulberry leaves to silk, they were susceptible to diseases.

Rajanna *et al.* (1986) stated that bivoltine races of silkworm are excellent in quality and quantity but has poor disease resistance. They have described increased disease resistance of bivoltine Kalimpong-A (KA) by selection and crossing to males of multivoltine Pure Mysore.

Use of RD_1 x NB_{18} gave 80 per cent increase in yield and 160 per cent increase in average returns. It was shown that the hybrids of even susceptible parents showed improved resistance to nuclear polyhedrosis virus (Baig *et al.*, 1991).

Materials and Methods

3. MATERIALS AND METHODS

The present study was undertaken to identify region and season specific multi x bi and bivoltine hybrids of *Bombyx mori* with the conventional mulberry variety K-2 and the upcoming variety S-36, suitable for Vellanikkara conditions.

The rearing was conducted in the rearing house under the Department of Entomology, College of Horticulture, Vellanikkara in 1996 during four seasons namely January-February, March-April, May-June and June-July.

3.1 Materials

3.1.1 Mulberry leaves

The leaves of both K-2 and S-36 which were required for the rearing of the worms were collected from the standing crop attached to the rearing house. The plants were pruned 70 days prior to the actual brushing and were manured using FYM @ 20 t/ha and NPK as per the standard recommendations. Flood irrigation was administered, once a week, so as to maintain an optimum level of moisture content in the leaves.

3.1.2 Silkworm eggs

The breeds of silkworm used for the study were the following:

Multivoltine	- Pure Mysore as control
Multi x Bivoltine	- PM x NB_{18} PM x NB_4D_2
Reciprocal crosses	- NB_{18} x PM NB_4D_2 x PM
Bivoltine crosses	- NB_{18} x NB_4D_2 NB_4D_2 x NB_{18}

The dfls (disease free layings) of the above crosses were procured from the Silkworm Seed Production Centre, Palakkad, an institute under the Central Silk Board.

3.1.3 Rearing appliances

The method of rearing adopted was shelf rearing where in the larvae were reared in trays which were arranged one over the other in tiers, in shelves arranged parallel to the wall. Sufficient space was provided between the trays so that there was room for removing the trays and attending to feeding and bed cleaning operations.

The appliances used were:

3.1.3.1 Rearing stand

Metallic stands 2.5 m high, 1.5 m long and 1 m wide were used to support the rearing trays placed in vertical rows. A rearing stand could accomodate 20 trays i.e., there were two sets of 10 tiers of rearing trays.

3.1.3.2 Rearing trays

The trays used were rectangular in shape with dimension of length 90 cm, breadth 60 cm and 10 cm height. They had a metallic frame on which black nylon mesh was inlaid. These trays were placed one above the other in the rearing stand.

3.1.3.3 Antwells

There were made of concrete, 20 cm square, 7.5 cm high and with a groove of 2.5 cm running all around the top. The purpose was to prevent the ants from crawling on to the rearing trays and attacking the silkworm. They were placed below the legs of the rearing stand and were filled with water.

3.1.3.4 Paraffin paper

These are thick craft paper coated with paraffin wax with a melting point of 55°C. Paraffin papers were used in the rearing trays especially during chawki rearing to prevent withering of chopped leaves and to maintain proper humidity in the rearing bed.

3.1.3.5 Foam rubber strips

Longitudinal strips of 2.5 cm width and 2.5 cm thickness soaked in water were placed all around the bed of young worms. The purpose here again was to maintain optimum humidity conditions inside the rearing bed.

3.1.3.6 Chopsticks

Thin bamboo sticks 17.5 cm to 20 cm length which taper to one end were used to handle young age worms. These sticks were also used to handle diseased worms for hygienic reasons.

3.1.3.7 Feathers

White coloured bird feathers were used for brushing newly hatched larvae from the egg card on to the rearing trays.

3.1.4 Appliances used for feeding

3.1.4.1 Leaf baskets

Bamboo baskets of capacity 20 l were used for collecting and transporting the harvested leaves from the field to the rearing house.

3.1.4.2 Leaf chamber

The purpose of the leaf chamber was to store and preserve the harvested mulberry leaves so as to maintain it fresh for feeding, at specified intervals during the day. The chamber used for the purpose was 1.5 m long 0.9 m wide and 0.8 m deep and made of strips of wooden reapers. It was covered with gunny cloth on all the sides and sprinkled with water periodically to prevent the leaves from withering.

3.1.4.3 Chopping Board

This was used for cutting the mulberry leaves to suitable sizes required for feeding the larvae at different instars. The board used were made from softwood and of the dimensions 0.9 m x 0.9 m with a thickness of 5 cm.

3.1.4.4 Chopping knives

These were used for cutting the mulberry leaves for feeding the larvae. They were sickle like about 0.5 m long and with the cutting edge on the convex side with a broad and sharp blade and a wooden handle.

3.1.4.5 Mats

There were used for collecting cut leaves by placing it below the chopping board. It prevented the dust and the dirt on the floor from getting mixed with the leaves.

3.1.4.6 Feeding stands

These are folding stands about 1 m high made of wood or metal, used for holding the trays during feeding and at bed cleaning.

3.1.4.7 Feeding basins

Made of plastic were used to hold the chopped leaves before feeding.

3.1.4.8 Basin stands

Circular metal frames of about 60 cm height were used to hold the basins with chopped leaves at the time of feeding.

3.1.5 Appliances used for bed cleaning

Cleaning nets: For chawki rearing, nets made of cotton of mesh size 10 mm^2 were used, while for rearing late age worms nylon nets of larger mesh size (20 mm^2) were made use of.

3.1.6 Appliances used to support the spinning larvae or mountages

These are contrivances used for supporting the larvae at the time of spinning of cocoons. Plastic collapsible mountages commonly called as netrika were used for the purpose.

3.1.7 Appliances used for disinfection

3.1.7.1 Knapsack sprayer

A hand operated knapsack sprayer of 9 l capacity was used to spray 2 per cent formalin prior to rearing operation so as to disinfect the rearing house and all the rearing appliances.

3.1.7.2 Mask

This was used by the operator while spraying formalin so as to protect himself from the formalin fumes.

3.1.8 Appliances used for maintaining optimum conditions

3.1.8.1 Thermometer

Used for measuing the temperature.

3.1.8.2 Dry bulb/wet bulb thermometer

Used to measure the humidity.

Disinfection tray filled with bleaching powder solution was kept at the door.

3.1.9 Chemicals used for disinfection

Formaldehyde 40 per cent, bleaching powder and Reshamkeet oushad were used.

3.2 Method

3.2.1 Details of the experiment

The experiment was conducted to find out the adaptability of certain multi x bi and bivoltine races of silkworm *Bombyx mori* L. to Vellanikkara conditions when fed on K-2 and S-36 mulberry variety.

3.2.2 No. of replications - 3

3.2.3 Design of the experiment - CRD-3 factorial

3.2.4 Rearing techniques

3.2.4.1 Disinfection

Disinfection is the destruction of germs causing diseases. Prior to every rearing the rearing house and appliances were cleaned thoroughly. The appliances were sundried in shade. The rearing house was washed using five per cent bleaching power solution (50 g bleaching powder in one litre of water). Afterwards chemical disinfection was also carried out using two per cent formalin (commercially available formalin contains about 36 per cent formaldehyde. One part of this is mixed with 17 parts of water to make two per cent formalin solution). The rearing room was then kept closed for 24 hours for effective disinfection.

3.2.4.2 Black boxing of eggs

Four disease free layings (dfls) of each cross were procured for conducting the rearing and two dfls of each cross were maintained per tray for incubation. The incubation was done at 25°C temperature and 80 per cent RH in trays spread with paraffin paper. Starting from the head pigmentation stage, they were black boxed (kept in dark) by covering the trays with a black paper. After 2 days, when stray hatching started, they were exposed to light so that uniform hatching was obtained.

3.2.4.3 Brushing of silkworm larvae

Two dfls of each cross were fed with K-2 mulberry variety while the remaining two dfls were fed with S-36 mulberry variety. Cut leaves of 0.5 cm x 0.5 cm were sprinkled over the hatched larvae. After about 20 minutes when all the larvae crawled on to the cut leaves, the egg sheet was held upside down, thus transferring the leaves along with the larvae to the freshly prepared rearing tray. Worms still adhering on to the egg cards were brushed to the same tray using a feather.

Wet sponge pads were provided all around the bed and the trays were covered with a second paraffin sheet so as to provide the required temperature and humidity conditions as given below:

First instar	Temperature - 27°C, RH - 85%
Second instar	Temperature - 27°C, RH - 85%
Third instar	Temperature - 25°C, RH - 80%
Fourth instar	Temperature - 22-24°C, RH - 75%
Fifth instar	Temperature - 20-23°C, RH - 70%

3.2.4.4 Feeding of the larvae

Before feeding the mulberry leaves were chopped into specified sizes in the various instars as follows:

I	- 0.5 cm^2 - 2 cm^2
II	- 2.0 cm^2 - 4 cm^2
III	- 4.0 cm^2
IV	- whole leaf
V	- whole leaf

The leaves were preweighed and fed to the larvae four times daily (7 am, 11 am, 3 pm and 7 pm).

3.2.4.5 Bed cleaning

This is the practice of removing old and dry mulberry leaves, faecal matter of silkworms, exuviae and dead or unhealthy silkworm from the rearing bed. Bed cleaning was adopted once in the 1st instar, twice in the second instar and daily during the later instars. For chawki rearing cotton nets of 2-10 mm^2 were used. But for late age worms the nets used were nylon nets of 20 mm^2 size.

The net was spread covering the full rearing bed in the morning (7 am) and the feeding was given above the net. At the time of the next feed (11 am) the net along with the worms above it, was transferred to another newly prepared tray and fresh feed was given.

3.2.4.6 Mounting

This is the operation of picking up the fully matured silkworms from the rearing bed and distributing in proper frames called `mountages', in order to facilitate spinning.

Plastic collapsible mountages were used for the purpose. A newspaper was spread on the tray before the mountage was arranged in it, so that the urine and faeces of the larvae do not fall into trays kept underneath and stain the cocoons. The spinning worms along with the mountages were kept in a separate room, where the temperature and relative humidity were maintained at 25°C and 60-70 per cent respectively. Continuous air current was also maintained in the room so as to remove excess moisture and improve the reeling qualities of the cocoon. The mounting density was also maintained at 40-60 worms per square feet.

3.2.4.7 Harvesting of cocoons

Though the spinning of the cocoon is completed in two to three days, the worms inside the cocoon turns to pupa only on the 4th or 5th day. So harvesting of cocoons was done on the 6th day of spinning.

3.2.5 Observations recorded

The larval observations were recorded at the rearing house itself, while observations on reeling parameters were recorded at the Demonstration Cum Training Centre under Central Silk Board.

3.2.5.1 Larval duration

The larval duration from the day of hatching upto spinning was recorded in hours.

3.2.5.2 Leaf consumption

The quantity of leaves given at the time of feeding was noted. At the time of bed cleaning the fresh weight of the left over leaf was noted in grams. Thus leaf consumption was recorded at every instar.

3.2.5.3 Mature larval weight

This was recorded one day prior to spinning when the worms showed maximum weight. Ten larvae were selected at random from each tray and weighed in a digital electronic balance. From this, the weight of one larva was calculated.

3.2.5.4 Mature cocoon weight

After the harvest of cocoons, 10 cocoons were selected at random from each replication and the weight recorded using a digital electronic balance.

3.2.5.5 Shell weight

The same cocoons were cut open and the pupa taken out. The shell weight was recorded individually for each replication.

3.2.5.6 Shell ratio percentage

This gives a fair indication of the quantity of raw silk that can be reeled from a lot of fresh cocoons. It was calculated in percentage as

$$\frac{\text{Weight of the cocoon shell}}{\text{Weight of the whole cocoon}} \times 100$$

3.2.5.7 Length of the filament

This is calculated based on the total length of reeled silk and the actual number of filament casting, required for reeling it. The workload and efficiency of reeling as well as the evenness of the reeled silk depends upon the average length of unbroken filament actually available for reeling.

3.2.5.8 Denier of cocoon filament

The size or the denier of silk thread is measured gravimetrically by taking a constant length of 450 m and weighing it in units of denier 0.05 g or for convenience 9000 m in gram units. It is calculated as

$$\frac{\text{Weight of reeled silk}}{\text{Length of reeled silk}} \times 9000$$

3.2.5.9 Reelability

This is the suitability of cocoons for economic reeling or the ease with which the cocoons yield the bave in reeling. This was got assessed by the Demonstration cum Training Centre, Palakkad.

3.2.5.10 Effective rate of rearing

This is the yield of cocoons from 10000 larvae and is expressed either in numbers or weight in kg.

3.2.5.11 Meteorological data

Meteorological data at the time of rearing is given in Appendix 16. Correlations were worked out between the important economic parameters of the silkworm and the meteorological data.

Results

4. RESULTS

The present study was undertaken to identify region and season specific multi x bi and bivoltine hybrids of *Bombyx mori* L. with the conventional mulberry variety K-2 and the upcoming variety S-36, suitable for Vellanikkara conditions.

In order to achieve the objectives given under Chapter 1, rearing was conducted in the rearing house under the Department of Entomology, College of Horticulture, Vellanikkara and the necessary observations were recorded.

The observations were statistically analysed using the M-Stat Package programme available at the College of Horticulture, Vellanikkara.

4.1 Leaf consumption during the first instar

Consumption of leaf by the first instar larvae of the different hybrids on the K-2 and S-36 mulberry varieties for the four rearing periods is given as Table 1.

It was observed that during the first instar, leaf consumption was highest with S-36 mulberry variety (6.689 g) than with K-2 variety (6.520 g).

Among the hybrids, PM x NB_4D_2 was superior when reared using K-2 mulberry variety (6.962 g). On S-36 however, the bivoltine hybrid NB_4D_2 x NB_{18} consumed the highest quantity (7.063 g), followed by NB_{18} x NB_4D_2 (6.963 g). NB_{18} x NB_4D_2, PM x NB_{18}, NB_4D_2 x PM and PM x NB_4D_2 were on par with the superior. NB_{18} x PM and PM consumed the lowest quantity of leaf and were not significantly different from each other.

Table 1. Consumption of leaf by the first instar larvae of silkworm hybrids on two varieties of mulberry during 4 rearing periods (g fresh weight/100 larvae)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	6.900	6.000	7.150	6.150	6.550	7.050	6.350	7.000	7.250	6.913	6.731
NB_{18} x PM	6.050	6.200	6.250	5.800	6.075	6.050	6.650	5.650	6.250	6.150	6.113
PM x NB_4D_2	7.350	7.050	6.650	6.800	6.962	7.400	6.750	5.650	6.500	6.575	6.769
NB_4D_2 x PM	5.800	6.050	7.300	6.700	6.463	6.350	6.200	7.500	7.300	6.837	6.650
NB_4D_2 x NB_{18}	6.900	7.050	6.400	5.750	6.525	7.650	6.250	7.950	6.400	7.063	6.794
NB_{18} x NB_4D_2	7.150	5.900	6.500	7.300	6.713	7.150	6.650	7.650	6.400	6.963	6.838
PM	6.250	6.650	7.100	5.400	6.350	7.250	6.950	5.500	5.550	6.325	6.338
Mean	6.629	6.414	6.764	6.271	6.520	6.986	6.543	6.707	6.521	6.689	6.604

CD (0.05)

CD (0.05)	Races	= 0.3473
	Season	= 0.2624
	Race x season	= 0.6943
	Race x season x mulberry	= 0.9819

On K-2 the hybrid NB_{18} x NB_4D_2 did not exhibit any significant difference with PM x NB_4D_2. But the crosses PM x NB_{18}, NB_4D_2 x NB_{18} and NB_4D_2 x PM were significantly different from the superior. However, the multivoltine PM race was on par with NB_{18} x PM which consumed the lowest quantity of leaf (6.075 g).

Seasonal change had a significant effect on the leaf consumption during the first instar. When fed on K-2, the third season was the best recording the highest consumption (6.764 g). The first season was on par with the third. The least consumption was seen during the fourth season.

However, when reared on S-36, the first season was the best. The remaining 3 seasons differed significantly from this, though the second, third and fourth seasons were on par.

The interaction between races and seasons and that between mulberry, races and seasons were also significantly different.

4.2 Leaf consumption during the second instar

Data pertaining to the leaf consumption by the different hybrids of silkworm on the two different varieties of mulberry during the four experimental seasons are given in Table 2.

During the second instar, the consumption of mulberry varieties exhibited significant difference. The interaction between mulberry and races was also significant.

Table 2. Consumption of leaf by the second instar larvae of silkworm hybrids on two varieties of mulberry during 4 rearing periods (g fresh weight/100 larvae)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	21.550	19.050	22.900	21.300	21.200	19.050	21.650	22.850	21.400	21.238	21.219
NB_{18} x PM	19.350	19.050	22.100	21.800	20.575	19.600	22.700	19.500	22.400	21.050	20.812
PM x NB_4D_2	19.550	19.350	20.150	18.650	19.425	19.600	21.050	22.050	21.700	21.100	20.262
NB_4D_2 x PM	19.900	20.350	22.250	20.800	20.825	21.00	17.250	16.100	20.400	18.687	19.756
NB_4D_2 x NB_{18}	23.850	25.000	25.000	24.950	24.700	23.250	21.200	22.650	19.550	21.662	23.181
NB_{18} x NB_4D_2	23.550	23.900	24.000	24.550	24.000	22.100	22.100	19.600	20.400	21.050	22.525
PM	13.900	14.200	13.850	13.850	13.950	13.050	15.000	12.550	11.950	13.137	13.544
Mean	20.236	20.129	21.464	20.843	20.668	19.664	20.136	19.329	19.686	19.704	20.186

CD (0.05)
Races = 1.1145
Races x mulberry = 1.576

Of the two mulberry varieties, the variety K-2 performed better giving a value of 20.668 g. The total consumption of S-36 in this instar was 19.704 g.

On K-2, the bivoltine x bivoltine hybrid NB_4D_2 x NB_{18} was superior consuming 24.700 g of leaf. The reciprocal of the same cross was on par but differed significantly from all the other crosses. The multivoltine PM consumed the lowest quantity of leaves (13.950 g).

On S-36 mulberry variety also, PM consumed the lowest quantity while the superior hybrid was again the Bi x bivoltine hybrid NB_4D_2 x NB_{18}. But in this case, the crosses PM x NB_{18}, PM x NB_4D_2, NB_{18} x PM and NB_{18} x NB_4D_2 were on par with the superior.

The experimental seasons, did not influence leaf consumption by the second instar larvae either on K-2 or on S-36 mulberry variety.

4.3 Leaf consumption during the third instar

Data pertaining to the leaf consumption by the different hybrids of silkworm on two different varieties of mulberry during the four experimental seasons are given in Table 3.

During the third instar, races were significantly different among each other in their leaf consumption. When fed on K-2, the hybrid NB_4D_2 x PM recorded the highest leaf consumption (109.988 g). This was on par with that of PM x NB_4D_2, NB_{18} x PM and NB_4D_2 x NB_{18}. The lowest leaf consumption was shown by PM, which differed significantly with PM x NB_{18} and NB_{18} x NB_4D_2.

Table 3. Consumption of leaf by the third instar larvae of silkworm hybrids on two varieties of mulberry during 4 rearing periods (g fresh weight/100 larvae)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	94.900	101.350	110.500	98.650	101.350	107.550	99.300	119.350	99.900	106.525	103.938
NB_{18} x PM	106.300	110.450	108.400	106.200	107.838	109.350	107.850	119.250	103.100	109.888	108.863
PM x NB_4D_2	108.550	111.800	110.650	108.550	109.888	110.700	110.800	119.850	98.850	110.063	109.975
NB_4D_2 x PM	118.350	98.900	116.800	105.900	109.988	114.050	113.150	115.050	106.250	112.125	111.056
NB_4D_2 x NB_{18}	110.000	99.850	115.750	104.500	107.525	117.850	113.550	110.050	110.800	113.063	110.294
NB_{18} x NB_4D_2	95.800	101.300	118.900	108.250	106.063	105.900	111.900	106.350	101.450	106.400	106.231
PM	86.850	93.100	92.750	80.750	88.362	92.700	77.850	95.000	83.700	87.312	87.837
Mean	102.964	102.393	110.536	101.829	104.430	108.300	104.921	112.129	100.579	106.482	105.456

CD (0.05) Races = 6.4286
Season = 4.8596

When fed on S-36, the bivoltine hybrid NB_4D_2 x NB_{18} consumed the highest quantity of leaves (113.063 g). This was on par with NB_4D_2 x PM. However, NB_4D_2 x PM did not differ significantly from all other races except from control PM.

In the third instar also, seasons had a significant influence on the leaf consumption. The highest leaf consumption with K-2 variety was recorded in the third season (110.536 g) which differed significantly from the others. However, all other seasons were on par. With S-36 variety also, the third season was found to be the best (112.129 g) but this was on par with the first. The fourth season recorded the poorest consumption (100.579 g).

4.4 Leaf consumption during the fourth instar

Data pertaining to the leaf consumption by the different hybrids of silkworm on the two different varieties of mulberry during the four experimental seasons are given in Table 4.

During the fourth instar also, the different races of silkworm exhibited significant difference among each other in leaf consumption.

When reared on K-2, the bivoltine hybrid NB_4D_2 x NB_{18} was the superior consuming 308.937 g of leaves. The hybrids PM x NB_4D_2 and NB_4D_2 x PM were also on par. PM consumed the lowest quantity of leaf (224.188 g).

On S-36, again NB_4D_2 x NB_{18} was superior. The other bivoltine hybrid NB_{18} x NB_4D_2 was on par with this. PM again recorded the lowest leaf consumption (228.925 g).

Table 4. Consumption of leaf by the fourth instar larvae of silkworm hybrids on two varieties of mulberry during 4 rearing periods (g fresh weight/100 larvae)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	281.250	261.850	310.550	292.800	286.612	267.950	292.550	273.550	289.500	280.887	283.750
NB_{18} x PM	261.750	295.700	300.050	267.700	281.300	263.500	299.450	316.850	298.800	294.650	287.975
PM x NB_4D_2	296.850	296.400	336.050	298.850	307.037	299.250	306.850	322.850	294.150	305.775	306.406
NB_4D_2 x PM	272.100	308.850	312.00	322.700	303.912	281.300	289.250	303.300	300.100	293.487	298.700
NB_4D_2 x NB_{18}	309.550	299.850	307.500	318.850	308.937	313.00	303.700	315.450	298.000	307.537	308.237
NB_{18} x NB_4D_2	301.350	259.250	288.250	255.950	276.200	299.300	297.500	325.350	306.700	307.212	291.706
PM	226.200	225.250	239.200	206.100	224.188	236.950	236.350	218.150	224.250	228.925	226.556
Mean	278.436	278.164	299.086	280.421	284.027	280.179	289.379	296.500	287.357	288.354	286.190

CD (0.05)		
	Races	= 10.0445
	Races x mulberry	= 14.2050
	Season	= 7.5929
	Races x season	= 20.0887

As regards season, the third season was the most favourable recording a consumption of 299.086 g with K-2 variety and 296.500 g with S-36 variety. The superior season was significantly different from all other seasons. With K-2 the poorest season was second (278.164 g). While the first season showed a poor performance with S-36 (280.179 g).

The interactions between mulberry varieties and race and that between silkworm races and season were also significant.

4.5 Leaf consumption during the fifth instar

Data pertaining to the leaf consumption by the different hybrids of silkworm on two different varieties of mulberry during the four experimental seasons are given in Table 5.

Races and seasons were found to have significant influence on the leaf consumption, of the different hybrids during the Vth instar also.

The hybrid NB_4D_2 x NB_{18} consumed the highest quantity of K-2 leaves (1732.100 g) and this was significantly different from the rest of the hybrids. The multivoltine Pure Mysore consumed the lowest quantity (857.025 g) and this was also significantly different from other hybrids.

On S-36, the hybrid PM x NB_4D_2 consumed the highest quantity of leaves (1768.550 g) and this was on par with that of NB_4D_2 x NB_{18}. The lowest quantity was again consumed by Pure Mysore (877.862 g) which differed significantly from the others.

Table 5. Consumption of leaf by the fifth instar larvae of silkworm hybrids on two varieties of mulberry during 4 rearing periods (g fresh weight/100 larvae)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	1333.700	1542.600	1702.600	1401.400	1495.075	1315.350	1294.600	1675.200	1603.500	1472.162	1483.619
NB_{18} x PM	1274.250	1424.500	1698.350	1395.400	1448.137	1247.700	1566.450	1712.600	1394.450	1480.300	1464.219
PM x NB_4D_2	1494.100	1533.200	1907.200	1701.450	1658.988	1688.600	1711.500	1999.000	1675.100	1768.550	1713.769
NB_4D_2 x PM	1744.700	1483.900	1600.350	1546.950	1593.975	1489.800	1710.450	1770.450	1599.400	1642.525	1618.250
NB_4D_2 x NB_{18}	1905.750	1611.150	1814.050	1597.450	1732.100	1668.600	1834.400	1829.400	1598.400	1732.700	1732.400
NB_{18} x NB_4D_2	1520.550	1743.200	1744.850	1693.200	1675.450	1629.450	1711.950	1896.550	1690.800	1732.188	1703.819
PM	823.650	868.650	909.600	826.200	857.025	849.400	904.900	939.650	817.500	877.862	867.444
Mean	1442.386	1458.179	1625.286	1451.721	1494.393	1412.700	1533.464	1688.979	1482.736	1529.470	1511.931

CD (0.05)
Races = 104.2548
Season = 78.8093

Table 6. Total leaf consumption by different silkworm hybrids on 2 milberry varieties during 4 rearing periods (g fresh weight/100 larvae)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	1738.300	1930.850	2153.700	1820.300	1910.787	1716.950	1714.450	2097.950	2021.550	1887.725	1899.256
NB_{18} x PM	1667.700	1855.950	2135.150	1796.900	1863.925	1800.700	2003.100	2173.700	1825.000	1950.625	1907.275
PM x NB_4D_2	1926.400	1967.800	2380.700	2134.300	2102.300	2125.550	2157.000	2469.400	2096.300	2212.063	2157.181
NB_4D_2 x PM	2160.850	1918.050	2058.700	2003.050	2035.162	1912.550	2536.300	2212.400	2033.450	2173.675	2104.419
NB_4D_2 x NB_{18}	2356.050	2042.900	2268.700	2231.500	2224.787	2130.350	2279.100	2285.500	2033.150	2182.025	2203.406
NB_{18} x NB_4D_2	1948.400	2133.550	2182.500	2089.250	2088.425	2063.900	2150.100	2355.500	2125.750	2173.813	2131.119
PM	1156.850	1207.850	1262.500	1132.300	1189.975	1199.350	1241.050	1270.900	1142.950	1213.562	1201.719
Mean	1850.650	1865.279	2063.136	1886.800	1916.466	1849.907	2011.586	2123.621	1896.879	1970.498	1943.482

CD (0.05) Races = 123.17
Seasons = 93.11

Among the seasons, the third season was the best with both K-2 and S-36 leaf varieties registering 1625.286 g and 1688.979 g respectively. In both the cases, the first season gave the lowest leaf consumption. The seasons differed significantly among themselves in their contribution to leaf consumption by the fifth instar larvae.

4.6 Total leaf consumption by the larvae

Data pertaining to the leaf consumption of different silkworm hybrids reared on two varieties of mulberry during four rearing periods are given in Table 6.

The statistical analysis revealed that the leaf consumption varied significantly with different silkworm hybrids. The bivoltine hybrid NB_4D_2 x NB_{18} consumed the largest quantity of K-2 leaf (2224.987 g/100 larvae) wheareas the hybrid PM x NB_4D_2 was the best with S-36 variety (2212.063 g/100 g larvae). On K-2, PM x NB_4D_2 was on par with the superior, while on S-36 the crosses NB_4D_2 x NB_{18}, NB_{18} x NB_4D_2 and NB_4D_2 x PM did not differ significantly with PM x NB_4D_2. In either case, the multivoltine PM was significantly inferior to the remaining hybrids.

Seasonal change also significantly influenced leaf consumption by the larva. In either case the third season was significantly superior to all other seasons giving a consumption of 2063.136 g on K-2 and 2123.621 g on S-36 respectively. On K-2 the fourth, second and first seasons were on par. The most unfavourable season was the first in both cases registering a consumption of 1850.650 g with K-2 and 1849.907 g with S-36.B

4.7 Larval duration

Data pertaining to the larval duration of different hybrids of silkworm when reared on two different mulberry varieties during 4 experimental seasons are given in Table 7.

Table 7. Duration of larva of different silkworm hybrids reared on two varieties of mulberry during 4 rearing periods (hours)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	624.00	559.200	559.200	528.000	567.600	600.000	552.000	566.400	528.000	561.600	564.600
NB_{18} x PM	607.800	580.800	564.000	552.000	576.150	607.200	564.000	564.000	528.000	565.800	570.975
PM x NB_4D_2	603.600	552.000	552.000	528.000	558.900	624.000	528.000	528.000	528.000	552.000	555.450
NB_4D_2 x PM	607.000	580.800	552.000	552.000	573.150	600.000	580.800	564.000	552.000	574.200	573.675
NB_4D_2 x NB_{18}	603.600	528.000	552.000	504.000	546.900	600.000	528.000	552.000	504.000	546.000	546.450
NB_{18} x NB_4D_2	604.800	528.000	552.000	511.200	549.000	628.800	528.000	552.000	513.600	555.600	552.300
PM	609.600	552.000	576.000	494.400	558.000	600.000	552.000	576.000	494.400	555.600	556.800
Mean	608.743	554.400	558.171	524.229	561.386	608.571	547.543	557.486	521.143	558.686	560.036

CD (0.05)		
	Races	= 1.379
	Races x Mulberry	= 1.9505
	Seasons	= 1.0427
	Mulberry x season	= 1.475
	Race x season	= 2.758
	Race x season x mulberry	= 3.9009

All the three variables i.e., mulberry, races and seasons and also their interactions had a profound influence on the larval duration. The larval duration was seen to be prolonged when the worms were given K-2 than when given S-36.

When reared on K-2, the hybrid NB_{18} x PM showed the longest duration of 576.15 h which was significantly different from the duration of all the other races. The shortest duration was 546.900 h by the hybrid NB_4D_2 x NB_{18}.

When reared on S-36, again another bivoltine x multivoltine hybrid NB_4D_2 x PM showed the longest duration of 574.200 h. This was significantly different from that of all other races. On S-36, the races NB_{18} x NB_4D_2 and PM were on par.

As far as the seasons were concerned, the first season gave the longest larval duration for both K-2 (608.743 h) and S-36 (608.571) and this differed significantly with the remaining 3 seasons. The fourth season recorded the shortest larval duration of 524.229 g and 521.143 g respectively on K-2 and S-36.

Within the Ist season, PM x NB_{18} gave the longest duration of 624.000 h while the races PM x NB_4D_2 and NB_4D_2 x NB_{18} registered the shortest (603.600 h). On S-36 on the other hand in the first season, NB_{18} x NB_4D_2 recorded the longest duration of 628.800 h. The hybrids PM x NB_{18}, NB_4D_2 x PM and PM recorded the shortest duration of 600.00 h.

4.8 Larval weight

The data pertaining to the larval weight of different silkworm hybrids reared on two different mulberry varieties during four experimental seasons are given in Table 8. The statistical analysis reveals that in this case also, the mulberry

Table 8. Larval weight of different silkworm hybrids reared on two varieties of mulberry during 4 rearing periods (g/larvae)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	1.600	2.650	3.375	3.505	2.783	1.950	2.800	2.785	3.590	2.781	2.782
NB_{18} x PM	1.700	2.050	2.270	3.000	2.255	2.050	1.750	2.245	2.000	2.011	2.133
PM x NB_4D_2	2.200	3.440	3.615	3.475	3.183	2.400	3.335	3.680	3.640	3.264	3.223
NB_4D_2 x PM	2.100	4.460	4.050	3.590	3.550	1.950	3.000	2.965	2.950	2.716	3.133
NB_4D_2 x NB_{18}	2.250	3.000	1.680	1.895	2.206	1.700	2.750	2.135	1.725	2.077	2.142
NB_{18} x NB_4D_2	1.950	4.125	3.200	2.780	3.014	1.950	4.175	3.350	3.475	3.238	3.126
PM	1.550	1.450	1.460	1.635	1.524	1.550	1.350	1.400	1.350	1.413	1.468
Mean	1.907	3.025	2.807	2.840	2.645	1.936	2.737	2.651	2.676	2.500	2.572

CD (0.05)	Races	= 0.2203
	Races x Mulberry	= 0.3116
	Seasons	= 0.1668
	Races x season	= 0.4406

varieties, the different hybrids of silkworm and also the seasons significantly influenced the weight of the larvae. The interaction between mulberry and races and that between races and season were also highly significant.

The highest larval weight of 3.550 g was registered with NB_4D_2 x PM when fed on K-2 mulberry leaf. This was significantly different from all other races and most superior. When fed on S-36, the combination PM x NB_4D_2 recorded the maximum weight of 3.264 g. This was on par with NB_{18} x NB_4D_2 (3.238 g) but significantly different from PM x NB_{18} (2.781 g).

Among the seasons, second season proved to be the best for both K-2 and S-36 mulberry varieties, recording average weights of 3.025 g and 2.737 g respectively for the larvae reared on them. On K-2, the fourth season was on par with second (2.480 g). On both K-2 and S-36, the first season recorded the lowest weight (1.907 g and 1.936 g respectively). On S-36, fourth and third seasons were on par with the superior.

Between the mulberry varieties, K-2 gave a better larval weight (2.645 g) than S-36 (2.500 g). The lowest larval weight was recorded with multivoltine PM irrespective of the leaf fed. PM was significantly inferior to all other crosses in this respect.

In the second season, i.e., the best season, the hybrid NB_4D_2 x PM performed best on K-2. It recorded a maximum weight of 4.460 g/larva. On S-36 on the other hand NB_{18} x NB_4D_2 gave the maximum weight of 4.175 g during the most favourable season.

4.9 Weight of single cocoon

Data pertaining to the weight of single cocoon of different hybrids of silkworm when reared on two different mulberry varieties during four experimental seasons are given in Table 7.

When fed on K-2, PM x NB_{18} recorded the maximum cocoon weight of 1.531 g.This was on par with NB_4D_2 x NB_{18} (1.486 g). Interestingly, on S-36, the multivoltine PM gave the best cocoon weight of 1.462 g. But this was on par with PM x NB_4D_2, NB_4D_2 x PM, PM x NB_{18} and NB_4D_2 x NB_{18}.

The hybrid NB_{18} x PM registered the lowest cocoon weight on K-2 (1.115 g). The hybrid PM x NB_4D_2, NB_{18} x NB_4D_2 and NB_4D_2 x PM did not differ significantly from this. The hybrid NB_{18} x NB_4D_2 performed poorly on S-36 (1.045 g), NB_{18} x PM was on par with this.

4.10 Weight of single shell

Data pertaining to the weight of single shell of different silkworm hybrids when fed on two different mulberry varieties during four experimental seasons are given in Table 10.

The races and seasons differed significantly in the weight of single shell. The multivoltine, Pure Mysore gave the highest weight with both K-2 (0.319 g) and with S-36 variety (0.334 g). The superior variety differed significantly from others.

The next best hybrid with K-2 mulberry was the bivoltine hybrid NB_{18} x NB_4D_2 while with S-36 it was PM x NB_{18}. On K-2, NB_{18} x NB_4D_2 was on par with PM x NB_{18}, PM x NB_4D_2 and NB_4D_2 x NB_{18}. The lowest single shell weight when

Table 9. Weight of single cocoon of different silkworm hybrids reared on two different mulberry varieties during 4 rearing periods (g/cocoon)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	1.493	1.450	1.635	1.545	1.531	1.014	1.550	1.660	1.450	1.418	1.475
NB_{18} x PM	0.905	0.950	0.905	1.700	1.115	0.861	1.250	0.929	1.500	1.133	1.125
PM x NB_4D_2	0.932	0.850	1.835	1.350	1.242	1.000	1.515	1.765	1.479	1.440	1.341
NB_4D_2 x PM	0.947	1.100	0.907	1.550	1.126	0.950	1.950	0.986	1.850	1.434	1.280
NB_4D_2 x NB_{18}	0.942	1.700	1.750	1.550	1.486	0.915	1.750	0.803	1.850	1.330	1.408
NB_{18} x NB_4D_2	0.890	1.345	1.125	1.185	1.136	0.850	1.220	0.860	1.250	1.045	1.091
PM	1.450	1.150	1.250	1.480	1.332	1.290	1.450	1.552	1.558	1.462	1.397
Mean	1.080	1.221	1.344	1.480	1.281	0.983	1.526	1.222	1.562	1.323	1.302

CD (0.05)		
	Races	= 0.1468
	Races x Mulberry	= 0.2076
	Season	= 0.11086
	Mulberry x season	= 0.1569
	Race x season	= 0.2933

Table 10. Weight of single shell of different silkworm hybrids reared on two different mulberry varieties during 4 rearing periods (g/shell)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	0.115	0.245	0.305	0.350	0.254	0.165	0.350	0.285	0.250	0.263	0.258
NB_{18} x PM	0.130	0.158	0.305	0.270	0.216	0.145	0.156	0.315	0.255	0.218	0.217
PM x NB_4D_2	0.170	0.175	0.326	0.300	0.243	0.160	0.125	0.315	0.300	0.225	0.234
NB_4D_2 x PM	0.130	0.180	0.300	0.185	0.199	0.165	0.195	0.305	0.290	0.239	0.219
NB_4D_2 x NB_{18}	0.155	0.135	0.205	0.400	0.224	0.170	0.230	0.280	0.350	0.258	0.241
NB_{18} x NB_4D_2	0.150	0.245	0.250	0.400	0.261	0.135	0.195	0.290	0.300	0.230	0.246
PM	0.355	0.265	0.355	0.300	0.319	0.260	0.295	0.375	0.405	0.334	0.326
Mean	0.172	0.200	0.292	0.315	0.245	0.171	0.221	0.309	0.307	0.252	0.249

CD (0.05)		
	Races	= 0.0387
	Seasons	= 0.0294
	Race x season	= 0.0775

reared on K-2 was registered with the hybrid NB_4D_2 x PM. On S-36 on the other hand, NB_{18} x PM gave the lowest shell weight. NB_4D_2 x NB_{18}, NB_4D_2 x PM, NB_{18} x NB_4D_2 and PM x NB_4D_2 did not differ significantly with this.

Among the seasons, fourth season gave the highest shell weight of 0.315 g when reared on K-2. The third season did not differ significantly from this. The lowest shell weight was registered during Ist season (0.172 g).

When the rearing was done using S-36, the highest value was recorded during the third season (0.309 g) which was on par with the fourth (0.307 g).

4.11 Shell ratio percentage (SRP)

The races and seasons individually, as well as their interactions significantly influenced the shell ratio percentage as depicted in Table 11.

The SRP was maximum for the bivoltine hybrid NB_4D_2 x NB_{18} irrespective of the mulberry leaf fed. When fed with K-2 the SRP was 17.411 which was on par with NB_{18} x NB_4D_2. On S-36, on the other hand the SRP of 18.429 was significantly superior to all other hybrids. The lowest SRP was recorded for the multivoltine race PM - 13.896 in K-2 and 13.895 on S-36 respectively. This was on par with NB_4D_2 x PM, NB_{18} x PM and PM x NB_{18} on K-2 and with NB_{18} x NB_4D_2 and NB_4D_2 x PM on S-36.

With regard to the season for rearing, the fourth period was the best recording an SRP of 16.110 on K-2 and 16.683 on S-36. On K-2 this was significantly superior to all other seasons with the lowest SRP being in the first season. On S-36, however, the second season gave the lowest SRP. The first and third seasons were on par with the second in this case.

Table 11. Shell ratio percentage of different silkworm hybrids reared on different mulberry varieties during 4 rearing periods (%)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	13.610	14.400	15.575	16.650	15.059	14.555	14.510	15.435	19.835	16.084	15.571
NB_{18} x PM	15.080	15.070	14.945	13.900	14.749	16.260	15.955	16.295	15.500	16.003	15.376
PM x NB_4D_2	14.330	13.925	17.705	17.120	15.770	15.060	14.320	18.475	18.195	16.512	16.141
NB_4D_2 x PM	14.495	14.500	13.590	14.650	14.309	16.335	15.660	12.810	15.000	14.951	14.630
NB_4D_2 x NB_{18}	17.270	16.730	17.450	18.195	17.411	16.365	14.850	20.750	21.750	18.429	17.920
NB_{18} x NB_4D_2	12.905	21.650	13.480	18.450	16.621	15.075	15.130	12.740	14.650	14.399	15.510
PM	15.540	14.590	11.650	13.805	13.896	15.430	15.650	12.650	11.850	13.895	13.896
Mean	14.747	15.838	14.914	16.110	15.402	15.583	15.154	15.594	16.683	15.753	15.578

CD (0.05)	Races	= 1.1326
	Seasons	= 0.8569
	Race x season	= 2.2669

Within the fourth season, the highest SRP was for NB_{18} x NB_4D_2 when reared on K-2 (18.450) whereas the best hybrid on S-36 in the same season was NB_4D_2 x NB_{18} (21.750). In general, multivoltine PM gave the lowest SRP.

4.12 Average filament length (AFL)

Table 12 is a record of the average filament length obtained for the different hybrids fed on K-2 and S-36 mulberry varieties during the four experimental seasons.

The different silkworm hybrids were significantly influenced by change in mulberry variety and seasonal changes. The lowest filament length, when reared on K-2 was achieved with the hybrid NB_4D_2 x NB_{18} (632.466 m). This was on par with PM (583.463 m). The shortest filament length in either case was for NB_{18} x PM, 379.047 m and 408.805 m respectively for K-2 and S-36. On K-2, this was on par with PM x NB_{18}. Moreover, PM x NB_{18} did not differ significantly from PM x NB_4D_2 and NB_4D_2 x PM.

On S-36, the hybrids NB_4D_2 x NB_{18} and NB_{18} x NB_4D_2 did not differ significantly from the superior variety PM. Likewise the hybrids PM x NB_4D_2, PM x NB_{18} and NB_4D_2 x NB_{18} did not differ significantly from the inferior cross NB_{18} x PM.

Between the two mulberry varieties, K-2 performed best giving a mean value of 489.519 m compared to 467.756 m when reared on S-36.

Among the four seasons, the IInd season was superior giving an AFL of 561.956 m on K-2 and 475.536 m on S-36. On K-2 this differed significantly from the rest of the seasons. But on S-36 the fourth season was on par with the superior.

Table 12. Average filament length of different silkworm hybrids on 2 mulberry varieties reared during 4 rearing periods (m)

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	272.050	552.300	272.050	552.450	412.212	324.315	550.700	324.300	550.700	424.858	437.504
NB_{18} x PM	338.100	439.840	343.100	395.150	379.047	425.450	402.600	425.450	500.750	408.805	438.562
PM x NB_4D_2	387.250	445.850	377.100	548.850	439.763	417.050	431.690	417.050	493.665	439.813	439.864
NB_4D_2 x PM	455.600	524.100	455.600	391.00	456.575	419.650	322.810	419.650	300.450	411.108	365.640
NB_4D_2 x NB_{18}	597.800	699.975	597.800	634.290	632.466	383.800	511.200	383.800	415.925	528.074	423.681
NB_{18} x NB_4D_2	569.400	719.630	383.750	419.650	523.107	437.150	649.750	391.550	470.300	505.147	487.187
PM	602.350	552.000	602.350	577.150	583.463	521.900	460.000	507.000	542.500	545.656	507.850
Mean	460.364	561.956	433.107	502.649	489.519	418.474	475.536	409.829	467.756	442.898	466.209

CD (0.05)

	Races	= 44.909
	Race x Mulberry	= 63.510
	Season	= 33.948
	Race x season	= 89.817

The third season recorded the lowest values for AFL irrespective of the mulberry variety used for rearing, 433.107 m on K-2 and 409.829 m on S-36.

4.13 Denier

The experimental results for denier, recorded for different hybrids of silkworm, when reared on two different mulberry varieties during four different seasons are given in Table 13.

The different silkworm hybrids performed differently, on different mulberry varieties with regard to denier. Seasonal changes also significantly influenced denier.

The multivoltine PM was the superior race irrespective of the variety of mulberry. On K-2, the denier was 2.423 while on S-36 it was 2.377. On K-2, PM x NB_4D_2 differed significantly with the superior and with PM x NB_{18}. The hybrid NB_4D_2 x NB_{18} with a denier of 1.732 was significantly inferior to NB_4D_2 x PM (2.036).

On S-36, the superior race PM was on par with NB_{18} x PM (2.335) and PM x NB_{18} (2.297). The lowest denier on S-36 was registered with NB_4D_2 x NB_{18} itself, but here NB_{18} x NB_4D_2 was also on par.

The mulberry variety S-36 gave a better value for denier (2.176) than K-2 (2.127).

Among the four seasons, the second one was significantly superior over the rest. On K-2 the denier was 2.220 while on S-36 it was 2.293. The first and third seasons gave a low denier value and did not differ significantly from each other.

Table 13. Denier of different silkworm hybrids on different mulberry varieties during 4 rearing periods

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	1.925	2.575	1.925	2.575	2.250	1.975	2.620	1.975	2.620	2.297	2.274
NB_{18} x PM	1.915	2.070	2.145	2.170	2.075	2.350	2.350	2.350	2.290	2.335	2.205
PM x NB_4D_2	2.220	2.290	2.220	2.360	2.273	2.300	2.160	2.270	2.230	2.240	2.256
NB_4D_2 x PM	2.070	2.020	2.085	1.970	2.036	2.255	2.000	2.260	1.885	2.100	2.068
NB_4D_2 x NB_{18}	1.635	1.810	1.630	1.855	1.732	1.825	2.000	1.825	2.050	1.925	1.829
NB_{18} x NB_4D_2	1.910	2.510	1.910	2.070	2.100	1.705	2.485	1.705	1.925	1.955	2.028
PM	2.500	2.265	2.660	2.265	2.423	2.325	2.435	2.350	2.400	2.377	2.400
Mean	2.025	2.220	2.082	2.181	2.127	2.105	2.293	2.105	2.200	2.176	2.151

CD (0.05)	Races	= 0.1044
	Race x Mulberry	= 0.1476
	Season	= 0.0789
	Race x season	= 0.2087

During the most favourable season, the hybrid PM x NB_{18} was found to be superior yielding a denier size of 2.575 on K-2 and 2.620 on S-36 mulberry variety.

4.14 Reelability

Table 14 shows the reelability figures obtained for the various silkworm hybrids when reared on K-2 and S-36 mulberry varieties during four experimental seasons. Races and seasons were found to have a high influence on the reelability.

Among the races, PM x NB_4D_2 had a high reelability irrespective of the mulberry variety. On K-2, the reelability was 83.135. However the race PM and the hybrids NB_4D_2 x NB_{18}, PM x NB_{18} and NB_4D_2 x PM were on par with the superior. The reelability of PM x NB_4D_2 when the rearing was done using S-36 mulberry was 86.961. The hybrids NB_{18} x PM, NB_4D_2 x PM and PM x NB_{18} were on par with this. The lowest reelability was for NB_{18} x NB_4D_2 on both K-2 and S-36. Its reelability of 66.615 on S-36 was significantly inferior to all other crosses. On K-2 however, NB_{18} x NB_4D_2 was on par with NB_{18} x PM and NB_4D_2 x PM.

The IIIrd season proved to be the best for obtaining maximum reelability. With K-2 the reelability was 82.756 while with S-36 it was even higher (86.005). The next best season was the Ist, which was on par with the IIIrd in both the cases. The IInd season which gave the lowest reelability was significantly inferior to all other seasons.

4.15 Renditta

In Table 15, the renditta of different hybrids of silkworm, when reared on K-2 and S-36 mulberry varieties during four experimental seasons is presented.

Table 14. Reelability of different silkworm hybrids reared on 2 mulberry varieties during four rearing periods

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	84.125	71.790	91.665	76.920	81.125	81.010	69.710	87.115	89.850	80.107	80.616
NB_{18} x PM	77.360	69.040	71.410	69.710	71.880	87.115	89.850	87.115	82.860	86.735	79.308
PM x NB_4D_2	87.975	78.400	76.315	89.850	83.135	89.275	69.585	95.450	93.535	86.961	85.048
NB_4D_2 x PM	80.610	64.580	85.710	76.150	76.763	85.995	69.705	88.460	81.160	81.330	79.046
NB_4D_2 x NB_{18}	81.210	79.165	87.500	76.700	81.144	76.695	72.915	74.860	83.360	76.958	79.051
NB_{18} x NB_4D_2	82.170	47.855	83.360	64.775	69.540	69.040	66.955	74.150	56.315	66.615	68.077
PM	80.150	73.300	83.330	93.825	82.651	71.300	62.740	82.000	86.800	75.710	79.181
Mean	81.943	69.161	82.756	78.276	78.034	80.061	71.637	86.005	79.106	79.202	78.618

CD (0.05) Races = 8.5343

Season = 6.4512

Table 15. Renditta of different silkworm hybrids reared on two mulberry varieties during 4 rearing periods

Races of silkworm	Mulberry variety K-2					Mulberry variety S-36					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Grand mean
PM x NB_{18}	14.330	11.933	11.300	11.650	12.304	13.660	12.140	11.200	12.050	12.263	12.283
NB_{18} x PM	12.505	12.360	11.950	13.750	12.641	9.205	9.795	12.600	11.600	10.800	11.721
PM x NB_4D_2	11.195	13.150	10.785	12.500	11.908	10.095	10.190	11.350	13.500	11.284	11.596
NB_4D_2 x PM	9.630	9.335	9.830	12.700	10.374	10.155	11.620	14.000	12.600	12.094	11.234
NB_4D_2 x NB_{18}	7.995	13.185	13.125	12.850	11.789	10.625	11.135	15.500	14.400	12.915	12.352
NB_{18} x NB_4D_2	11.550	11.895	12.415	11.965	11.956	12.010	12.490	12.750	15.500	13.187	12.572
PM	10.245	9.455	13.825	12.450	11.494	13.025	11.350	10.690	13.900	12.241	11.868
Mean	11.064	11.616	11.890	12.552	11.781	11.254	11.246	12.584	13.364	12.112	11.946

CD (0.05)

	Race x mulberry	= 1.4044
	Season	= 0.7506
	Mulberry x season	= 1.0616
	Race x season x mulberry	= 2.8088

The statistical analysis reveals that when reared on K-2, the cross PM x NB_{18} was superior giving the lowest renditta of 11.650. The hybrids PM x NB_4D_2, PM and NB_{18} x NB_4D_2 were on par. The maximum renditta value was obtained with NB_{18} x PM (13.750) which was on par with NB_4D_2 x NB_{18} (12.850).

In the case of S-36 variety, NB_{18} x PM was the superior variety (10.800). PM x NB_4D_2 again was on par with this. The superior hybrid on S-36 was NB_{18} x NB_4D_2 with a renditta of 13.187, though NB_4D_2 x NB_{18}, PM x NB_{18} and PM did not differ significantly.

Seasonal changes had significant influence on renditta. Of the four seasons, the Ist season was the most favourable when reared using K-2 variety giving a renditta value of 11.064. The second season (11.616) was not significantly different from this. However, with S-36, the IInd season was the best (11.246), the first season remaining on par (11.254).

Within the Ist season, NB4D2 x PM proved to be the most superior when fed with K-2 leaves (9.630). However, in the IInd season which was the best when the rearing was done using S-36, NB18 x PM was the best (9.795).

The interaction between mulberry and variety and season was also significant as far as renditta is concerned.

4.16 Effect of climatic conditions on larval duration, cocoon weight, shell weight and SRP

Correlations were worked out between economic characters of *Bombyx mori* L., like larval duration, cocoon weight, shell weight and SRP as against the

Table 16. Correlation between some important economic parameters of silkworm and meteorological data

	Cocoon weight	Shell weight	Shell ratio percentage	Maximum temperature (highest value)	Maximum temperature (lowest value)	Minimum temperature (highest value)	Minimum temperature (lowest value)	Relative himidity (highest value)	Relative humidity (lowest value)	Total rainfall	Larval duration
Cocoon weight	1.0	-									
Shell weight	+0.308**	1.0	-								
Shell ratio (%)	0.165	0.09	1.0								
Maximum temp. (highest value)	-0.006	-0.391**	-0.088	1.0-							
Maximum temp. (lowest value)	-0.309**	-0.427**	-0.182	0.763**	1.0	-					
Minimum temp. (highest value)	0.175	0.267**	-0.04	0.386**	0.37**	1.0-					
Minimum temp. (lowest value)	0.39**	0.442**	0.068	0.183	-0.113	0.851**	1.0	-			
Relative humidity (highest value)	0.449**	0.579**	0.178	-0.517**	-0.848**	0.168	0.622**	1.0	-		
Relative humidity (lowest value)	0.431**	0.631**	0.138	-0.43**	-0.65**	0.466**	0.795**	0.941**	1.0-		
Rainfall	0.361**	0.431**	0.193*	-0.653**	-0.987**	-0.293**	0.22*	0.893**	0.696**	1.0-	
Larval duration	-0.449**	-0.523**	-0.253**	0.156	0.561**	-0.363**	-0.734**	-0.829**	-0.821**	-0.646**	1.0

* Significant at 5% level

** Significant at 1% level

maximum-minimum temperature, relative humidity and rainfall recorded during the rearing periods.

The correlation statistics points out that a highly significant negative correlation exists between cocoon weight and the lowest value of maximum temperature. As the maximum temperature was on the decrease, the cocoon weight increased. However, highly significant positive correlations were worked out between the cocoon weight and lowest value of minimum temperature, relative humidity and rainfall. Cocoon weight was also negatively correlated with larval duration.

In the case of shell weight, highly significant negative correlations were found between the highest and lowest values of maximum temperature, while significant positive correlation was seen between shell weight and highest and lowest minimum temperature recorded, relative humidity and rainfall. Here also, larval duration negatively influenced the shell weight.

SRP was significantly correlated to minimum value of RH whereas with rainfall there was a significant negative correlation.

It was also seen that weather parameters like highest and lowest values of minimum temperature, highest and lowest values of RH and rainfall negatively influenced the larval duration, causing a lower rearing time. A positive correlation existed between larval duration and the lowest value of maximum temperature, denoting that at higher temperatures, the larval duration tended to increase.

Discussion

5. DISCUSSION

The experiment was conducted to evaluate region and season specific multi x bi and bivoltine hybrids of *Bombyx mori* suitable for Kerala conditions, taking Vellanikkara as a representative area and also to evaluate mulberry varieties S-36 and Kanva-2 (K-2).The results obtained after the statistical analysis are discussed below based on earlier literature and in the present context.

5.1 Leaf consumption by the larva

The total leaf consumption with K-2 was highest for NB_4D_2 x NB_{18} (2224.787 g/100 larvae) and for S-36 it was PM x NB_4D_2 (2212.063 g/100 larvae). PM consumed the lowest quantity in either case (Fig.6). Figures 1 to 5 are a graphical representation of leaf consumption by the different instars of silkworm *B. mori* when fed on K-2 and S-36 mulberry varieties during four experimental seasons.

The leaf consumption which is an indicator of the performance of silkworm race with respect to productivity is an important parameter for the efficient conversion of food into cocoons. The genetic makeup of the particular race combined with the quality of the leaf and climatic conditions usually decide the rate of consumption (Thomas, 1995). Here, it was seen that the leaf consumption involving bivoltines as parents were the highest.

Similar reports were given by Prakash and Delvi (1987), who reported that food consumption by the larva of bivoltines was two times more than that of PM.

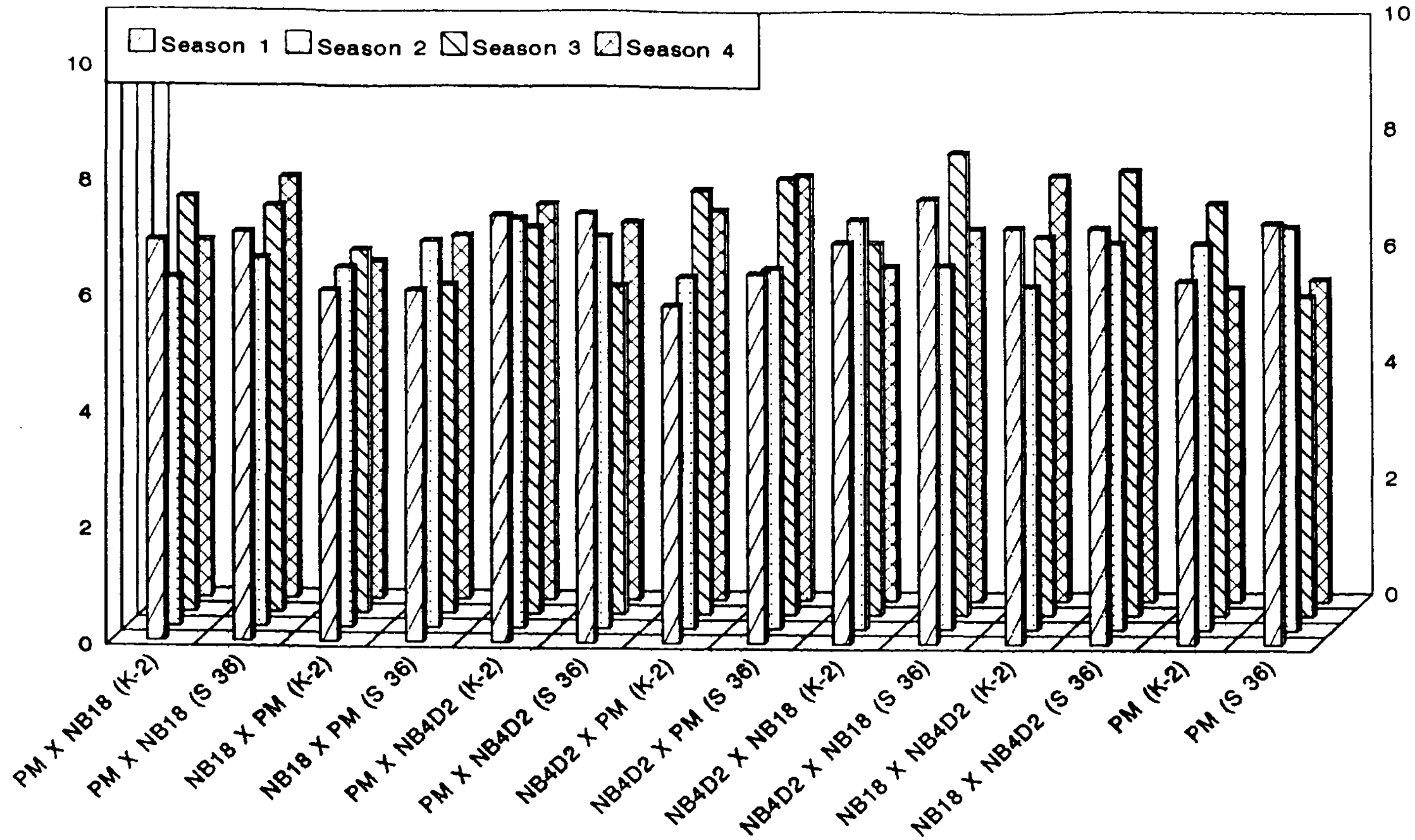

Fig. 1. Consumption of leaf by the first instar larvae of silkworm hybrids on two varieties of mulberry during 4 rearing periods (g fresh weight/100 larvae)

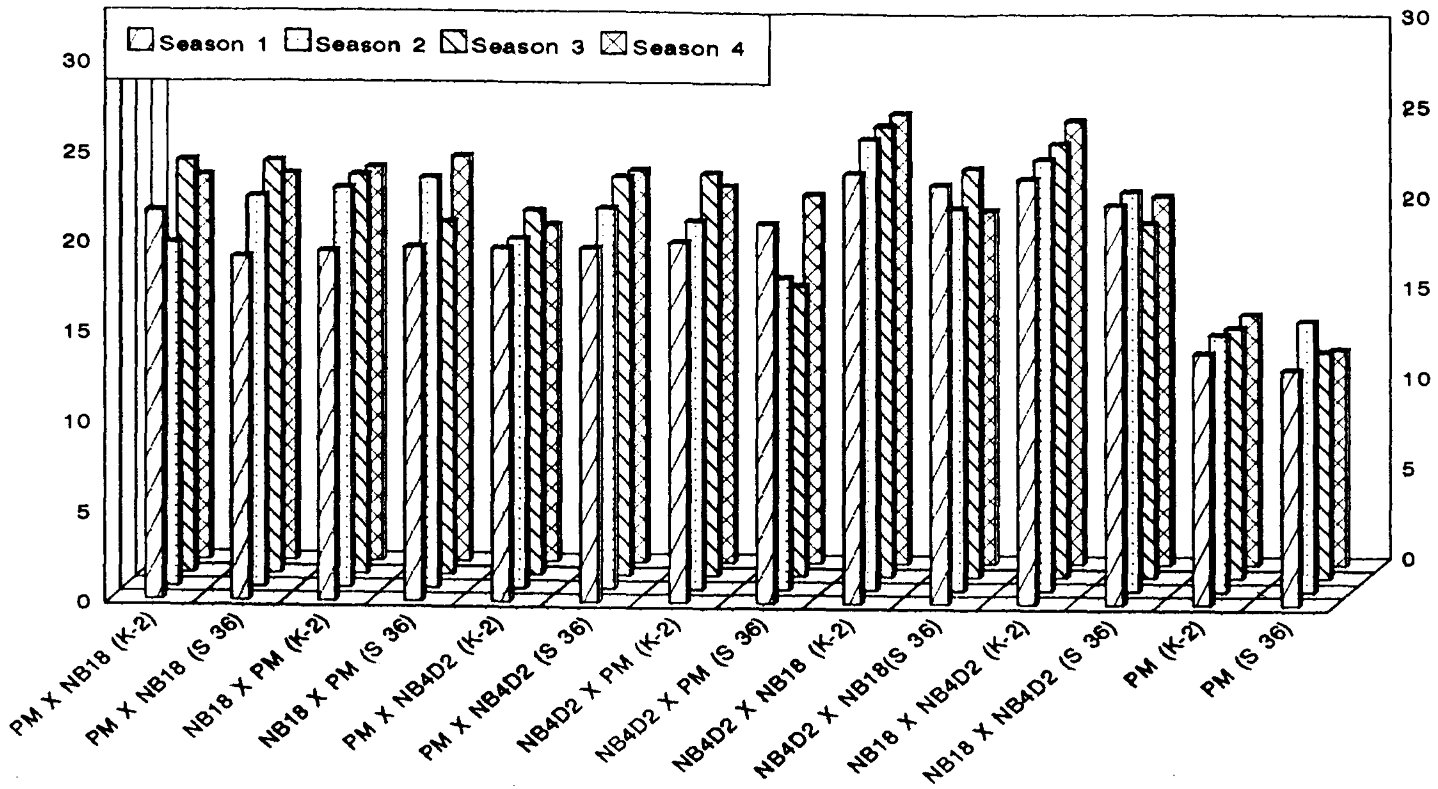

Fig. 2. Consumption of leaf by the second instar larvae of silkworm hybrids on two varieties of mulberry during 4 rearing periods (g fresh weight/100 larvae)

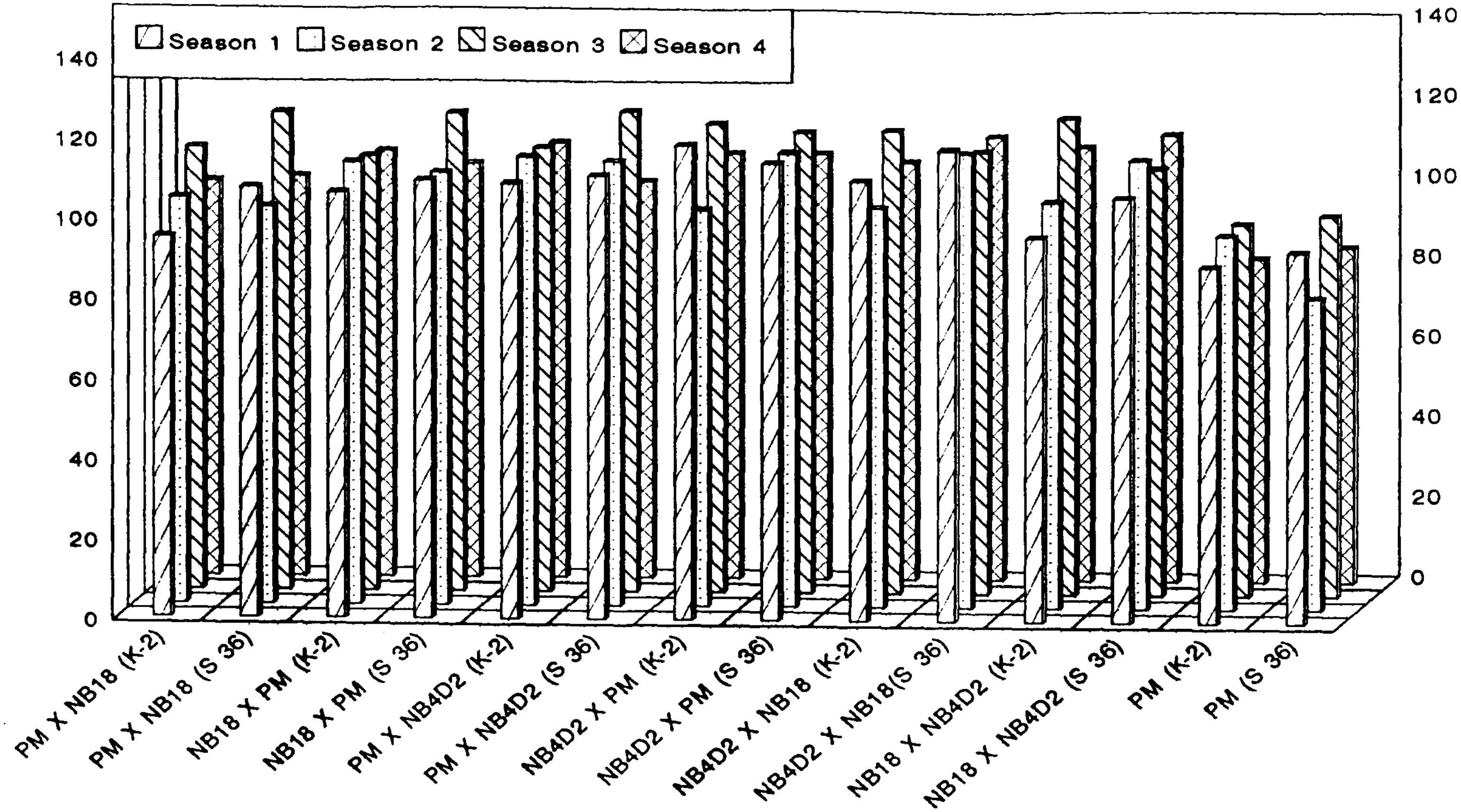

Fig. 3. Consumption of leaf by the third instar larvae of silkworm hybrids on two varieties of mulberry during 4 rearing periods (g fresh weight/100 larvae)

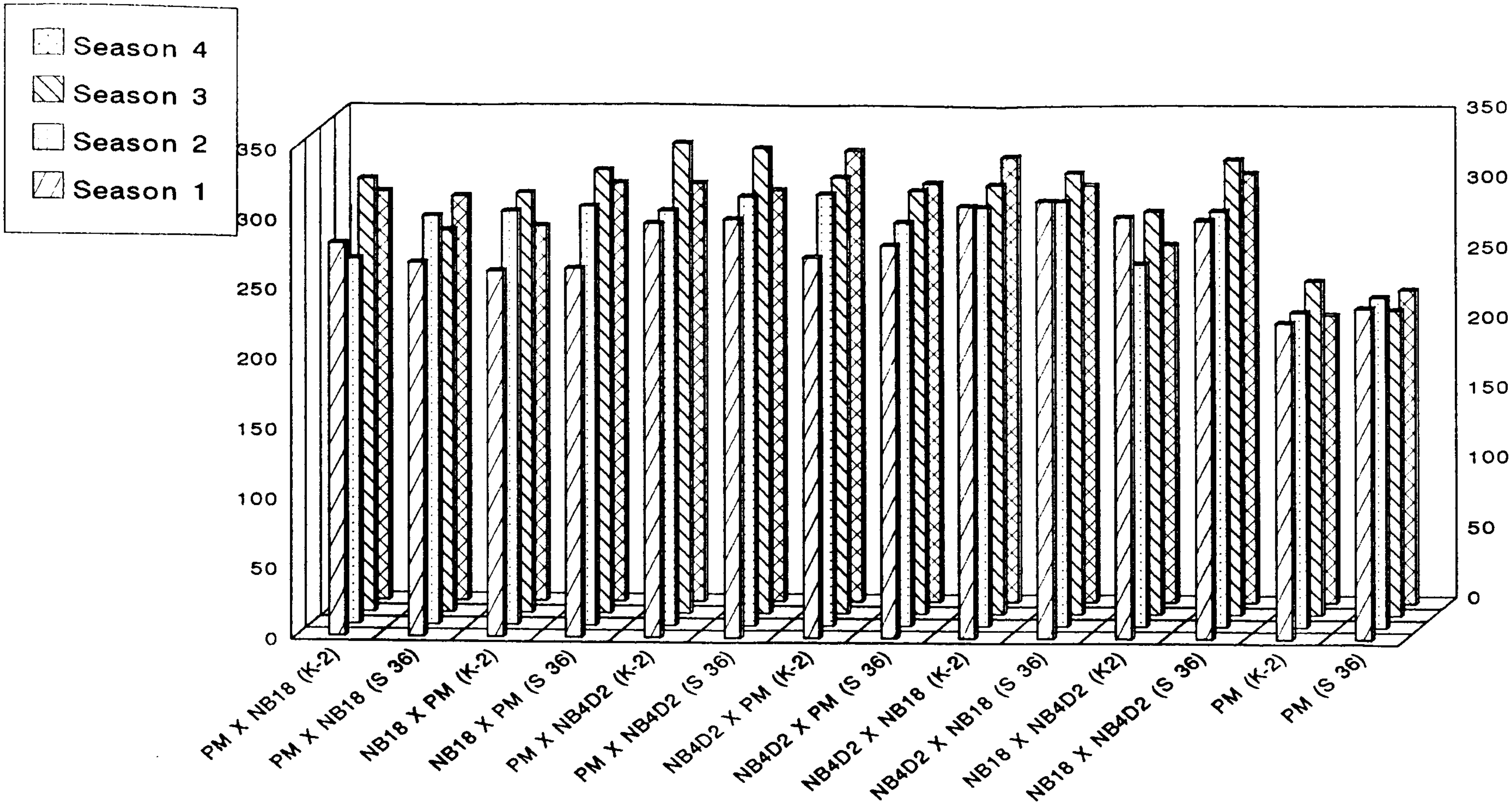

Fig. 4. Consumption of leaf by the fourth instar larvae of silkworm hybrids on two varieties of mulberry during 4 rearing periods (g fresh weight/100 larvae)

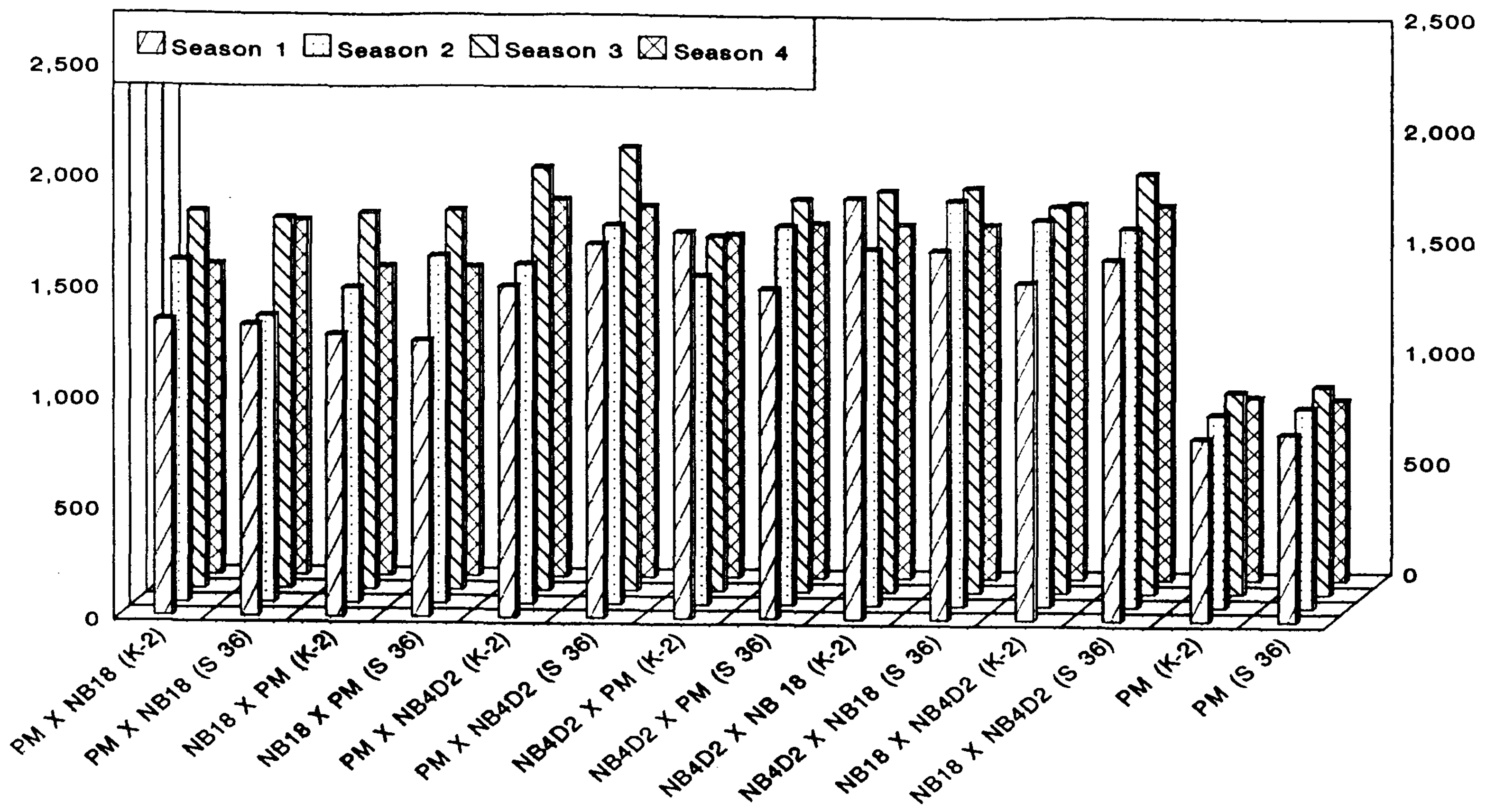

Fig. 5. Consumption of leaf by the fifth instar larvae of silkworm hybrids on two varieties of mulberry during 4 rearing periods (g fresh weight/100 larvae)

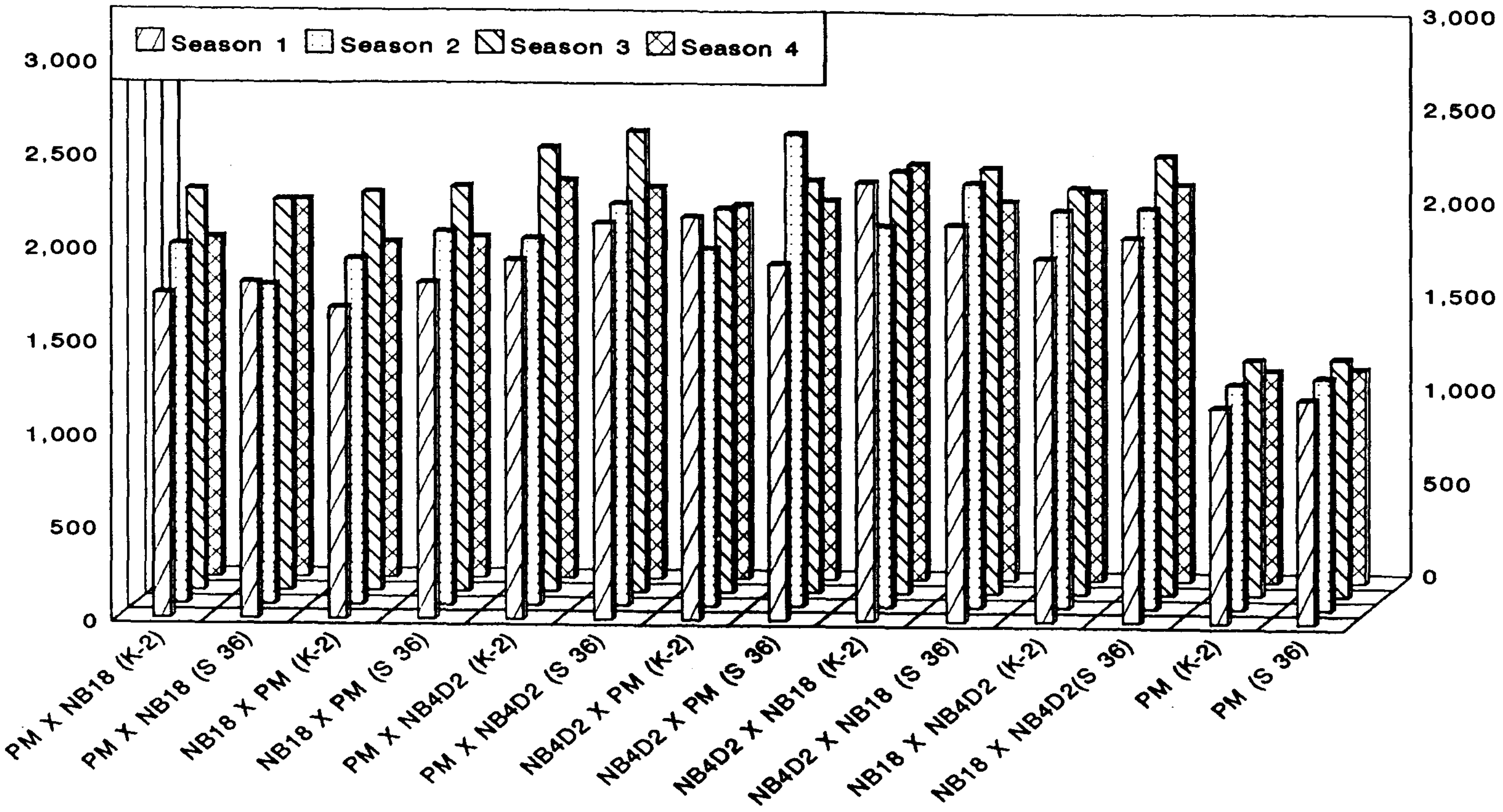

Fig.6. Total leaf consumption by different silkworm hybrids on two varieties of mulberry during four rearing periods (g fresh wt./100 larvae)

It was also seen from the present experiments, that the total consumption of S-36 was higher (1970.498 g/100 larvae) as compared to K-2. The importance of quality of leaf on growth, development and health of silkworm has been stressed by Yokayama, 1963. Studies by Das and Vijayaraghavan (1990) have indicated that there was a higher content of moisture in the leaves of S-36 mulberry variety which appeared to be a conducive factor for better larval growth and higher shell weight. So the increased consumption of S-36 can be attributed to higher moisture content in its leaves.

A greater consumption index can also mean lack of or imbalance of nutrients in the plants. High consumption index values indicate the nutritional unsuitability of the particular food as a rearing medium (Ranjith, 1980). Total fresh weight consumption was seen to increase with increased dilution of nutrients in the case of artificial diets (House, 1965).

Among the seasons, the IIIrd season (May-June) was found to be the best for leaf consumption with the lowest consumption being recorded in the Ist season which was cooler (January-February).

5.2 Larval duration

Graphical representation of the larval duration of different silkworm hybrids when reared on two different mulberry varieties during four experimental seasons is depicted in Fig.7. The bivoltine x multivoltine cross NB_{18} x PM had the longest duration with K-2 (576.15 hours) while another bivoltine x multivoltine NB_4D_2 x PM with 574.200 hours had the longest duration with S-36. The shortest duration was recorded for the bivoltine hybrid NB_4D_2 x NB_{18} on both K-2 (546.900 hours) and S-36 (546.000 hours). The multivoltine Pure Mysore recorded a duration of 558.000 hours on K-2 and 555.600 hours on S-36.

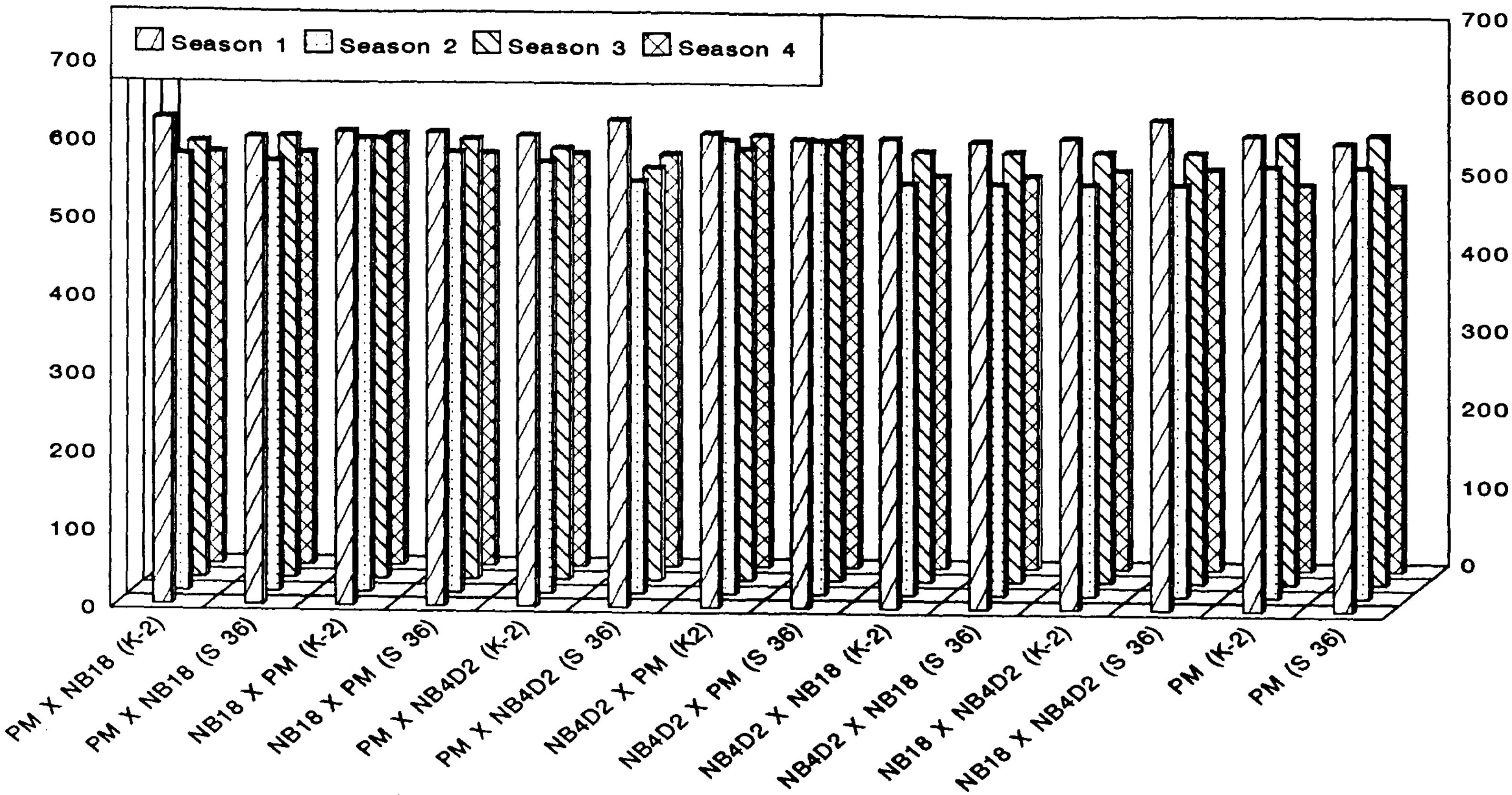

Fig.7. Duration of larva of different silkworm hybrids reared on two varieties of mulberry during four rearing periods (hours)

In the present experiment, larval duration of the pure multivoltine was found to be longer than or at par with bivoltine crosses. The duration was shorter by 9-12 hours on an average. The longer duration in Pure Mysore was earlier reported in Tamil Nadu by Thankavelu and Rajakumar (1988), and was attributed to the degeneration of the race. Bivoltine breeds in general have shorter larval duration than multivoltines. Shorter larval duration in crosses using bivoltines as female parent compared to multivoltines as female parent has been earlier reported by Benchamin *et al.* (1988). Our results establish that a bi x bi cross takes a much shorter duration than other crosses.

Between the mulberry varieties, larval duration was shorter with S-36 (558.600 hours) while with K-2 it was 561.386 hours. The mulberry varieties had significant interaction with characters like larval duration, larval weight and average filament length. No specific pattern or interaction could be noted with larval duration because the bivoltine hybrids and multi x bi hybrids showed varied interaction when offered the two mulberry leaves.

Among the four seasons, the rainy season (June-July) gave the shorter duration (522.686 hours) followed by the summer season (550.971 hours). The Ist season which was cooler than the others, registered the longest duration.

The results show that it would be prudent to go in for bivoltine races as female parents for obtaining a shorter larval duration in the situation existing in Kerala. Variety S-36 also supports a shorter duration. Since there is significant interaction between the races, seasons and also the mulberry varieties, further experimentation is necessary to establish the best race, best season and also the mulberry variety. However, our results indicate a longer duration for the races when grown in the cold season which could be avoided for rearing. But it is premature to arrive at such conclusions by taking larval duration alone into consideration.

5.3 Larval weight

Graphical representation of the larval weights of different silkworm hybrids when reared on two mulberry varieties during four experimental seasons is shown in Fig.8. The larval weight was highest in the cross NB_4D_2 x PM on K-2 (3.550 g) and PM x NB_4D_2 on S-36 (3.264).The lowest larval weight irrespective of mulberry was registered for the multivoltine race Pure Mysore. With K-2, the weight was 1.524 g while for S-36 it was 1.413 g.

Jayaswal (1992) had reported that multi x bi voltine hybrids exhibited significantly high superiority over multi x multi hybrids for larval weight. However, higher larval weight had no significant correlation with cocoon, shell weight and nutritional parameters in multivoltine hybrids as reported by Anantharaman *et al.* (1995).

Between seasons, the summer season (March-April) gave the highest larval weight (2.881 g) followed by the rainy season. The lowest larval weight was registered in the Ist season which was colder.

The mulberry variety had significant interaction with larval weight. The weight was highest with K-2 (2.645 g) than S-36 (2.500 g).

It would be evident from the results that Pure Mysore is inferior in its capability for consuming leaf and also for subsequent weight gain. This is exactly the reason why hybrids involving bivoltine and multivoltine parents have been developed. An observation of importance is that even though the mulberry variety S-36 is consumed to a greater extent than K-2 by almost all the races, it did not allow the larvae to have an increased weight gain. It was the K-2 fed worms that

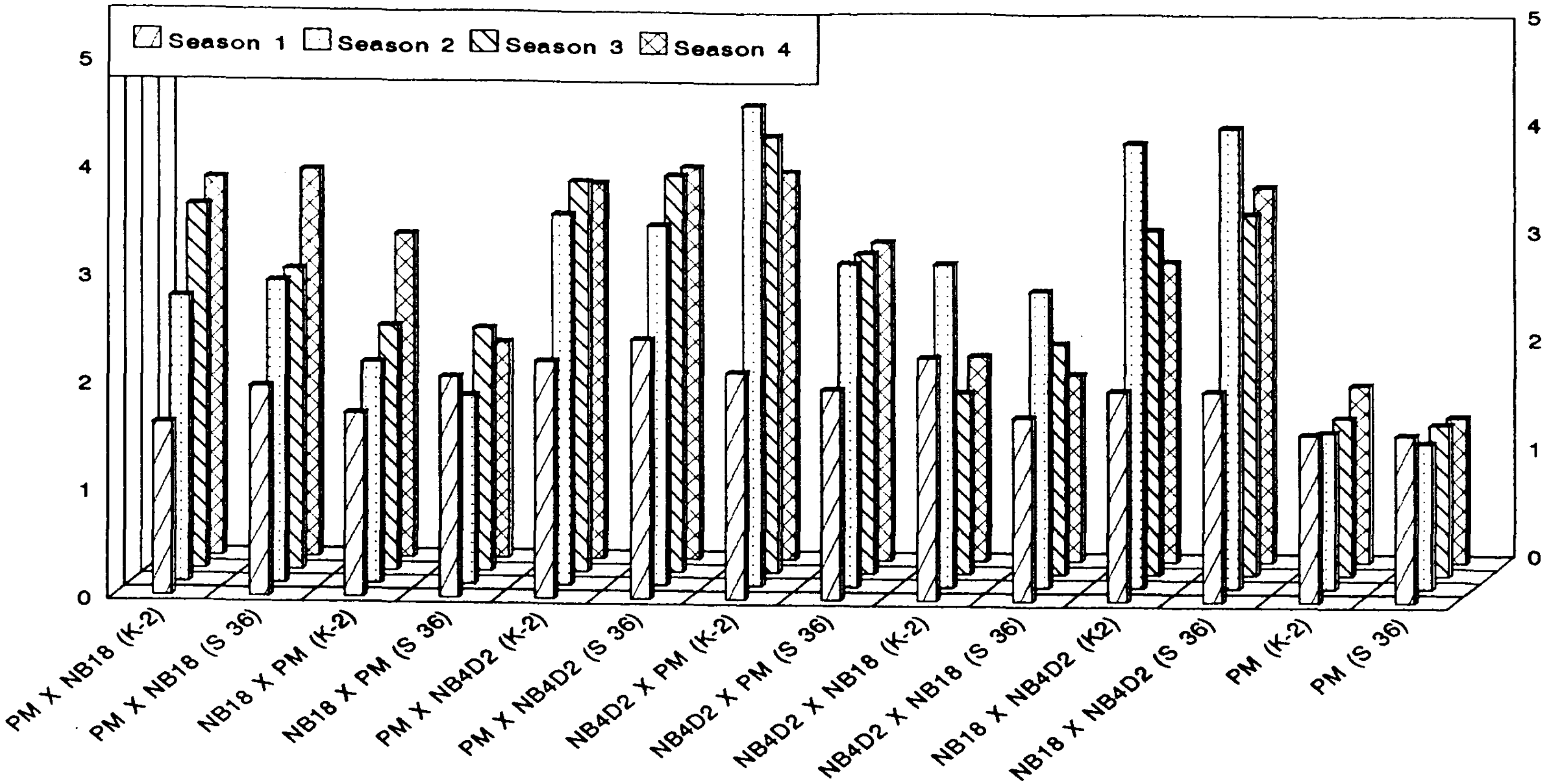

Fig.8. Larval weight of different silkworm hybrids reared on two varieties of mulberry during four rearing periods (g/larvae)

realised better weights. It had already been reported that S-36 has a higher moisture content (Das and Vijayaraghavan, 1990).

Hence, the palatability may be increased but both the nutritional quality and dry matter consumption may be lower in S-36 so that the larvae are forced to eat more for sustenance. It is also worthwhile to quote that higher larval weight do not lead to higher cocoon weight (Anantharaman *et al.*, 1995).

5.4 Weight of single cocoon

Graphical representation of single cocoon weight of different silkworm hybrids when reared on two mulberry varieties during four experimental seasons is shown in Fig.9. The highest cocoon weight was recorded with multi x bivoltine cross PM x NB_{18} (1.531 g) on K-2 and with multivoltine PM on S-36 (1.462 g). The lowest weight was registered with NB_{18} x PM on K-2 (1.115 g) and NB_{18} x NB_4D_2 (1.045 g). Siddappaji *et al.* (1987) has reported that cross breed PM x NB_4D_2 gave better yield than PM x NB_{18}.

Benchamin *et al.* (1988) had opined that cocoon weight was significantly higher in crosses using multivoltine as female parent than in crosses using bivoltine as a female parent. The results of the experiments conducted here also shows the same trend especially when reared on S-36.

Studies in Assam by Senapati *et al.* (1996), has revealed that multi x bi combinations gave a higher cocoon yield than multi x multi or bi x bi combinations through out the year. Assam being comparable to Kerala in climatic conditions, the results may also be comparable.

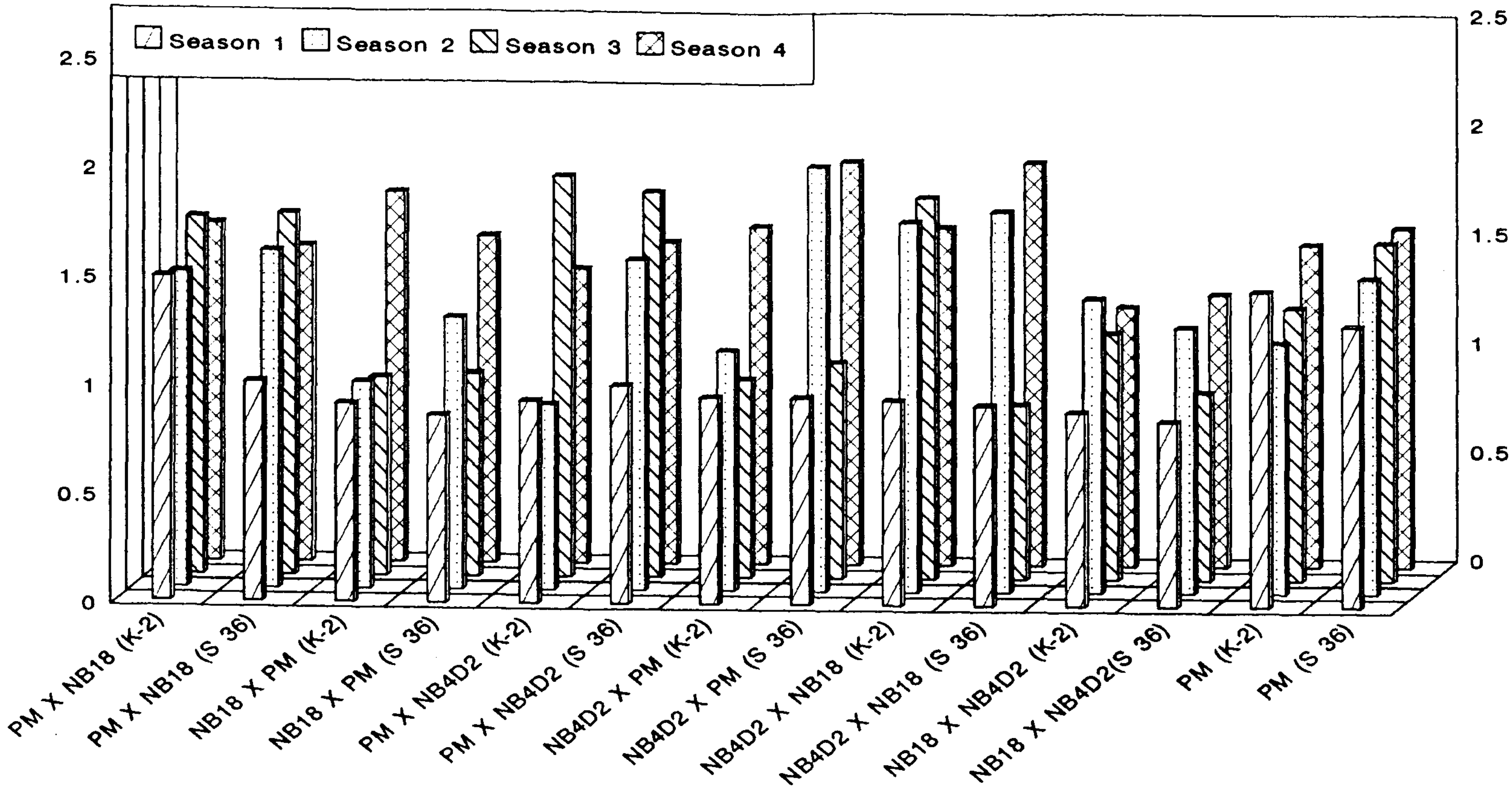

Fig.9. Weight of single cocoon of different silkworm hybrids reared on two varieties of mulberry during four rearing periods (g/cocoon)

Among the seasons, IVth season, that is the rainy season gave a higher cocoon weight with both K-2 (1.480 g) and S-36 (1.562 g) variety even though the consumption of food was low during this season.

Between the mulberry varieties S-36 gave a higher cocoon weight than K-2. PM x NB_{18} was found to perform better during rainy season compared to NB_7 as reported by Venkatagiriyappa *et al.* (1989).

These results stress the importance of further experimentation using different combinations of silkworm hybrids and mulberry varieties during the different rearing seasons to arrive at suitable races for specific situations. A general observation is that the multivoltine parents are more acclimatised than the bivoltine parents. Also, during the rains, the varieties of mulberry are in a much better physiological and nutritional status so that even a lower consumption of the leaves could support a higher cocoon weight.

5.5 Weight of single shell

Graphical representation of single shell weight of different silkworm hybrids when reared on two mulberry varieties during four experimental seasons is depicted in Fig.10. The multivoltine Pure Mysore gave the highest shell weight when reared on both K-2 and S-36 (0.319 g and 0.334 g) respectively. NB_4D_2 x PM recorded the least weight with K-2 while NB_{18} x PM was inferior on S-36. The bivoltine hybrids were not significantly different from each other in respect of single shell weight and came next to PM along with other hybrids. The cocoon weight generally revealed a positive correlation with shell weight. Anantharaman *et al.* (1995) had observed that cocoon weight was positively correlated with shell weight in both multi x bivoltine hybrids and bi x bivoltine hybrids.

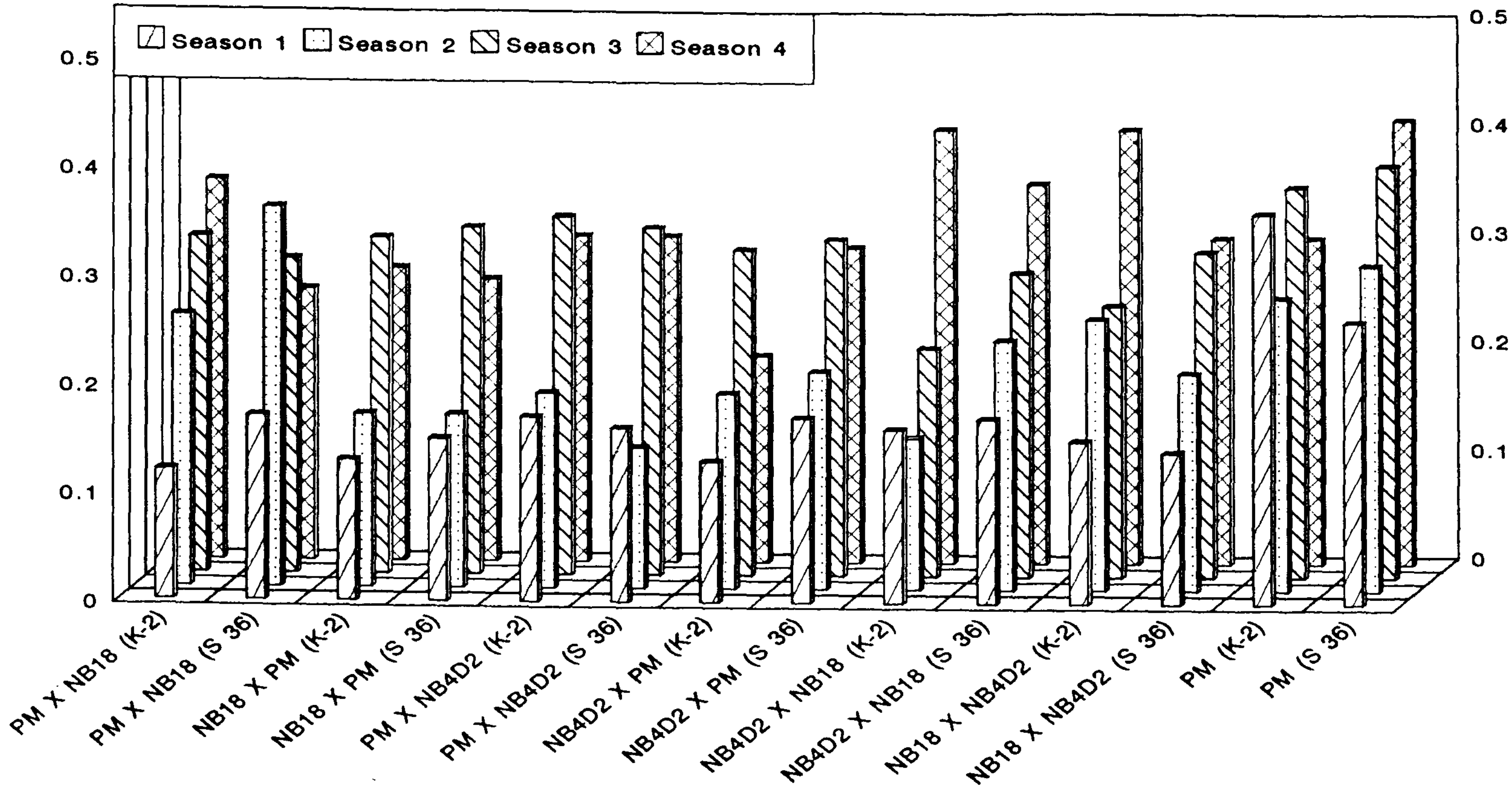

Fig.10. Weight of single shell of different silkworm hybrids reared on two varieties of mulberry during four rearing periods (g/shell)

Benchamin *et al.* (1988) had reported that shell percentage did not differ significantly in various crosses using multivoltine and bivoltine as female parent.

The results show that the popular PM x NB_4D_2 and PM x NB_{18} were on par as regards shell weight. However, Siddappaji *et al.* (1987) got PM x NB_4D_2 as giving a better yield than PM x NB_{18}.

The shell weight of PM x NB_4D_2 was higher than that of PM x NB_{18} as reported by Ravi in 1986. Our results however indicate that both these crosses were on par as regards this character.

5.6 Reeling characters (SRP, Reelability, Denier and Renditta)

The performance of different silkworm hybrids with regard to the reeling characters when reared on two mulberry varieties during four experimental seasons are depicted in Figs.11 to 15. The mulberry variety S-36 enabled the silkworms reared on them to have a higher shell ratio percentage (15.753), denier (2.176) and reelability (79.202). However, reeling parameters like AFL and renditta were marginally high when reared with K-2. This was in conformity with the findings of Raju *et al.* (1990).

Among the seasons, the summer season (March-April) was superior with regard to AFL and denier, whereas May-June gave the highest reelability. While SRP was maximum during the rainy season (June-July) the best renditta was recorded during the cold season (January-February). It may be noted that May-June was best in terms of leaf consumption. However this was not seen reflected highly in other characters except on reelability. Earlier work by Pershad *et al.* (1986) had substantiated that seasons and races were significant for all characters valuable in silkworm breeding.

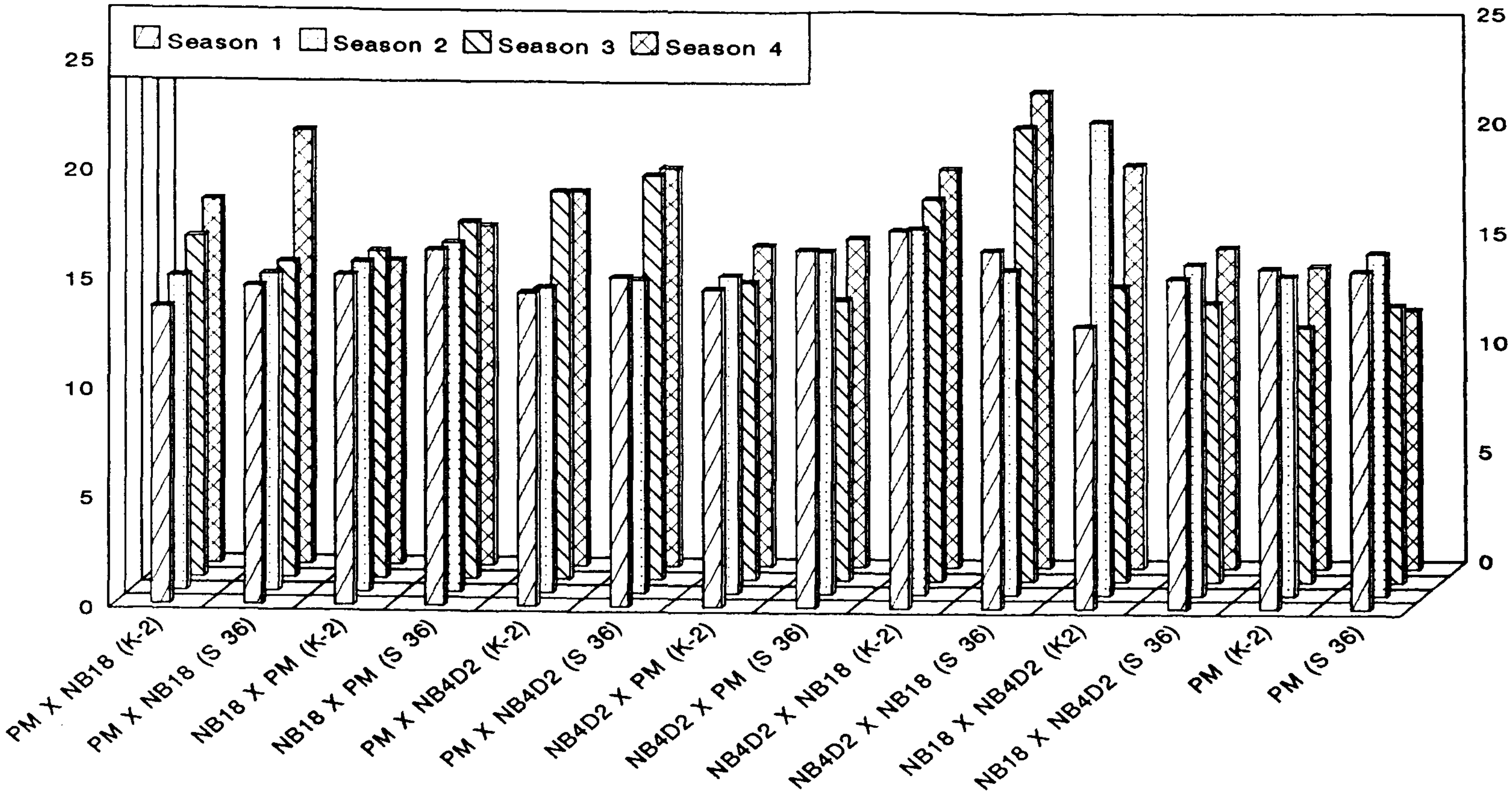

Fig.11. Shell ratio percentage of different silkworm hybrids reared on two varieties of mulberry during four rearing periods (%)

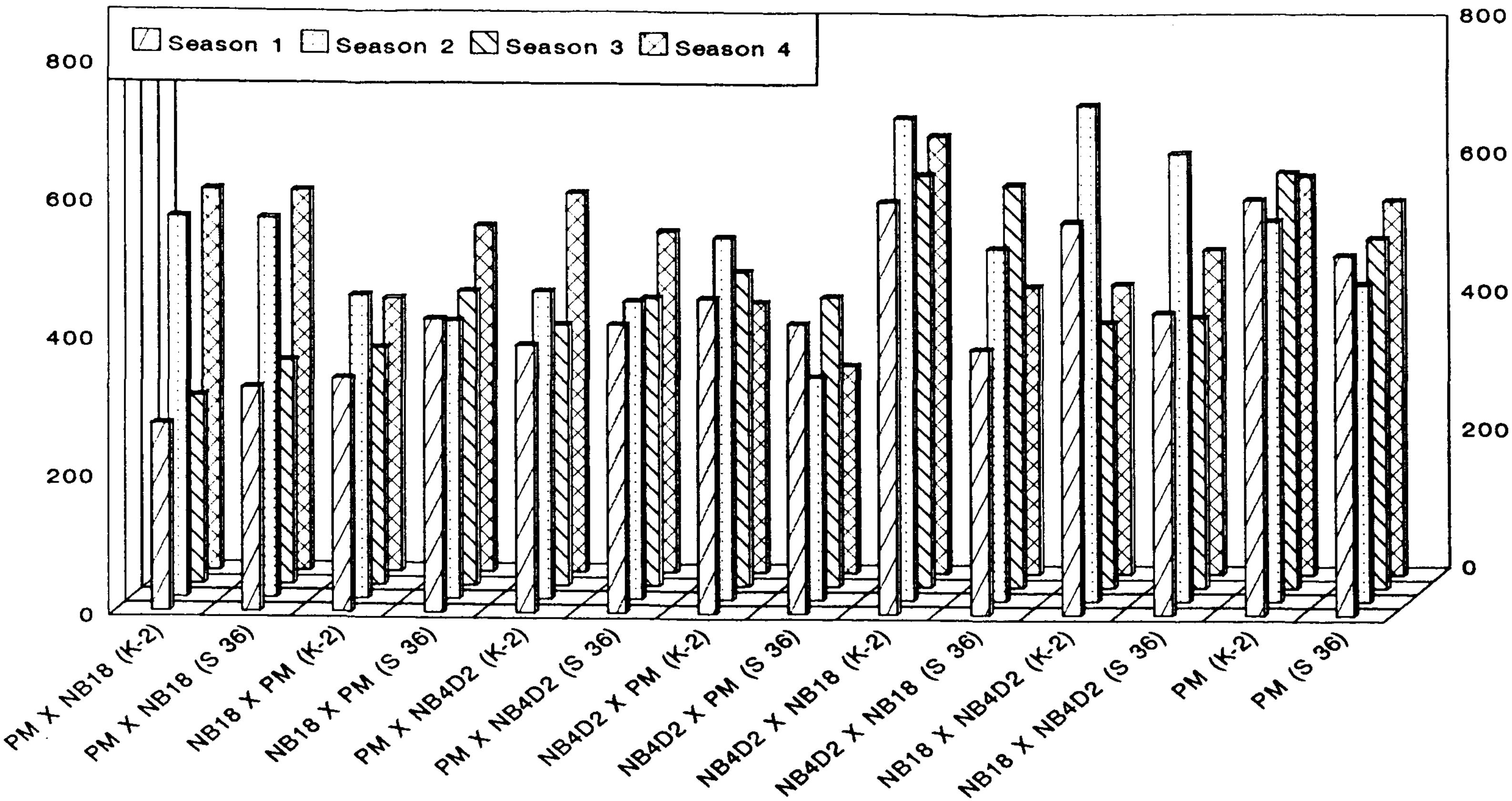

Fig.12. Average filament length of different silkworm hybrids reared on two varieties of mulberry during four rearing periods (m)

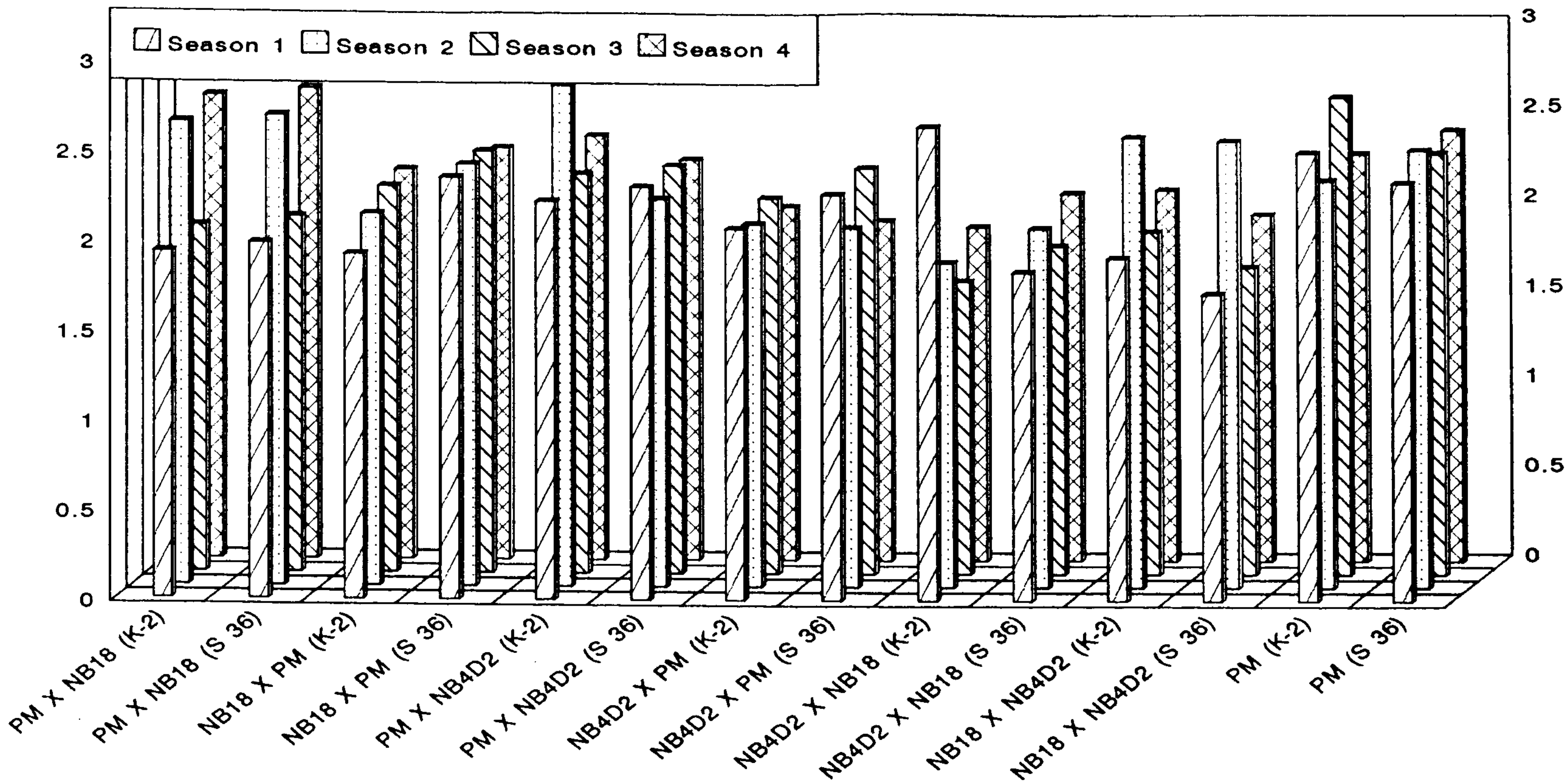

Fig.13. Denier of different silkworm hybrids reared on two varieties of mulberry during four rearing periods

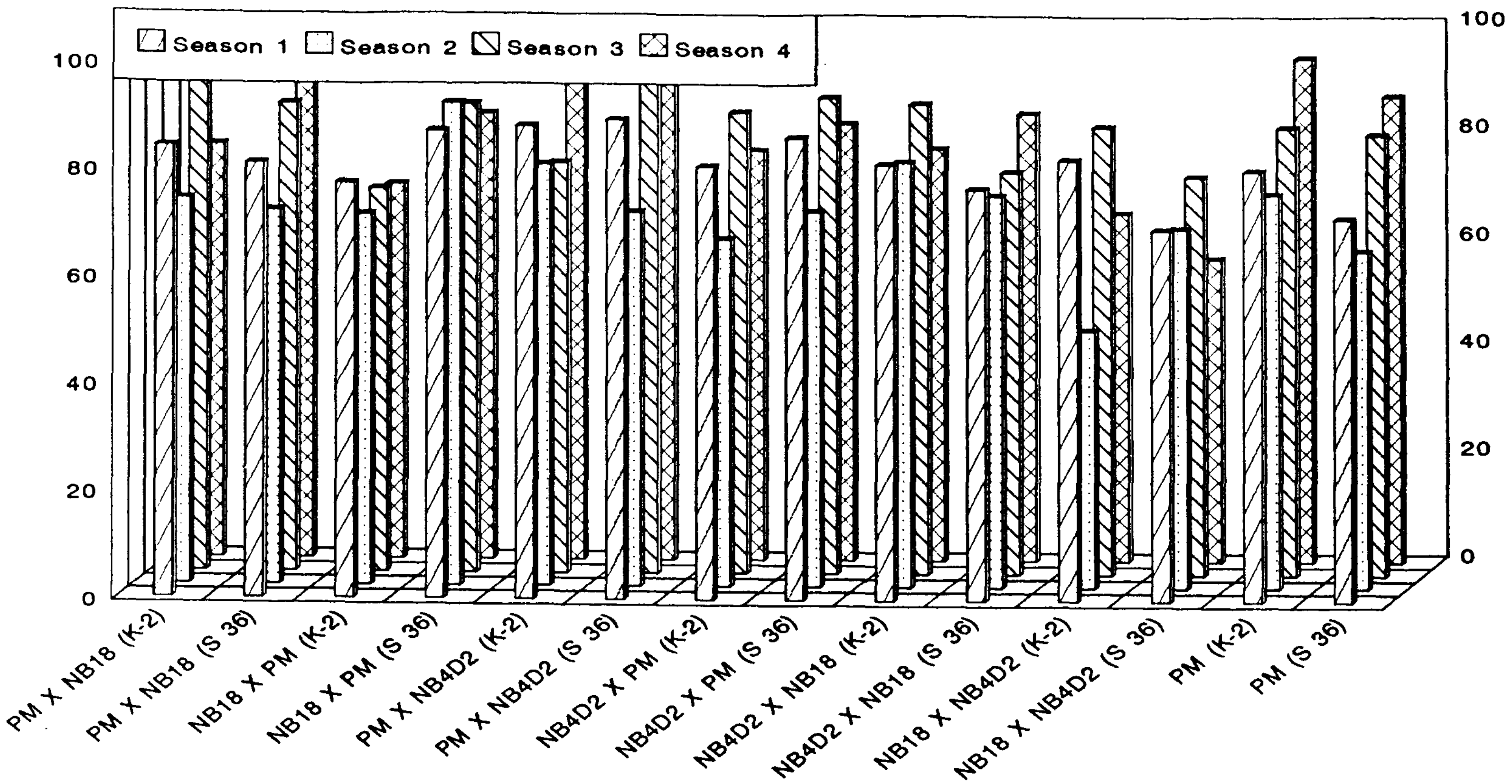

Fig.14. Reelability of different silkworm hybrids reared on two varieties of mulberry during four rearing periods

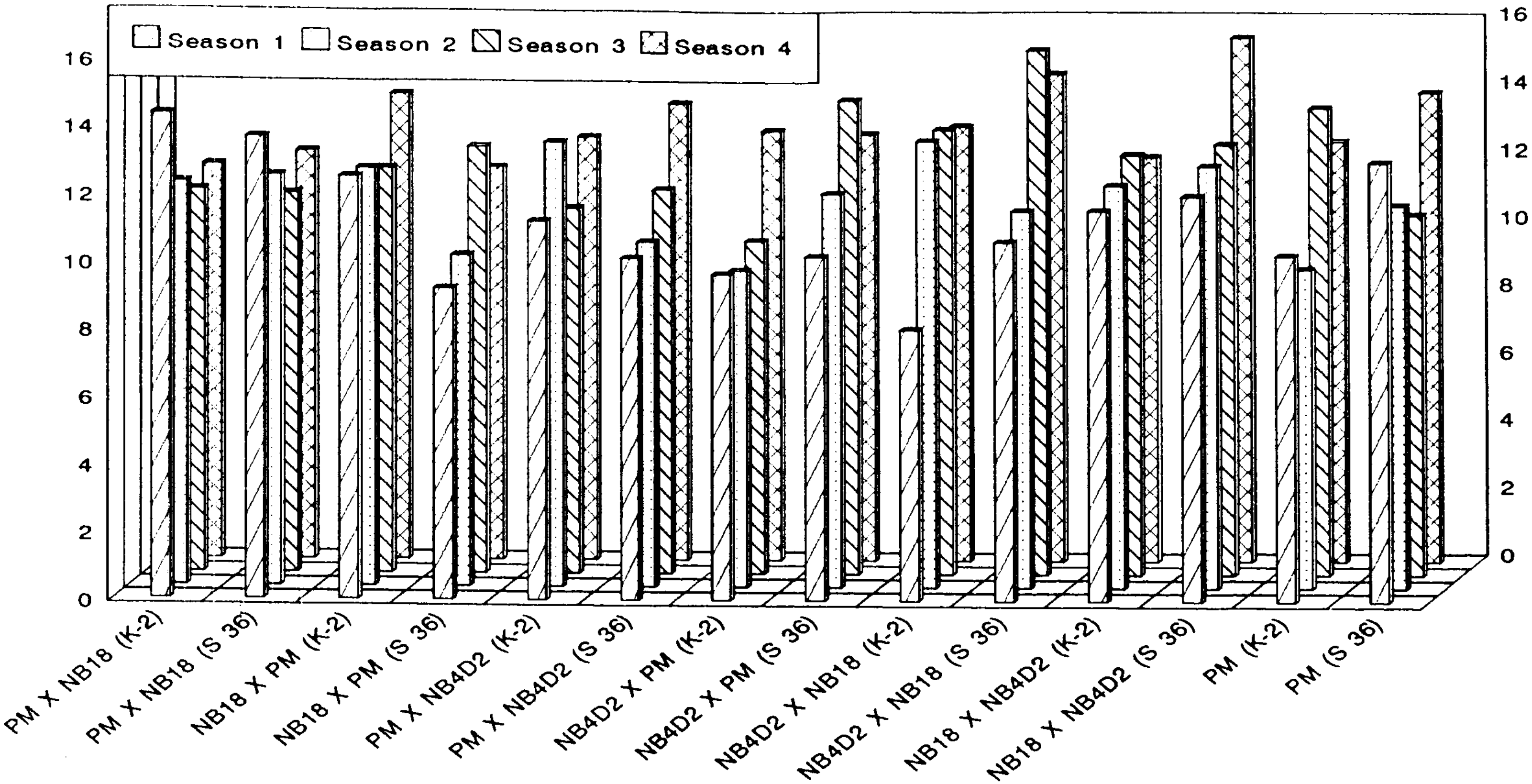

Fig.15. Renditta of different silkworm hybrids reared on two varieties of mulberry during four rearing periods

With regard to the silkworm hybrids, the SRP, AFL and renditta were generally high with bivoltine crosses, though multivoltine Pure Mysore also had a good filament length irrespective of the mulberry variety used. On K-2 the renditta was maximum with the hybrid NB_{18} x PM. But for this exception, bivoltine crosses performed better.

However, denier and reelability was high in multivoltine Pure Mysore and crosses involving PM as female parent.

It would be useful to compare the different hybrids evaluated in this experiment based on the average filament length per gram of cocoon and the SRP.

A perusal of the figures in Table 17 indicates that the bivoltine hybrids NB_{18} x NB_4D_2 and NB_4D_2 x NB_{18} gave an AFL of 460.480 m and 425.620 m respectively per each gram of cocoon, when reared on K-2 mulberry. It is clear that crosses involving Pure Mysore either as female or male parent though they had a shell to cocoon ratio in the range of 0.16 to 0.28 was inferior to these bivoltine hybrids in terms of AFL/g of cocoon.

The AFL yield when reared on S-36 also relfect the same trend. The bivoltines gave a higher AFL of 397.05 m per gram of cocoon for NB_4D_2 x NB_{18} and 483.39/gram of cocoon for NB_{18} x NB_4D_2. The shell to cocoon ratio for these were 0.2 and 0.194 respectively. The PM which had a higher shell to cocoon ratio of 0.228 was inferior in terms of AFL yielding only 373 m/g of cocoon. Crosses involving PM as one of the parents had a lower shell to cocoon ratio and lower filament length.

In pure races, high floss percentage is characteristic of multivoltine PM. In crosses, floss percentage was significantly higher when bivoltine was used as female parent compared to multivoltine as female parent (Benchamin *et al.*, 1988).

Table 17. Comparison of different silk worm hybrids based on AFL/g of cocoon and SRP

	Single cocoon weight	Shell weight	Shell to cocoon ratio	AFL	AFL/g cocoon	SRP
K-2 Mulberry variety						
PM x NB_{18}	1.531	0.254	0.17	412.212	269.24	16.6
NB_{18} x PM	1.115	0.216	0.19	379.047	339.95	19.4
PM x NB_4D_2	1.242	0.243	0.20	439.763	354.076	19.7
NB_4D_2 x PM	1.126	0.199	0.18	456.575	405.48	17.7
NB_4D_2 x NB_{18}	1.486	0.224	0.15	632.466	425.62	15.1
NB_{18} x NB_4D_2	1.136	0.261	0.229	523.107	460.48	23.0
PM	1.332	0.319	0.24	583.463	438.04	28.0
S-36 Mulberry variety						
PM x NB_{18}	1.418	0.263	0.19	424.858	299.617	18.5
NB_{18} x PM	1.133	0.218	0.19	408.805	360.82	19.2
PM x NB_4D_2	1.440	0.225	0.16	439.813	305.43	15.6
NB_4D_2 x PM	1.437	0.239	0.28	411.108	286.69	16.6
NB_4D_2 x NB_{18}	1.330	0.258	0.194	528.074	397.05	19.4
NB_{18} x NB_4D_2	1.045	0.230	0.220	505.147	483.39	22.0
PM	1.462	0.334	0.228	545.656	373.23	22.8

It can be inferred that silkworm hybrids have an edge over multivoltines because of better SRP and yield of a better filament length per gram of cocoon, under situations existing in Kerala. Also efficiency of conversion of food into silk is more with bivoltine hybrids which may be a parental character as reported by Thomas (1995).

5.7 Influence of environment on rearing

It is evident from the results that as the maximum temperature was on the increase, the cocoon weight decreased. This indicates that the temperature exceeding a certain limit may be a limiting factor in realising a higher cocoon weight.

The reduction in growth characters during the hot and less humid season was due to the influence of climatic conditions (Adikson, 1965). This may be because the metabolism at higher levels of temperature is high and a lot of energy may be expended on this so that conversion of ingested food to the body may be low. This causes a reduction in cocoon weight. However, it is also relevant to understand that a lower minimum temperature coupled with higher RH and higher rainfall increased the cocoon weight. A lower rearing temperatures were reported to increase the rate of utilisation of protein in mulberry leaves (Shen, 1986).

Again under conditions that exist in Kerala, the general level of temperature is slightly higher than the optimum for silkworm rearing. When higher rainfall occurs it is a corollary that the RH increases and the minimum temperature decreases. Still it may be reasonable to presume that wide fluctuations in abiotic factors may not be to the advantage of silkworm rearing. It is only mild fluctuations within a reasonable limit that may be useful.

A similar situation exists with regard to shell weight also. This is also expected since, barring the influence of variations in floss percentage, a higher cocoon weight might yield a higher shell weight. Anantharaman *et al.* (1995) had observed the positive correlation of cocoon weight with shell weight in both multi x bi and bi x bivoltine hybrids. The difference obtained with respect to the correlation of SRP, than what was observed hitherto may be attributable to the peculiar characteristic of different races where the shell may be contributed more by floss than by silk. SRP was seen to be highly correlated to lower RH in the present situation. The inherent genetic make up of the races might also have influenced such a relationship.

Larval duration was negatively correlated with minimum temperature (Gangawar and Somasundaram, 1991). This is only expected, since there may be a certain minimum temperature threshold for the growth of the larvae. At higher temperature, the larvae consume the food faster and metabolise the nutrients faster. With increasing temperature, a decrease in food passage time for the mid and hindgut of silkworm was reported by Upadhyay and Mishra (1994).

The influence exerted by RH and rainfall causing a protracted larval period may be indirect, since higher rainfall increases the RH and lowers the temperature. With the lowest value of maximum temperature there is a direct positive correlation for the larval duration. This again indicates that the maximum temperature was towards the higher side and the reduction in this would have positively influenced the larval duration. This is a pointer towards artificially improving the rearing condition in the rearing house by providing heat reduction strategies during peak hours of sunshine.

In conclusion it can be said that if shell weight SRP and AFL are taken as indicators of a better yield, the bivoltine hybrids of silkworm, also have good chances of success under the situation existing in Kerala. The bivoltine hybrids NB4D2 x NB18 and NB_{18} x NB_4D_2 may now be popularised along with the popular PM x NB_4D_2.

The mulberry varieties and the seasons have shown variable results with regard to the economic characters of silkworm. However it can be inferred that successful and good quality cocoon crops are possible due to S-36 also, when reared through out the year, provided the optimum conditions for rearing are maintained. More studies are needed to evaluate the nutritional indices of mulberry which attributes to a profitable cocoon crop under the situations existing in Kerala.

Rao *et al.* (1997) had obtained higher yield for multivoltines than bivoltines. It was only in specific seasons that bivoltines performed better. In the present instance since silkworm rearing was conducted for the first time in the campus, the results were not on expected lines. There is a general decline in shell weight in respect of the hybrids than in Pure Mysore eventhough they had higher larval weights. This is a problem to be investigated. It may be that, the mounting methods employed in the study was not perfect, but PM, because of its high adaptability could produce a reasonably heavy cocoon. These factors indicate the superiority of the local breed PM when offered the minimum conditions of rearing. It would be worthwhile to go in for PM or other traditional adapted varieties initially, until the rearers become accustomed to good sericultural practices. From then on they could switch over to better races and hybrids.

Summary

6. SUMMARY

The present study was undertaken to evaluate region and season specific multi x bi and bivoltine hybrids of *Bombyx mori* L. suitable for Kerala, taking Vellanikkara as a representative area.

The silkworm hybrids used for the study were the multivoltine x bivoltine crosses viz., PM x NB_4D_2, PM x NB_{18} and NB_{18} x NB_4D_2 and their reciprocal crosses against the multivoltine check Pure Mysore. Two varieties of mulberry were used for rearing, the popularly used Kanva-2 (K-2) and the upcoming variety S-36. The actual rearing was conducted in the rearing house attached to the College of Horticulture during four rearing periods.

(i) January-February
(ii) March-April
(iii) May-June
(iv) June-July

Observations were recorded during the rearings to assess the performance of the hybrids when fed with the different mulberry varieties. The recorded observations were on the actual leaf consumption during each instar, larval duration and weight, weight of single cocoon and shell, shell ratio percentage, average filament length, denier, reelability and renditta. The economic characters were also correlated with the meteorological observations at the time of study.

The total leaf consumption with K-2 was highest for NB_4D_2 x NB_{18} (2224.787 g/100 larvae) and for S-36 it was PM x NB_4D_2 (2212.063 g/100 larvae). PM consumed the lowest quantity of leaf in either case. S-36 was seen to be consumed more as against K-2. Among the seasons, the consumption was highest during the IIIrd season. However, this higher leaf consumption was not seen greatly reflected on the economic parameters of the hybrids.

Larval duration was shortest for the bivoltine hybrid NB_4D_2 x NB_{18} irrespective of the mulberry leaf fed, while the longest duration was seen with the reciprocal crosses. The mulberry variety S-36 was seen to give a shorter larval duration than K-2. With regard to seasons the IVth season recorded the shortest duration.

As regards larval weight the crosses NB_4D_2 x PM and PM x NB_4D_2 registered high weights with K-2 and S-36 respectively while PM recorded the lowest. Summer season was seen to be conducive for weight gain while the mulberry variety K-2 had an edge over S-36 in inducing weight gain.

The highest cocoon weight was recorded for the multi x bivoltine cross PM x NB_{18} (1.531 g) with K-2 and for the multivoltine PM on S-36 (1.462 g). Rainy season gave the highest cocoon weight with both K-2 and S-36. The mulberry variety S-36 gave a higher cocoon weight than K-2.

The shell weight was good with bivoltine hybrids NB_{18} x NB_4D_2 and NB_4D_2 x NB_{18} and also crosses involving PM as the female parent. Third season was superior with the IVth being on par.

The shell ratio percentage which is a good indicator of the quality of cocoons was maximum for bivoltine hybrids NB_4D_2 x NB_{18} irrespective of the mulberry leaf fed. The lowest shell ratio percentage was for the multivoltine PM. The IVth season recorded highest shell ratio percentage with both K-2 and S-36.

Average filament length was also best with the same bivoltine hybrids along with multivoltine PM. The mulberry variety K-2 gave longer average filament length than S-36, while among the seasons IInd season was superior.

Other reeling parameters like denier, reelability and renditta exhibited a variable trend. While PM race gave the highest denier, the hybrid PM x NB_4D_2 exhibited the highest reelability. The best renditta was given by the crosses PM x NB_{18} and NB_{18} x PM respectively on K-2 and S-36. The seasons II, III and I came superior with respect to denier, reelability and renditta.

Larval duration was seen to be negatively correlated with minimum temperature. As the maximum temperature increased cocoon weight decreased. However, a lower minimum temperature coupled with higher relative humidity and higher rainfall increases the cocoon weight.

The present study indicates that it may be possible to select desirable mulberry silkworm breed combinations suited for every season in Kerala. It is evident that bivoltine crosses have high chances of success, when reared on high quality mulberry varieties like K-2 and S-36. However, the crops should be planned in a systematic way by strictly adhering to the brushing period in correlation with the season. In terms of better returns to farmers the bivoltine hybrids fared better in the present analysis. More extensive studies with more crosses and mulberry varieties would help to identify season specific and variety specific races of silkworm that would ensure the best profit for the farmer.

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EVALUATION OF MULTI X BI BIVOLTINE HYBRIDS OF SILKWORM
Bombyx mori L.

By
RAJENI NARAYANAN

ABSTRACT OF THE THESIS

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Kerala Agricultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 654
KERALA, INDIA

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ABSTRACT

In a study undertaken to evaluate the region and season specific multi x bi and bivoltine hybrids of silkworm *Bombyx mori*, for commercial exploitation in Kerala, six hybrids of silkworm were reared using K-2 and S-36 mulberry varieties under Vellanikkara condition. The crosses used were PM x NB_{18}, PM x NB_4D_2 and their reciprocals, NB_4D_2 x NB_{18} and its reciprocal and PM as check.

The evaluation was carried out based on characters like leaf consumption, larval duration and weight, cocoon and shell weights, shell ratio percentage, average filament length, denier, reelability and renditta. The climatic factors were also correlated with major economic characters of silkworm.

The present study confirms the superiority of bivoltine silkworm hybrids like NB_4D_2 x NB_{18} and NB_{18} x NB_4D_2 justifying their wide acceptance in states other than Kerala. It is evident that if rearing is done in a systematic way, by strictly adhering to the brushing period in correlation with the seasons and if the use of high quality mulberry varieties is advocated these crosses will yield good returns in Vellanikkara.

Though the various economic parameters reflected a variable trend, ultimately when the average filament length/g cocoon, shell ratio percentage and cocoon weight were considered, the bivoltine hybrids performed superior to the others.

Appendices

APPENDIX-1

ANOVA for leaf consumption - Ist instar

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	0.806	0.806	3.3414	0.0729
4	Races	6	7.177	1.196	4.9601	0.0004**
6	Mulberry x races	6	2.314	0.386	1.5989	0.1646
8	Season	3	3.288	1.096	4.5449	0.0064**
10	Mulberry x season	3	0.663	0.221	0.9166	-
12	Race x season	18	17.550	0.975	4.0429	0.0000**
14	Mulberry x race x season	18	10.505	0.584	2.4200	0.0061**
15	Error	56	13.505	0.241		
	Total	111	55.808			

** Significant at 1% level

APPENDIX-2

ANOVA for leaf consumption - IInd instar

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	26.036	26.036	10.4787	0.0020**
4	Races	6	963.385	160.565	64.6226	0.0000**
6	Mulberry x races	6	78.727	13.121	5.2809	0.0002**
8	Season	3	3.052	1.017	0.4095	-
10	Mulberry x season	3	17.552	5.851	2.3548	0.0817
12	Race x season	18	58.395	3.244	1.3057	0.2201
14	Mulberry x race x season	18	73.890	4.105	1.6522	0.0780
15	Error	56	139.140	2.485		
	Total	111	1360.177			

** Significant at 1% level

APPENDIX-4

ANOVA for leaf consumption - IVth instar

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	524.190	524.190	2.5971	0.1127
4	Races	6	74352.664	12392.111	61.3956	0.0000**
6	Mulberry x races	6	4705.618	784.270	3.8856	0.0026**
8	Season	3	5407.998	1802.666	8.9311	0.0001**
10	Mulberry x season	3	760.925	253.642	1.2566	0.2981
12	Race x season	18	9393.132	521.841	2.5854	0.0035**
14	Mulberry x race x season	18	60966.838	338.713	1.6781	0.0719
15	Error	56	11303.062	201.840		
	Total	111	112544.425			

** Significant at 1% level

APPENDIX-3

ANOVA for leaf consumption - IIIrd instar

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	117.875	117.875	1.4257	0.2375
4	Races	6	6401.771	1066.962	12.9048	0.0000**
6	Mulberry x races	6	151.977	25.329	0.3064	-
8	Season	3	1564.615	521.538	6.3079	0.0009**
10	Mulberry x season	3	154.867	51.622	0.6244	-
12	Race x season	18	694.943	38.608	0.4670	-
14	Mulberry x race x season	18	1391.933	77.330	0.9353	-
15	Error	56	4630.055	82.680		
	Total	111	15108.037			

** Significant at 1% level

APPENDIX-5

ANOVA for leaf consumption - Vth instar

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	34450.658	34450.658	1.5843	0.2134
4	Races	6	889458.015	1482430.836	68.1744	0.0000**
6	Mulberry x races	6	43845.974	7307.662	0.3361	-
8	Season	3	852951.610	284317.203	13.0753	0.0000**
10	Mulberry x season	3	46524.231	15508.077	0.7132	-
12	Race x season	18	476561.471	26475.637	1.2176	0.2796
14	Mulberry x race x season	18	371513.485	20639.638	0.9492	-
15	Error	56	1217701.778	21744.675		
	Total	111				

** Significant at 1% level

APPENDIX-6

ANOVA for total leaf consumption (gm/fresh weight/100 larva)

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	81745.291	81745.291	2.6933	0.1064
4	Races	6	11645052.452	1940842.075	63.9469	0.0000**
6	Mulberry x races	6	114106.967	19017.828	0.6266	-
8	Season	3	947753.379	315917.793	10.4089	0.0000**
10	Mulberry x season	3	94419.816	31473.272	1.0370	0.3833
12	Race x season	18	549314.640	30517.480	1.0055	0.4681
14	Mulberry x race x season	18	589766.945	32764.830	1.0795	0.3954
15	Error	56	1699.648	30350.860		
	Total	111	15721807.641			

** Significant at 1% level

APPENDIX-7

ANOVA for larval duration

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	204.120	204.120	53.6350	0.0000**
4	Races	6	9639.077	1606.513	422.1307	0.0000**
6	Mulberry x races	6	763.739	127.290	33.4469	0.0000**
8	Season	3	107690.755	35896.918	9432.3501	0.0000**
10	Mulberry x season	3	195.172	65.057	17.0946	0.0000**
12	Race x season	18	14306.579	794.810	208.8459	0.0000**
14	Mulberry x race x season	18	2835.128	157.507	41.3869	0.0000**
15	Error	56	213.121	3.806		
	Total	111				

** Significant at 1% level

APPENDIX-8
ANOVA for larval weight

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	0.587	0.587	6.0493	0.0170*
4	Races	6	42.968	7.161	73.7699	0.0000**
6	Mulberry x races	6	2.773	0.462	4.7616	0.0006**
8	Season	3	16.185	5.395	55.5754	0.0000**
10	Mulberry x season	3	0.357	0.119	1.2263	0.3087
12	Race x season	18	16.114	0.895	9.2217	0.0000**
14	Mulberry x race x season	18	3.023	0.168	1.7299	0.0609
15	Error	56	5.436	0.097		
	Total	111				

* Significant at 5% level
** Significant at 1% level

APPENDIX-9

ANOVA for weight of single cocoon

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	0.050	0.050	1.1676	0.2845
4	Races	6	2.049	0.342	7.9326	0.0000**
6	Mulberry x races	6	0.730	0.123	2.8511	0.0171*
8	Season	3	3.552	0.184	27.4992	0.0000**
10	Mulberry x season	3	0.821	0.274	6.3584	0.0009**
12	Race x season	18	3.716	0.206	4.7954	0.0000**
14	Mulberry x race x season	18	1.355	0.075	1.7488	0.0573
15	Error	56	2.411	0.043		
	Total	111				

* Significant at 5% level

** Significant at 1% level

APPENDIX-10

ANOVA for weight of single shell

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	0.001	0.001	0.4833	-
4	Races	6	0.133	0.022	7.3893	0.0000**
6	Mulberry x races	6	0.016	0.003	0.8840	-
8	Season	3	0.391	0.130	43.4640	0.0000**
10	Mulberry x season	3	0.004	0.001	0.4348	-
12	Race x season	18	0.134	0.007	2.4874	0.0049**
14	Mulberry x race x season	18	0.071	0.004	1.3238	0.2092
15	Error	56	0.168	0.003		
	Total	111	0.919			

* Significant at 5% level

** Significant at 1% level

APPENDIX-11

ANOVA for shell ratio percentage

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	3.451	3.451	1.3427	0.2515
4	Races	6	153.231	25.538	9.9360	0.0000**
6	Mulberry x races	6	34.795	5.799	2.2562	0.0509
8	Season	3	26.668	8.889	3.4585	0.0223*
10	Mulberry x season	3	10.250	3.417	1.3292	0.2740
12	Race x season	18	226.958	12.609	4.9056	0.0000**
14	Mulberry x race x season	18	73.077	4.060	1.5795	0.0980
15	Error	56	143.936	2.570		
	Total	111	672.366			

* Significant at 5% level

** Significant at 1% level

APPENDIX-12

ANOVA for average filament length

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	60857.744	60857.744	15.0833	0.0003**
4	Races	6	326293.622	54382.270	13.4784	0.0000**
6	Mulberry x races	6	191340.410	31890.068	7.9038	0.0000**
8	Season	3	163530.126	54510.042	13.5100	0.0000**
10	Mulberry x season	3	16021.677	5340.559	1.3236	0.2758
12	Race x season	18	410508.551	22806.031	5.6524	0.0000**
14	Mulberry x race x season	18	46368.167	2576.009	0.6385	-
15	Error	56	225947.624	4034.779		
	Total	111	1440867.920			

** Significant at 1% level

APPENDIX-13

ANOVA for Denier

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	0.067	0.067	3.0541	0.0860
4	Races	6	3.472	0.579	26.5618	0.0000**
6	Mulberry x races	6	0.474	0.079	3.6242	0.0042**
8	Season	3	0.654	0.218	10.0056	0.0000**
10	Mulberry x season	3	0.022	0.007	0.3316	-
12	Race x season	18	2.748	0.153	7.0069	0.0000**
14	Mulberry x race x season	18	0.314	0.017	0.8008	
15	Error	56	1.220	0.022		
	Total	111	8.971			

** Significant at 1% level

APPENDIX-14
ANOVA for reliability

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	38.224	38.224	0.2623	-
4	Races	6	72521.667	420.278	2.8843	0.0161*
6	Mulberry x races	6	1287.656	214.069	1.4728	0.2043
8	Season	3	2980.360	993.453	6.8179	0.0005**
10	Mulberry x season	3	108.186	36.062	0.2475	-
12	Race x season	18	2766.155	153.675	1.0546	0.4191
14	Mulberry x race x season	18	1394.386	77.466	0.5316	
15	Error	56	8159.888	145.712		
	Total	111				

* Significant at 5% level
** Significant at 1% level

APPENDIX-15

ANOVA for renditta

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
2	Mulberry	1	3.072	3.072	1.5573	0.2173
4	Races	6	21.714	3.691	1.8344	0.1089
6	Mulberry x races	6	37.258	6.210	3.1475	0.0099**
8	Season	3	55.831	18.610	9.4331	0.0099**
10	Mulberry x season	3	6.132	2.044	1.0360	0.0000**
12	Race x season	18	86.420	4.801	2.4336	0.3838
14	Mulberry x race x season	18	66.487	3.694	1.8722	0.0058**
15	Error	56	110.481	1.973		0.0384
	Total	111	387.395			

** Significant at 1% level

APPENDIX-16

Meteorological data during the four rearing periods

Jan-Feb.	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Max. temp.	34.2	34.0	34.2	33.0	33.4	32.8	32.3	33.5	33.6	33.5	33.0	34.0	34.2	33.5	33.4	33.5	34.0	34.3	34.0	33.6	33.8	34.8	34.0	35.0	35.0	35.3
Min. temp.	22.0	21.5	23.0	22.6	23.5	22.0	17.0	21.5	22.0	23.0	23.0	20.6	22.5	22.0	22.5	20.4	21.5	24.0	24.0	23.0	23.2	22.9	23.0	21.2	22.0	24.2
R.H.	64.5	47.5	51.5	45.5	47.5	46.5	43.5	34.0	45.5	83.0	45.5	42.0	42.0	53.5	66.5	44.5	59.5	45.0	41.0	44.5	48.5	58.0	61.0	50.5	46.0	53.5
Rainfall																										

March-April	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8
Max. temp.	38.8	37.8	35.0	34.8	35.6	35.0	35.5	35.0	38.5	40.4	35.8	37.2	35.2	34.8	33.8	33.6	34.2	36.0	34.0	35.0	36.7	36.0	38.8	35.8	36.0
Min. temp.	24.8	26.0	25.4	26.6	26.5	26.4	25.3	25.0	24.5	25.5	26.0	26.2	25.7	23.0	23.0	26.5	25.0	25.4	25.6	26.5	25.4	26.0	26.0	24.4	23.6
R.H.	70.5	67.5	66.5	68.5	71.0	69.0	68.0	68.0	54.5	68.5	69.0	69.5	70.0	73.0	76.5	72.5	69.5	73.0	71.0	73.5	73.5	60.5	64.5	83.0	69.0
Rainfall																									9.0

May-June	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2
Max. temp	33.0	33.0	32.4	32.2	33.0	33.4	34.0	33.0	33.2	32.5	33.0	33.3	34.0	33.5	32.7	34.0	33.0	33.8	32.8	32.0	32.5	34.5	33.8	33.9
Min. temp.	24.6	24.0	26.4	26.6	25.2	25.0	24.5	24.5	26.5	25.6	23.0	27.0	26.0	25.4	23.6	25.2	26.0	25.8	24.8	25.4	24.8	26.4	25.0	26.0
R.H.	72.0	79.0	77.0	74.0	72.5	69.0	73.5	76.5	76.0	78.5	79.0	73.5	79.0	70.5	77.5	78.0	78.0	78.0	78.0	80.5	72.5	78.5	81.0	76.5
Rainfall											16.2			1.0		5.0	3.6	72.5		1.6				

June-July	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7
Max. temp.	24.8	27.2	25.2	27.0	29.2	29.2	27.8	30.0	27.2	30.0	31.4	31.4	31.8	32.0	31.5	31.0	30.6	32.0	32.0	31.8	32.4	30.6	28.6
Min. temp.	22.0	23.0	23.0	22.6	23.2	23.2	23.4	23.5	23.2	24.2	25.0	24.2	25.0	24.5	24.3	23.5	23.4	23.5	24.0	23.4	24.4	24.4	23.0
R.H.	89.5	96.0	89.0	87.5	95.5	92.5	85.5	94.0	83.0	81.0	79.0	80.5	77.5	84.5	82.0	81.0	77.0	80.0	77.0	77.0	82.0	94.5	89.5
Rainfall	53.0	27.4	72.6	35.4	26.5	34.7	19.6	18.2	4.0	2.8	0.4											28.0	35.4