PERFORMANCE OF BIVOLTINE HYBRIDS OF SILKWORM(*Bombyx mori* L.) ON MULBERRY

By
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B.Sc. (AGRI.)

MASTER OF SCIENCE
(AGRICULTURE)
IN
AGRICULTURAL ENTOMOLOGY

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF AGRICULTURE, LATUR
MARATHWADA AGRICULTURAL UNIVERSITY, PARBHANI

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DISSERTATION

Submitted to
The Marathwada Agricultural University, Parbhani in partial fulfillment of the requirements for the Degree of

MASTER OF SCIENCE
(AGRICULTURE)
IN
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DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF AGRICULTURE, LATUR
MARATHWADA AGRICULTURAL UNIVERSITY, PARBHANI

2010

Dedicated
To My Beloved
Parents
&
Research Guide

CANDIDATE'S DECLARATION

I hereby declare that the dissertation

or part thereof, has not been

previously submitted by

me for a degree of

any University.

Place : Latur

(CHAVAN S.L.)

Date : 04/05/ 2010

DR. C.B. Latpate
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CERTIFICATE – I

This is to certify that the dissertation entitled **"PERFORMANCE OF BIVOLTINE HYBRIDS OF SILKWORM (*Bombyx mori* L.) ON MULBERRY"** submitted by Shri. **CHAVAN SANDEEP LAXMAN** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL ENTOMOLOGY** is record of original and bonafide research work carried out by him under my guidance and supervision. It is of sufficiently high standard to warrant its presentation for the award of the said degree.

I also certify that the dissertation or part there of has not been previously submitted by him for a degree of any university.

Place : Latur
Date :04/05/2010.

(C.B. Latpate)
Research Guide
&
Chairman
Advisory committee

CERTIFICATE – II

This is to certify that the dissertation entitled **"PERFORMANCE OF BIVOLTINE HYBRIDS OF SILKWORM (*Bombyx mori* L.) ON MULBERRY"** submitted by Shri. **CHAVAN SANDEEP LAXMAN** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL ENTOMOLOGY** has been approved by the student's advisory committee after viva-voce examination in collaboration with the external examiner.

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(Dr. R.B. Mokat)

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Place : Latur
Date : 04/05/ 2010.

Chavan

(Chavan S.L.)

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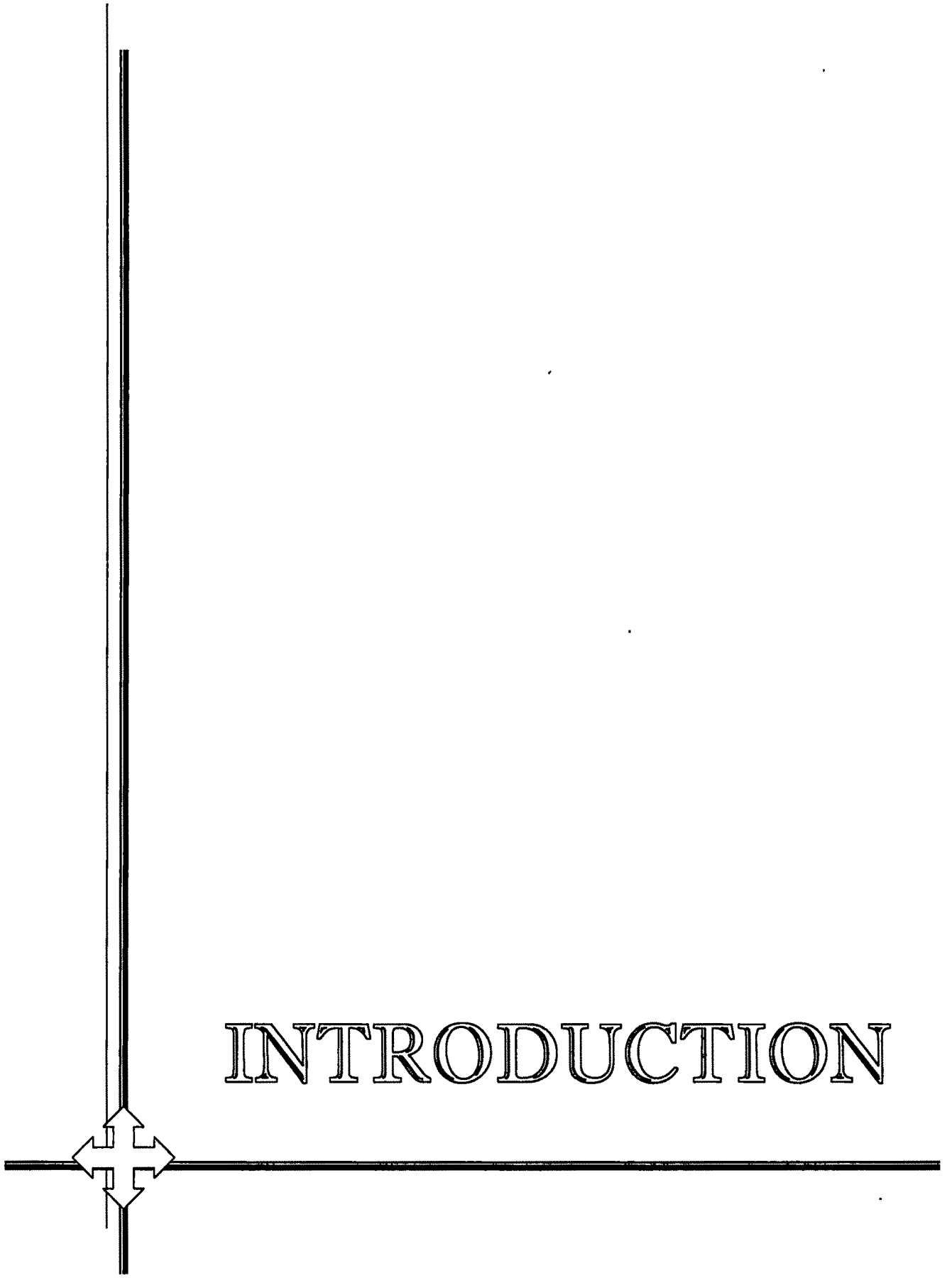


INTRODUCTION

Chapter-I

INTRODUCTION

Agriculture is the backbone of Indian economy and Indian agriculture is the gamble of monsoon. Hence, in order to reduce the risk in agriculture the concept of multiple farming came forward. Multiple farming means combining the farm cultivation practices and farm production, by adopting different farming system. Amongst these, sericulture is gaining importance now a days.

Sericulture has remarkable advantage of simultaneously addressing several Government of India's development priorities related to economic growth and social development. It can provide downstream employment and income generation in rural and semi-urban areas and which bears huge potential for contribution to export and ever-growing world and domestic market for silk products.

India is only the country having distinction in the world for all four types of silkworm viz., mulberry silkworm (*Bombyx mori* L.), tasar sillkworm (*Antheraea mylitta* D.), eri silkworm (*Philosamia ricini*) and muga silkworm (*Antheraea assama*). About 95 per cent production is from mulberry silkworm (Anonymous, 1983). Indian silk production steadily rose out pacing with some countries that were once leading silk producer. India is now the second largest producer of raw silk in the world next to China. India's raw silk production was 14510 MT in 1997-98 which is increased upto 18370 MT in 2008-09(Anonymous, 2009). The total area under mulberry cultivation is 1,77,943 ha. producing about 15,610 MT of raw silk, in which bivoltine contribute 1250 MT in year 2008-09. Mulberry raw silk contribute about 85 per cent to the total silk production of India. The area under mulberry plantation and raw silk

production of Maharashtra and Marathwada is 4504 ha., 200MT and 444 ha., 10.53 MT respectively (Anonymous, 2009). India presently also the largest importer of raw silk and largest consumer of silk in the world.

Silk industry in India presently provide gainful employment to an estimated five million persons in the downstream activities of mulberry and non mulberry sub sector. In this challenging scenario, more investment are required for seeding technology, building farmer level infrastructure and for empowering bivoltine sericulture industry. It is not only technology but also capital intensive, financial assistance is important for upgrading mulberry gardens with productive varieties, building rearing houses, purchase of new silkworm culturing and cocooning equipment like shelves and rotary mountages, water management device like drip irrigation kits. A major parts of such assistance to the farmer as a long term measure would insure building foundation of bivoltine sericulture laid in the country.

The success of sericulture business is completely depends on the factors like silkworm variety, quality of mulberry leaves and management. Because these factors decides the quality and quantity of good cocoon production. To increase the cocoon production and to reduce the labour cost, it is advisable to choose silkworm strain and mulberry variety which is suitable for particular set of condition, soil and climate.

It is very essential to increase the silk production to minimize the gap between production and demand of silk and hybridization is easy and more successful way to increase the silk production. It is observed that hybrid strains showed superior performance over parental strains (Bhargava *et al.*, 1996).

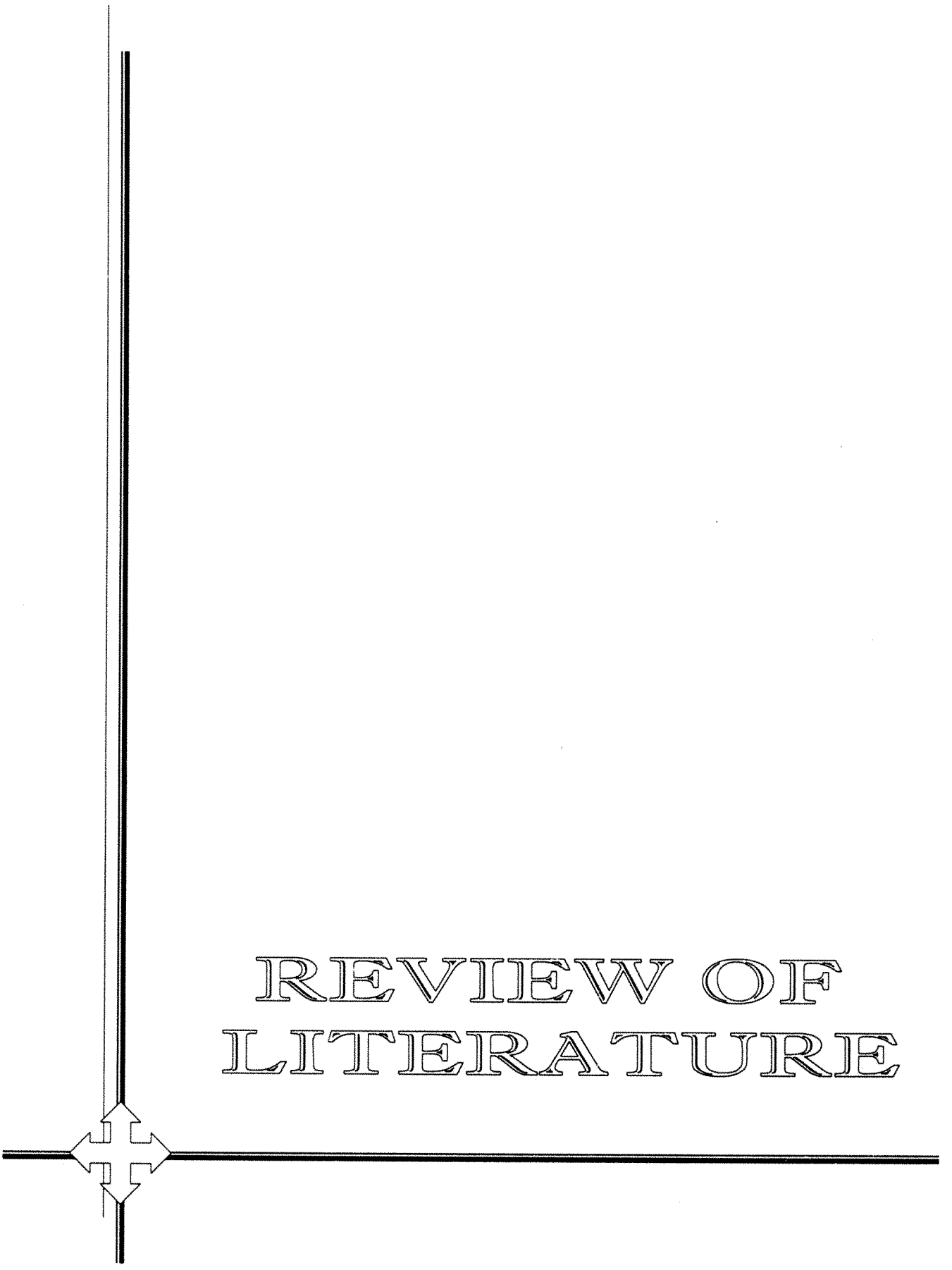
Till recently the production of bivoltine silk was considered as mirage for tropical regions. But with the introduction of highly productive bivoltine silkworm races and associated package of practices for bivoltine rearing, the concept of bivoltine rearing has now been successfully introduced in Karnataka. The bivoltines viz., CSR breeds, KSO1, NP2, CTM, NTCM for favourable and adverse climatic conditions and moderate input situation have been evolved (Bongale and Raghukumaran, 1999). Among these the CSR breeds viz., CSR_2, CSR_4, CSR_5 were highly productive and recommended for rearing during favourable months (Sept.-Feb.) (Basavaraja , 2002a).

In addition the two robust breeds namely CSR_{18} and CSR_{19} have been developed and its hybrid is recommended for summer and autumn season, as they are tolerant to high temperature.

Although it is considered that the Marathwada region was non-traditional area for mulberry silkworm. The Marathwada Agricultural University had proved the suitability of Marathwada region for sericulture as an enterprise and best farming system through the research work carried out at Sericulture Research Unit, Marathwada Agricultural University, Parbhani.

The present investigation was undertaken with the following objectives:

1) To evaluate suitable biovltine hybrid for Latur district.
2) To study the quality parameters of bivoltine silkworm hybrid.
3) To study the economic traits of newly released bivoltine silkworm hybrid.



REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

The research work carried out in the country and elsewhere in past on the aspects relevant to the present investigations was reviewed and has been presented in this chapter under following headings.

2.1 Taxonomic position of mulberry silkworm, *Bombyx mori* L.

Bombyx mori L. is a domesticated type of mulberry silkworm belong to the family Bombycidae and order Lepidoptera. There are number of species belonging to the genus *Bombyx.* The importance one are *Bombyx textor* (Hutton), *Bombyx aroesi* (Hutton), *Bombyx fortunatus* (Hutton) and *Bombyx meridionalis* (Hutton) (Anonymous, 1972). However *Bombyx mori* L. is a principal and commercially important species of this genus.

In India, Karnataka ranks first in raw silk production, followed by Andhra Pradesh, West Bengal, Tamil Nadu and Jammu & Kashmir, are the five traditional states practicing sericulture. It also practiced in 22 non- traditional states including Maharashtra. The species *Bombyx mori* L. is exploited in more than 22 in the world countries for practicing sericulture.

2.2 History of hybrid development research on mulberry silkworm (*Bombyx mori* L.) in India.

F_1's were introduced in West Bengal during 1956 and in Jammu and Kashmir in 1959, with the introduction of hybrid Taihri x Choan and Koko x Singyoku from Japan (Anonymous, 1972).

Since 1920, hybrid vigour was exploited by rearing hybrids of Mysore female and exotic bivoltine male (Krishnaswami and Narasimhanna, 1974).

Yakoyama (1974) quoted in old times in Japan that silkworm breeding was practiced by only selection of superior strains for collective culture. By this method, earlier widely used and well known old strains such as Matamukashi (1740), Akajuka (1780), Koishimaru (1790), Aojuka (1851) were released. The first cross was made between Japanese multivoline strain for spring and a bivoltine strain for summer variety by Uichi Sasaki in Nagano prefecture in 1790. He succeeded in breeding the strains Okusa at an early stage of such cross breeding. European variety, for the first time during 1903, was used for cross breeding with Japanese variety by Hyakuzo Taguchi who evolved the Kosekimaru breed.

In 1924 the concept of exploring F1 hybrids for stabilizing the cocoon crops and improving the cocoon quality was introduced with considerable success. Since then the Pure Mysore had been used as female parent and more productive foreign races were used as male parents (Krishnaswami, 1979).

The bivoltine races of Indian origin were very few and even these were extinct (Jolly, 1983).

By the end of 1978, the use of double cross hybrid was started in Karnataka state. Although the double cross hybrid are considered slightly inferior to F1 hybrids. Recent studies have proved that specific combination with the advantage of higher productivity and stability can be obtained (Jolly, 1983).

Krishnaswami (1983) brought with him four different polyhybrid industrial silkworm eggs viz., Hosho x Shungetsu, Kinshu x Showa and (Kokko x Seihaku) x (N124 x C124) from Japan during 1971. These hybrids were used for breeding experiments and designated as NB_1, NB_2, NB_3 and NB_4 through different breeding experiments. New hybrid NB_7 (NB_2C_1) was extracted from the hybrid Kinshu x Showa under NB_2 Series. Similarly, NB_{18} (NB_4D_1) and NB_4D_2 were extracted from NB_4 series.

Later on the hybrid of bivoltine breeds NB_7 and NB_{18} was released in the field as Chamundi cross (Datta, 1984). This was the first time in Karnataka, bivoltine hybrid rearing was introduced in 1971 and N_6D was replaced by the above hybrid (Krishnaswami, 1983).

Simultaneously, in early seventies another hybrid Nandi was also evolved from crossing of KA x NB_4D_2 at CSR and TI, Mysore.

During 1940, attempts were made to improve indigenous races Nistari and Chotapolu by crossing with popular Italian races viz., Nistid, Nismo, Ichot and Itan. These races had performed well except during rainy season (Datta, 1984).

In 1960 to 1970 fixed breeds like Mysore Princes, Kolar Gold, Kollegal Jawan, TEP_2, NS_4 and Hosa Mysore were developed at Central Sericultural Research and Training Institute, Mysore (CSR and TI) by crossing Pure Mysore with bivoltine races (Datta, 1984).

2.3 Rearing performance of different mulberry silkworm(*B. mori* L.) hybrids under Marathwada conditions

Sengupta *et al.*, (1971) studied the performance of F1 combinations did not differ significantly from the best parent Nistari. All Nistari combinations were superior to non-Nistari combinations in respect to cocoon weight. They concluded that, F1 hybrid combinations specially of Nistari were significantly superior to the pure Nistari race and should be used for commercial rearing.

Tikoo *et al.*, (1971) studied the performance of twelve different combinations of multi x bivoltine races which included ten crosses utilizing Pure Mysore as the female parent. These ten crosses were not significantly different with regard to practically all important characters. Relative performance introduced races such as C. Nichi, HS_6, J_{112}, C_{108} and KA showed better performance.

Prabha *et al.*, (1974) opined that the bivoltine silkworm could be successfully reared from July to February a favorable season for them in dry belt and the average yield of cocoons for 10,000 larvae brushed was 11 kg with renditta of 8 to 10.

Nineteen new lines of bivoltine races were evolved during 1974-75 of which three races namely NB_4D_2, NB_3C_1 and NB_1C performed better as pure races in comparison to KA and NN_6D in all combinations, KA x NB_4D_2 and its reciprocal had survival rate of over 80 per cent and cocoon yield was up to 80 kg per 100 dfl's. Cocoon weight of 2 g, shell weight was 0.4 g with renditta of 6.5. Realizing the

potentiality, the combination (i.e. KA x NB_4D_2) was released for commercial rearing and named as 'Nandi' hybrid.

New silkworm races (M-series) did not show significant differences in the larval weight, survival rate and yield in all the three seasons. The differences in the mean number of eggs per laying, hatching percentage and larval duration were significant only during November-December. The ten breed of M-series did not differ significantly among themselves in silk content, filament length and renditta in any season. The difference in denier was significant in all three seasons, while they were significant in only one season for cocoon weight, cocoon shell weight and reelability (Anonymous, 1976b).

Among three races studied, highest cocoon weight of 1.83 g with cocoon shell ratio of 18.10 per cent was produced by NB_4D_2 during September-October 1975. The survival rate of KA ranged from 42.00 to 76.60, N_6D from 44.00 to 78.00 and NB_4D_2 from 65.00 to 79.50 per cent. Maximum single cocoon weight of 1.67 g and shell weight of 0.28 g obtained during July-August for KA, September-November was the best season for N_6D with cocoon weight of 1.70 g and shell weight of 0.28 g (Anonymous, 1976c).

Nataraju *et al.,* (1980) studied eight varieties of mulberry with bivoltine hybrid NB_4D_2 x NB_2C_1 in three seasons for cocoon crop performance and incidence of disease. Yield per 10,000 larvae by number and by weight was maximum in Assambola xPhilippines where as S-30 and S-54 gave highest single cocoon weight.

Benchamin and Krishnaswami, (1981) observed high index value in the newly evolved bivoltine breeds for different characters contributing to productivity. Hybrids were found to be superior as compared to parental stocks in many respects including growth and yield. The production index was as high as 152.2 in hybrids as compared to 87.9 in pure races.

Bhekhariah (1981) reported that average yield of 40.4 kg per 100 dfl's of multivoltine was 35.9 kg with an average price of Rs. 27.44 per kg of cocoons. Fetching a return of Rs. 985. Thus the overall performance of bivoltine hybrids was markedly superior as compared to multivoltine hybrids.

Among all the three season, NB_7 and NB_{18} gave highest yield of 78.41 and 81.58 kg cocoons per 100 dfl's respectively during August-September rearing while NB_4D_2 and KA yielded 50.13 and 51.45 kg cocoons/100 dfls respectively during October-November (Anonymous, 1983).

Results from the experiment conducted during 1971-72, to evolve the hardier and high yielding bivoltine for tropical conditions revealed that, out of 19 lines, NB_4D_2, NB_4D_1 (NB_{18}) and NB_2C_1 (NB_7) were selected as pure races and in the form of hybrids. The rearing performance was fairly good in all the lines. With fecundity of 607 eggs per laying, hatching 93.2 per cent, yield by weight 13.700 kg, cocoon weight 1.733 g, shell weight 0.363 g and shell ratio 20.8 per cent (Krishnaswami, 1983).

Tayade (1983b) observed in Marathwada region that the bivoltine and their hybrids were superior in yield and quality. The bivoltine particularly NB_7 and NB_{18} and their hybrid proved better during winter than any other season. Further, it was observed that the bivoltine hybrid NB_7 and NB_{18} showed best performance in respect of different economic traits than parental lines NB_7 and NB_{18} in F1 generation.

Periasamy and Radhakrishnan (1984) studied the performance of polyvoltine Chinese race of *B. mori* i.e. Guangnong 3 and its cross breed with bivoltine race. They found that, both Chinese race and its hybrids had proved superior in several aspects to the Pure Mysore (Local) and its bivoltine cross breed Hitherto released.

Tayade (1984) reported the comparative merits of four varieties of mulberry viz., Kanva-2, S-54, Kosen and LM-2 on the cocoon qualities of two bivoltine races NB_7 , NB_{18} and a hybrid race (PM x NB_{18}).S-54 showed higher values in different characters namely a larval duration, larval weight, single cocoon weight and cocoon yield. The hybrid PM x NB_{18} was proved superior in cocoon yield.

Tayade (1987) studied the comparative merits and relative performance for economic traits in some strains of *B. mori* under Marathwada condition in 4 x 4 diallel set including reciprocal for F1 hybrid and F2 generations. The results revealed that the F1 hybrid NB_7 x NB_{18} showed than parental lines NB_7 and NB_{18} in F1 generation.

The performance of pure Mysore based sex limited strain with Bivoltine breeds was studied by Nagaraj *et al.*,(1989). Mean cocoon yield per 10,000 larvae for males of PM (SL) x NB_7 was 14.160 kg while

females gave 15.930 kg PM (SL) x NB_{18}, females gave yield as 11.593 kg and male 10.639 kg per 10000 larvae and PM (SL) x KA females gave yield of 15.789 kg and males 14.588 kg per 10,000 larvae.

Venugopalapillai *et al.*, (1987) reported that the bivoltine hybrids (KA x NB_4D_2, NB_4D_2 x KA, KA x NB_{18}, NB_7 x NB_{18}, NB_4D_2 x NB_7, NB_{18} x NB_7 and NB_{18} x KA) reared on local variety of mulberry, raised under rain fed conditions recorded an average cocoon yield of 45 to 50 kg per 100 dfl's during July to February.

Govindan *et al.*, (1990) studied variations in cocoon and pupal weights, length of ovariole, ovariole egg number and fecundity in a multivoltine breed Pure Mysore. Five bivoltine breeds Sanish 18, J_{112}, J_{122}, Kalimpong A and NB and their F1 hybrids with Pure Mysore as the maternal parent.

Narashimharaju and Govindan (1990) reported that, the bivoltine single cross hybrids Sanish -18 x NB_{18} (16.90 g), NB_{18} x Sanish 18 (16.74 g), NB_{18} x J_{22} (16.11 g) and parent KA (16.65 g) registered maximum weight for to pupae. It was minimum in C. Nichi (10.57 g).

Kale *et al.*, (1993) studied economics of sericulture in Parbhani district of Maharashtra. Per annum yield of cocoon recorded was 232.49 kg. Gross and net income obtained was Rs. 10,462.41 and Rs. 5314.14. The per kg gross and net income received was Rs. 45 and Rs. 22.85 respectively.

Banuprakash *et al.*, (1994) quoted the work of Benchamin *et al.*, (1988) by further studying the performance of possible hybrid crosses between five multivoltine and three bivoltine strains of *B. mori* for ten

different larval and cocoon taints. The results concluded that, the hybrid crosses between multivoltine female and bivoltine male represents more heterosis than their reciprocals.

Research conducted at Marathwada Agricultural University, Parbhani on performance of bivoltine hybrids and pure races, concluded that, bivoltine hybrid NB_{18} x NB_7 performed best over remaining F1 hybrids and pure races viz., NB_7, NB_{18} and NB_4D_2 for four economic traits.(Anonymous, 1994)

Nirmalkumar *et al.*, (1994) conducted a field evaluation of CSR hybrids (CSR_2 x CSR_4, CSR_2 x CSR_4 and CSR_3 x CSR_6) in different location of Karnataka, Tamil Nadu and Kerala using the regression analysis and found that in the tested hybrids the mean yield is correlated with location that is the hybrids with a high sensitivity over range of locations were found to have a tendency showing a high mean performance. They also indicated that a perfect hybrid will not change its performance from location to location and such hybrid does not exist and breeders have to be satisfied only with obtainable level of productivity.

Nirmalkumar *et al.*, (1995) evaluated the performance of new bivoltine hybrids in the field. Among them CSR_2 x CSR_4, CSR_2 x CSR_5 showed promising results in the field. The hybrid CSR_2 x CSR_5 showed the best performance recording an average cocoon yield of 40.48 kg per 100 dfl's.

Nirmalkumar *et al.*, (1996) tested the field performance of two productive bivoltine hybrids (CSR_2 x CSR_4 and CSR_2 x CSR_5). The hybrids recorded average cocoon yield of 41.74 kg per 100 dfl's in first

trails and above 62.0 kg/100 dfls in the second and third trails. The results revealed that hybrids CSR_2 x CSR_4 and CSR_2 x CSR_5 had an average filament length of 935 m and 1002 m respectively.

CSR_2 x CSR_4 and CSR_2 x CSR_5 showed a value of 22.66 per cent in shell ratio. Which is considerably higher than SH_6 x NB_4D_2 (18.56 per cent) under laboratory conditions. Under field conditions shell ration ranged from 15.18 (SH_6 x NB_4D_2) to 18.90 (CSR_2 x CSR_5) (Anonymous, 1998).

The performance of cross breed and bivoltine hybrids was evaluated at Central Sericulture Research and Training Institute, Mysore. The results showed that bivoltine hybrids CSR_2 x CSR_4, CSR_2 x CSR_5, CSR_{16} x CSR_{17} and CSR_{18} x CSR_{19} recorded 2.024 g, 1.992 g, 2.134 g and 1.743 g cocoon weight and 0.468 g, 0.466 g , 0.492 g and 0.377 g shell weight and 23.4 per cent, 23.6 per cent, 23.00 per cent and 21.7 per cent shell percentage, respectively and denier was recorded to be 3.21 (CSR_2 x CSR_4), 2.95(CSR_2 x CSR_5) and 3.44 (CSR_{16} x CSR_{17}) (Anonymous, 1999).

The performance of the robust hybrid CSR_{18} x CSR_{19} recorded in RSRS, Hodati and Salem. The cocoon yield per 100 dfl's was 60.06 kg and 76.00 kg, whereas at Central Sericulture Research and Training Institute, Mysore,it was 55.28 kg. However, at farmer fields in Bangalore and Ananthpur it was 26.52 kg and 43.42 kg respectively(Anonymous, 1999).

Fotadar *et al.*, (1999) recorded highest cocoon weight of 1.540g in CSR_2 x CSR_4 and maximum shell weight of 0.309 g in CSR_2 x CSR_5.

Akio (2000) reported performance of authorized hybrids of CSR. He recorded single cocoon weight of 2.13 g (CSR_{16} x CSR_{17}), 2.0 g (CSR_2 x CSR_4), 1.95 g (CSR_2 x CSR_5) and 1.85 g (CSR_{18} x CSR_{19}) and recorded shell percentage of 23.5 per cent (CSR_2 x CSR_4) 23.6 per cent (CSR_2 x CSR_5) whereas these hybrids recorded denier of 3.2, 2.9, 2.7 and 3.4 respectively.

Datta (2000) studied performance of CSR_{18} x CSR_{19} in different states in adverse season. Robust hybrid CSR_{18}x CSR_{19} was found relatively tolerant to high temperature and humidity and also characterized by its shorter larval duration i.e. 22 days. Cocoon yield of 71.80 kg/100 dfls was recorded in RSRS, Salem. Whereas, lowest yield was recorded in Gudimangalam, Tamil Nadu (51.38 kg per100 dfl's).

Malareddy *et al.*, (2000) observed that hybrids CSR_2 x CSR_4, CSR_2 x CSR_5, CSR_3 x CSR_6, CSR_{12} x CSR_6 and CSR_{16} x CSR_{17} recorded five times had significant differences for survival, cocoon shell weight, cocoon shell ration, raw silk percentage and filament length when compared to KA X NB_4D_2.

Basavaraja (2002a) recorded single cocoon weight of CSR_2 x CSR_4, CSR_2 x CSR_5 and CSR_{18} x CSR_{19} hybrids as in year 2001 as 2.1 g, 2.09 g , 1.88 g, respectively. Whereas, respective shell weight was 0.495 g (CSR_2 x CSR_4), 0.503 g (CSR_2 x CSR_5) and 0.419 g (CSR_{18} x CSR_{19}) at the basic seed farms under PPPBST programme.

Basavaraja (2002b) studied heterosis in CSR hybrids cover and mid parent value during 1997 and 2001 and observed that CSR_2 x CSR_5 is better than CSR_2 x CSR_4 and CSR_{18} x CSR_{19} in pupation rate, cocoon yield, cocoon weight, shell weight that is 81 per cent, 23.7 kg, 11.1 g, 11.4 g, respectively.

Sureshkumar *et al.*, (2002), the average filament length was ranged form 1023 m (KA x NB_4D_2) to 1333 m (CSR_{12} x CSR_6). In other hybrids 1231 m in CSR_2 x CSR_4, 1322m in CSR_2 x CSR_5, 1151 m CSR_{16} x CSR_{17} and 1083 m CSR_{18} x CSR_{19}.

Krishnaprasad *et al.*, (2003) undertaken the study of comparative performance of newly evolved bivoltine breeds of for most of the economic traits studied.

Vidhate (2003) studied 11 silkworm hybrids under Marathwada conditions and recorded significantly short larval duration (21.26 day) in MY x NB_4D_2 and CSR_{16} x CSR_{17} followed by CSR_{18} x CSR_{19} (21.68 days) and longest (22.55 days) in CSR_2 x CSR_4 and more single cocoon except in BL_{24} x NB_4D_2 (1.985 g), CSR_{16} x CSR_{17} (1.975 g) and P_2D_1 x NB_4D_2 (1.956 g). Highest shell weight was recorded in CSR_{16} x CSR_{17} (0.458 g) and lowest in PM x NB_4D_2 (0.32 g) significantly highest cocoon yield was observed in hybrid CSR_{16} x CSR_{17} (18.05 kg) followed by BL_{43} x (17.36 kg), BL_{24} x NB_4D_2 (17.07 kg), CSR_{18} x CSR_{19} (17.07 kg), P_2D_1 x NB_4D_2 (16.70 kg) and PM x NB_4D_2 (16.55 kg). Hybrid CSR_{16} x CSR_{17} (1191.66m) recorded maximum length than all other hybrids except CSR_2 x CSR_5 (1125 m) and CSR_2 x

CSR_4 (1058.33 m) and lowest filament length was recorded in PM x NB_4D_2 (755.33 m).

Rahmathulla *et al.*, (2003) studied evaluation, consumption and nutritional efficiency. They found that food consumption and feed conversion efficiency of three new bivoltine silkworm hybrids viz., CSR_2 x CSR_4, CSR_4 x CSR_5,and CSR_{18} x CSR_{19},reared on mulberry leaves, were examined. Differences in the nutritional indices measured such as digesta, approximate digestability and reference ratio were not significant among the hybrids except for ingesta which was significantly highest in CSR_2 x CSR_4. The hybrid CSR_{18} x CSR_{19} recorded the highest efficiency of digesta conversion in the larvae (70.58%), cocoon (57.45%) and shell (30.18%); and efficiency of ingesta conversion in the cocoon (17.79%) and shell (9.44%) the hybrid CSR_2 x CSR_4 recorded the highest ingesta per gram cocoon (5.92%) and shell (10.89%) and digesta per gram shell (3.53%). Differences in the efficiency of ingesta conversion in the larvae and digesta per gram cocoon were not significant among the hybrids

Munde (2006) studied three parents and seven hybrids of bivoltine silkworm, *B. mori* L. for different economic traits and larval duration were found promising in rearing performance.

The earliest published information on vital disease in insects was a disease of silkworm. *B. mori* known as jaur or grasserie in India (Mukherji, 1912).

According to Vaidya (1960) about 30 to 40 per cent the silkworm crop was lost due to disease in India. The chief diseases

affecting the mulberry silkworm are flacherie, muscardine, grasserie and pebrine of which flacherie is in more proportion than others.

Sidhu and Singh (1968a) estimated crop loss of 30 to 40 per cent due to viral diseases.

Sidhu and Singh (1968b) studied the resistance of silkworm mutant strain and breeds and inductive factors leading to development of grasserie disease of silkworm. They reported that infected fourth and fifth instars spun only two and nine cocoons out of 50 worms, respectively.

Study condition at CSR and IT with silkworm races viz., J_{112}, C_{108}, J_{112} and PM to NPV revealed that J_{112} was highly susceptible while PM was least susceptible fourteen silkworm races comprising of pure breeding lines and their hybrids were evaluated for their reaction to BmNPV under inoculated condition. It was found that the grasserie was the highest in NB_4D_2 race with 67.87 per cent incidence, while the lowest incidence of 37.57 per cent was observed in 2CSS (Anonymous, 1970).

The studies conducted by Satish (1984) indicated that the nuclear polyhydrosis prevailed throughout the year under large scale rearings. June-July (1983) affected maximum incidence of to 44 per cent which coincides with warm rainy days. The incidence of disease was minimum during November-December (1982) (0.12 per cent).

Singh *et al.*, (1990) reported that four bivoltine and three multi bivoltine races of *B. mori* were recorded following standard methods. The incidence of the disease grasserie and assessed. The experiment was conducted in the winter, summer and rainy seasons.

Disease incidence was found to be higher in bivoltine than in multivoltine races. PM was the best multivoltine and NB_{18} the best bivoltine race.

Singh *et al.*, (1990) studied the relative susceptibility of few important pure bivoltine (NB_7, NB_{18}, NB_4D_2 and PCN) and multivoltine (PM, C.Nichi and MY) races over the seasons. Higher incidence of disease was recorded in bivoltine as compare to multivoltine races. On an average to 89, 10.44, 12.05, 2.34 2.06, 2.76 and 1.39 per cent incidence of grasserie was affected in NB_7, NB_{18}, NB_4D_2, PCN, PM C.nichi and MY, races respectively. Higher incidence of flacherie was seen in NB_7 (10.44 per cent) followed by NB_{18} (10.177) NB_4D_2 (9.95 per cent) and PCN (9.60 per cent), while minimum of 4.33 per cent was effected in PM race.

Venkatasubbaiah *et al.*, (1990) conducted a study on relative susceptibility of different silkworm breeds and indicated that biovoltine races exhibited highest disease occurrence and multivoltine recorded minimum incidence of disease.

Baig *et al.*, (1991) reported the relative susceptibility of 21 breeds to Nuclear Polyhydrosis Virus, screened under natural and induced conditions. The bivoltine breeds were comparatively more susceptible than the multivoltine breeds. However, in induced conditions all the breeds were susceptible to grasserie but the degree of susceptibility varied greatly under natural conditions. The highest incidence of nuclear polyhydrosis was recorded the DF and nil in PM x NB_{18} under induced conditions, the most susceptible breed was NB_2D_1 with 68.7 per cent grasserie and the least in pure Mysore with 18.5 per cent incidence. The

hybrids of susceptible parents showed improvement in their resistance to polyhydrosis.

Swamy and Nagaraj (1992) around Chandragiri and Chittor in Andhra Pradesh, grasserie was a serious disease recording 17.2 per cent in rainy (July-October) season. Muscardine was significantly higher in winter (November-February) with 22.70 per cent. During summer (March-May) non bacterial flacherie disease was maximum being 24.3 per cent.

MATERIAL AND METHODS

Chapter-III

MATERIAL AND METHODS

The present investigation was undertaken during September 2009 to study the different bivoltine hybrids of mulberry silkworm (*Bombyx mori* L.) for the study of rearing performance and economic traits of mulberry silkworm. The details of materials used and methods followed are described under suitable headings.

3.1 Experimental site

The experiment was conducted in rearing house at Department of Agricultural Entomology, College of Agricultural,.Latur.

3.2 Design

The experiment was conducted in a Randomised Block Design (RBD) with seven treatments and three replications. Each treatment consisted of 100 silkworms.

3.3 Materials

Seven bivoltine hybrids viz., CSR_2 x CSR_4, CSR_3 x CSR_6, CSR_{12} x CSR_6, CSR_{16} x CSR_{17}, CSR_{18} x CSR_{19}, CSR_{48} x CSR_4 and double hybrid (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) were procured from Central Sericultural Research and Training Institute, Mysore, Karnataka as an experimental material. The disinfectants used were Formalin 2% solution, Bleaching powder 0.3%, Lime powder and Vijeta powder. The fresh mulberry leaves of variety S-1635 was obtained from already established mulberry garden at Department of Agricultural Entomology, College of Agriculture, Latur.

3.4 Equipments

The equipments which were used during rearing programme are listed below.

1 Rearing trays

These are portable receptacle wooden trays having 18″x5″x3″ size mainly used for keeping the silkworm larvae during rearing programme.

2 Rearing stand

These are the wooden frames on which the rearing trays containing silkworms were placed.

3. Chopping board

It was made-up of soft wood of size 36.6″ x 36.6″ with thickness 3.0″ and used for chopping the mulberry leaves during Chawki rearing of silkworms.

4. Chopping knife

During the chawki rearing, mulberry leaves were chopped in an ideal size with an iron blade knife 6″ having wooden handle.

5. Chop sticks

These sticks measure about 8″ long, 3 cm in diameter and tapering at one end; they were used for giving space to the worms in rearing bed and picking the young stage larvae.

6. Feather / Camel hair brush

White feather was used for brushing newly hatched worms and cleaning and preparation of the beds in younger stages.

7. Cleaning nets

The nylon nets were used to clean the beds in different developmental stages of worms.

8. Mountages

These are also known as Chandrika, prepared from rectangular bamboo mats on which spiral bamboo strips were fixed at a distance of 2″ between them. The usual size is 1.8 m x 1.2 m. These were used to keep the ripe worms for spinning the cocoons. Collapsible plastic mountages are of 6″ x 3″ size are also used now a days. Those are easy for handling and disinfection purpose.

9. Paraffin papers and Foam pads

These were used to cover the silkworm in the rearing tree and to maintain the required optimum humidity in the rearing beds.

10. Epprovate

This is a manually operated reeling machine used to width single filament from a cocoon and measuring the filament length. It is expressed in meters.

11 Leaf storing chamber

The wooden chamber 5' x 3' x 3' size covered with gunny cloth from all size was used for storing the fresh leaves for the period of maximum 24 hours.

12. Hygrometer

It was used to measure the humidity in rearing house, the humidity expressed in percentage.

13. Thermometer

It was used to measure the temperature in rearing house, it is expressed in ^{0}C.

14. Antwells

It was used as barrier for ant and other predators.

15. Electronic balance

They were used for measuring weight of larvae, pupae, and single cocoon, it is expressed in gm.

3.5 Experimental Method

Before starting the experiment the rearing room was disinfected daily two times with the help of 2% Formalin solution and 0.3% Bleaching powder. All the rearing equipments were also disinfected. The rearing room temperature was maintained at 24°C to 28^{0}C. Disease free layings (Dfl's) of seven bivoltine hybrids viz., CSR_2 x CSR_4, CSR_3 x CSR_6, CSR_{12} x CSR_6, CSR_{16} x CSR_{17}, CSR_{18} x CSR_{19}, CSR_{48} x CSR_4 and double hybrid (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) were procured from the Central Sericultural Research and Training Institute, Mysore, Karnataka, and which was used as experimental material. The Dfl's of experimental hybrids were properly black boxed at pin head stage and incubated at 25^{0}C and 70% relative humidity for hatching. During this period care was taken to protect the eggs from predators. Before hatching start the eggs were exposed to sun light in morning hours to promote the hatching of larvae from eggs. After hatching the larvae, brushing was made on date 11.09.2009 and 12.09.2009 at 11.00 am.

Krishnaswami (1978) described the improved technology of silkworm rearing and it was adopted in this investigation. The newly hatched larvae were fed with chopped mulberry leaves of S-1635 variety. 100 larvae of each race treated as on treatment, kept in 36.6″ x 36.6″

wooden tray. Rearing trays were arranged randomized manner in each replication to minimize the experimental error. The leaves were chopped into small pieces of 0.5 cm and sprinkled over the newly hatched worms for their feeding. The feeding was given four times in a day, at 6.00 hrs, 10.00 hrs, 16.00 hrs and 21.00 hrs. The rearing trays were cleaned daily as per recommendation.

The silkworm (*B. mori.* L.) moults four times during its larval growth period. The stage between two moults is called as instar and hence there are five instars of silkworm *B. mori* L. During moulting the worms cease feeding and cast their skin. During moulting they were not provided any food and also not disturbed. Moulting was completed in 20 to 30 hrs. After completion of each moult a bed disinfectant Vijeta @ 4 kg/100 Dfl's was dusted as per recommendation after passing every moult for the control of diseases and feeding was given after half an hour. Later on cleaning was done.

After full development, the ripe worms were identified for spinning, as they looked transparent with creamy colour. The ripe worms ceased to eat, move towards periphery of the trays and tried to spin the cocoons, were handpicked and put on the Netrika, the collapsible plastic mountages. The worms spun the cocoons within 48 to 72 hours. The pupae remained inside the cocoons till emergence.

The harvesting of cocoon was carried out on fifth day of release of worms for mounting on Netrika. Randomly selected ten cocoons of each treatment were used for recording cocoon parameters.

3.6 Observations noted

The observation was made on 11 economic characters. These were as follows.

1 Hatching Percentage

Empty whitish eggs shells were counted immediately after brushing, which indicates the emergence of larvae, excluding late born larvae, unhatched and unfertilized eggs.

2 Larval duration (days)

The total larval period was measured by recording the period from hatching to start of spinning.

3 Larval weight (g)

The maximum larval weight was recorded by taking the weight of randomly selected 10 matured larvae before the onset of spinning.

4 Single cocoon weight (g)

The cocoon was recorded on 6^{th} day of spinning, when cocoon weight assumes to be maximum. The average of 10 randomly selected cocoons was taken as single cocoon weight.

5 Single shell weight (g)

The cocoon cut was open at one end and the shell weight was recorded after removing the pupae. The average of 10 shells was taken as single shell weight.

6 Cocoon – shell ratio (%)

It is the ratio of shell weight to cocoon weight, expressed in percentage. The cocoon-shell ratio will be calculated as,

$$\text{Cocoon-Shell ratio (\%)} = \frac{\text{Cocoon shell weight (g)}}{\text{Cocoon weight (g)}} \times 100$$

7 Cocoon filament length (m)

Length of filament was worked out with the help of epprovate. It is an average of 10 cocoons. The randomly selected cocoons

were boiled in water and individual filament length measured on epprovate.

8 Incidence of diseases

Observations for grasserie and flacherie diseases was recorded separately by recording number of healthy and diseased larvae during the course of rearing by different hybrids and percentage incidence of diseases was worked out as below.

$$\text{Disease \%} = \frac{\text{No. of diseased larvae}}{\text{Total No. of larvae}} \times 100$$

9 Denier

It is the term used to denote the thickness of silk filament and expressed in terms of ratio of weight of filament, to the filament length multiplied by 9000.

$$\text{Denier} = \frac{\text{Filament weight (g)}}{\text{Filament length (m)}} \times 9000$$

10. Yield/10,000 larvae brushed (kg)

Randomly selected 100 cocoons were weighed and the cocoon yield per 10,000 larvae brushed was computed. It is expressed in kg.

11. Filament weight (g)

The filament weight was recorded by taking the weight of randomly selected 10 reeled silk filaments. It is expressed in g.

12 Moth emergence (%)

Number of moth emerged from cocoon was measured and expressed in per cent.

$$\text{Moth emergence \%} = \frac{\text{No. of moth emerged}}{\text{Total No. Cocoon}} \times 100$$

RESULTS

Chapter IV

RESULTS

The experiment was carried out to evaluate the performance of bivoltine hybrids of mulberry silkworm, (*Bombyx mori* L) on mulberry. The experimental findings obtained in the present investigation are presented in this chapter are as under.

4.1 Performance of different bivoltine mulberry silkworm hybrids for hatching (%)

Data presented in Table no. 1. revealed that significantly highest hatching per cent of 94.08 per cent was recorded in the hybrid CSR_{16} x CSR_{17} over rest of hybrids followed by (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (91.12 per cent), CSR_2 x CSR_4 (91.54 per cent) and CSR_3xCSR_6 (93.27 per cent) which were at par with each other. Whereas, the bivoltine hybrid CSR_{18} x CSR_{19} (72.17 per cent) recorded lowest hatching per cent over rest of the hybrids.

Table no.1. Performance of different bivoltine silkworm hybrids for hatching (%)

Sr. No.	Treatment	Hatching (%)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	90.12	91.25	93.27	274.64	91.54
2	CSR_3 x CSR_6	96.63	92.18	91.00	279.81	93.17
3	CSR_{12} x CSR_6	80.71	79.26	84.00	243.97	81.32
4	CSR_{16} x CSR_{17}	93.22	93.90	95.12	282.24	94.08
5	CSR_{18} x CSR_{19}	76.14	71.20	69.16	216.5	72.17
6	CSR_{48} x CSR_4	88.27	91.56	91.40	271.23	90.41
7	(CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26})	91.37	91.83	90.17	273.37	91.12
	SE ±					1.27
	CD at 5%					3.93

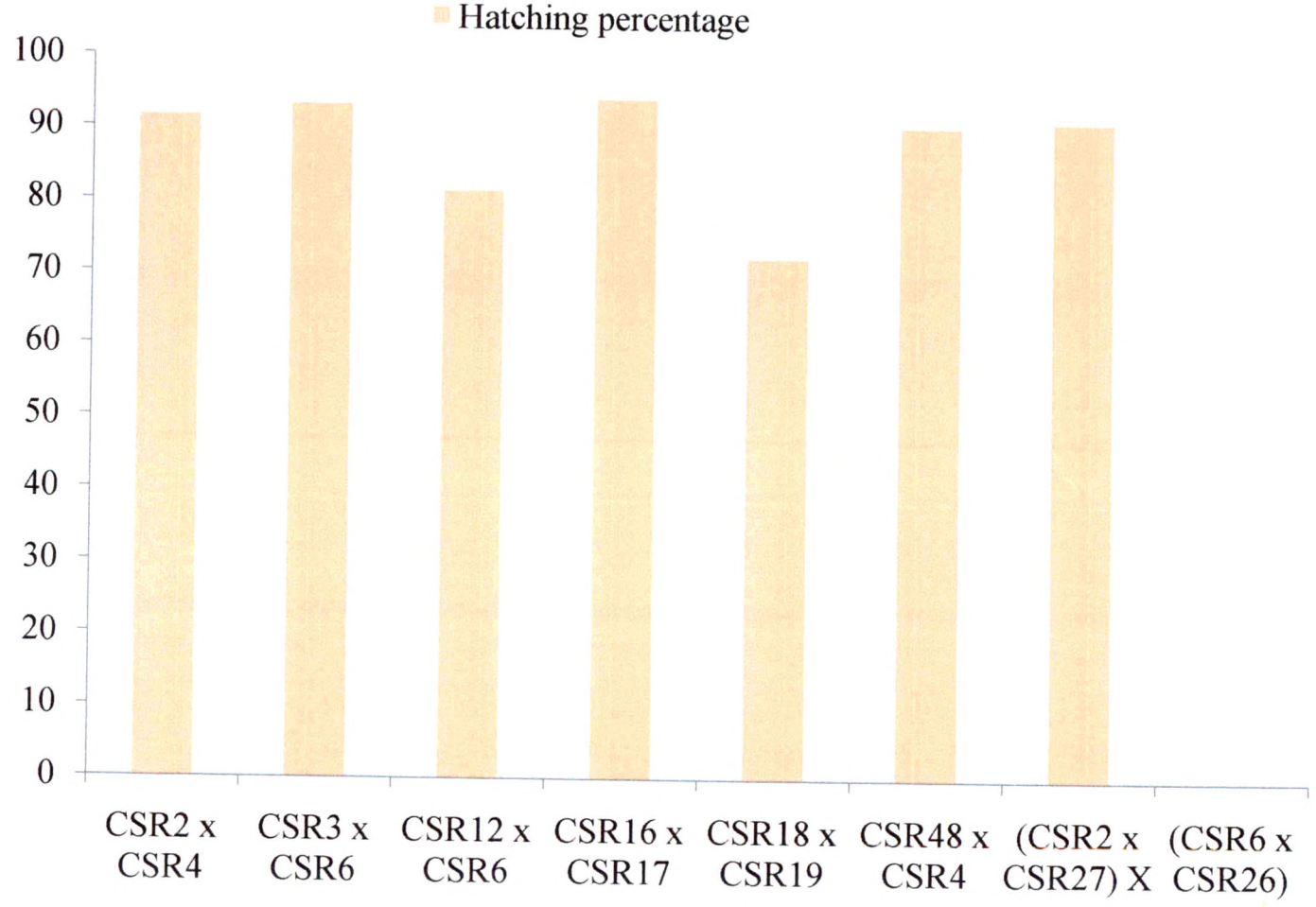


Fig.1 Performance of different bivoltine silkworm hybrids for hatching per cent

4.2 Performance of different bivoltine silkworm hybrids for larval duration

Data presented in Table no. 2 revealed that bivoltine hybrid CSR_{18} x CSR_{19} had shown the shortest larval duration (22.20 days) and found significantly superior over rest of hybrids except (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (22.70 days), CSR_{48} x CSR_4 (22.80 days) and CSR_{16} x CSR_{17} (23.19 days), whereas CSR_{12} x CSR_6 had shown longest larval duration (24.28 days).

Table no. 2. Performance of different bivoltine silkworm hybrids for larval duration (days)

Sr. No.	Treatment	Larval duration (days)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	23.33	23.52	24.04	70.89	23.63
2	CSR_3 x CSR_6	23.37	22.91	23.83	80.11	23.37
3	CSR_{12} x CSR_6	24.95	23.80	24.09	72.84	24.28
4	CSR_{16} x CSR_{17}	23.35	23.90	22.32	69.57	23.19
5	CSR_{18} x CSR_{19}	21.90	21.98	22.72	66.60	22.20
6	CSR_{48} x CSR_4	22.15	22.40	23.85	68.40	22.80
7	(CSR_2 x CSR_{27}) X (CSR_6 x CSR_{26})	22.90	22.90	22.30	68.10	22.70
	SE $\pm$					0.365
	CD at 5%					1.12

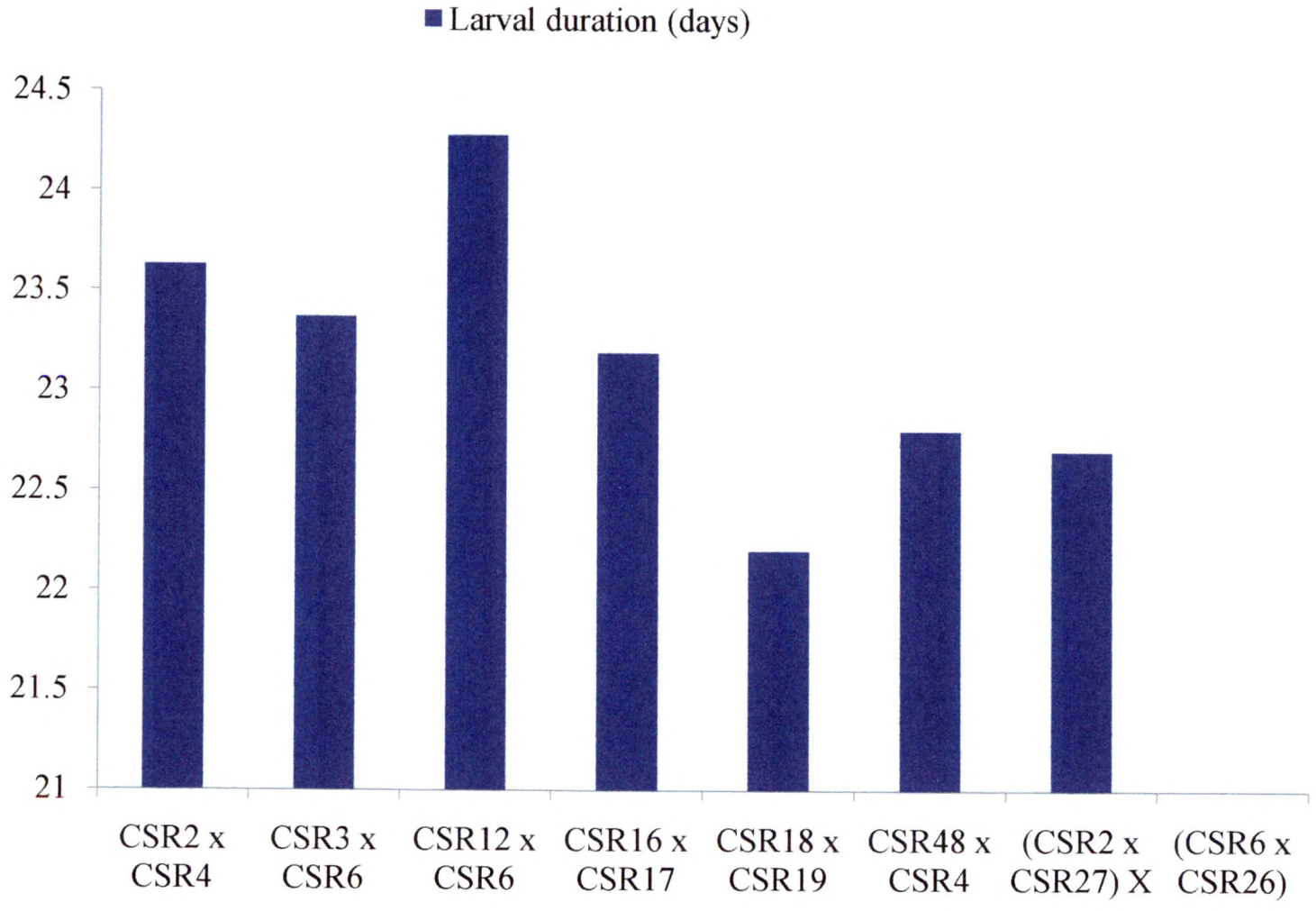


Fig.2 Performance of different bivoltine silkworm hybrids for larval duration.

4.3 Performance of different bivoltine mulberry silkworm hybrids for weight of ten mature larvae (g)

Data presented in Table no. 3 revealed that ten matured larval weight varied in the range of 38.40 to 44.90 g.

Table no. 3. Performance of different bivoltine silkworm hybrids for weight of ten mature larvae (g)

Sr. No.	Treatment	Weight of 10 mature larvae(g)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	39.34	41.40	40.85	121.59	40.53
2	CSR_3 x CSR_6	37.95	40.50	39.85	120.30	40.13
3	CSR_{12} x CSR_6	48.45	38.75	39.20	116.40	38.80
4	CSR_{16} x CSR_{17}	44.65	46.75	43.30	134.70	44.90
5	CSR_{18} x CSR_{19}	38.45	37.65	39.10	115.20	38.40
6	CSR_{48} x CSR_4	38.20	39.60	37.88	115.68	38.56
7	(CSR_2 x CSR_{27}) X (CSR_6 x CSR_{26})	46.90	43.14	41.60	131.64	43.88
	SE $\pm$					0.867
	CD at 5%					2.667

The performance of CSR_{16} x CSR_{17} (44.90 g) was observed significantly superior over rest of the tested hybrids, whereas (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (43.88 g) found at par with CSR_{16} x CSR_{17}(44.90 g). The lowest ten matured larval weight was recorded in CSR_{18} x CSR_{19} (38.40 g).

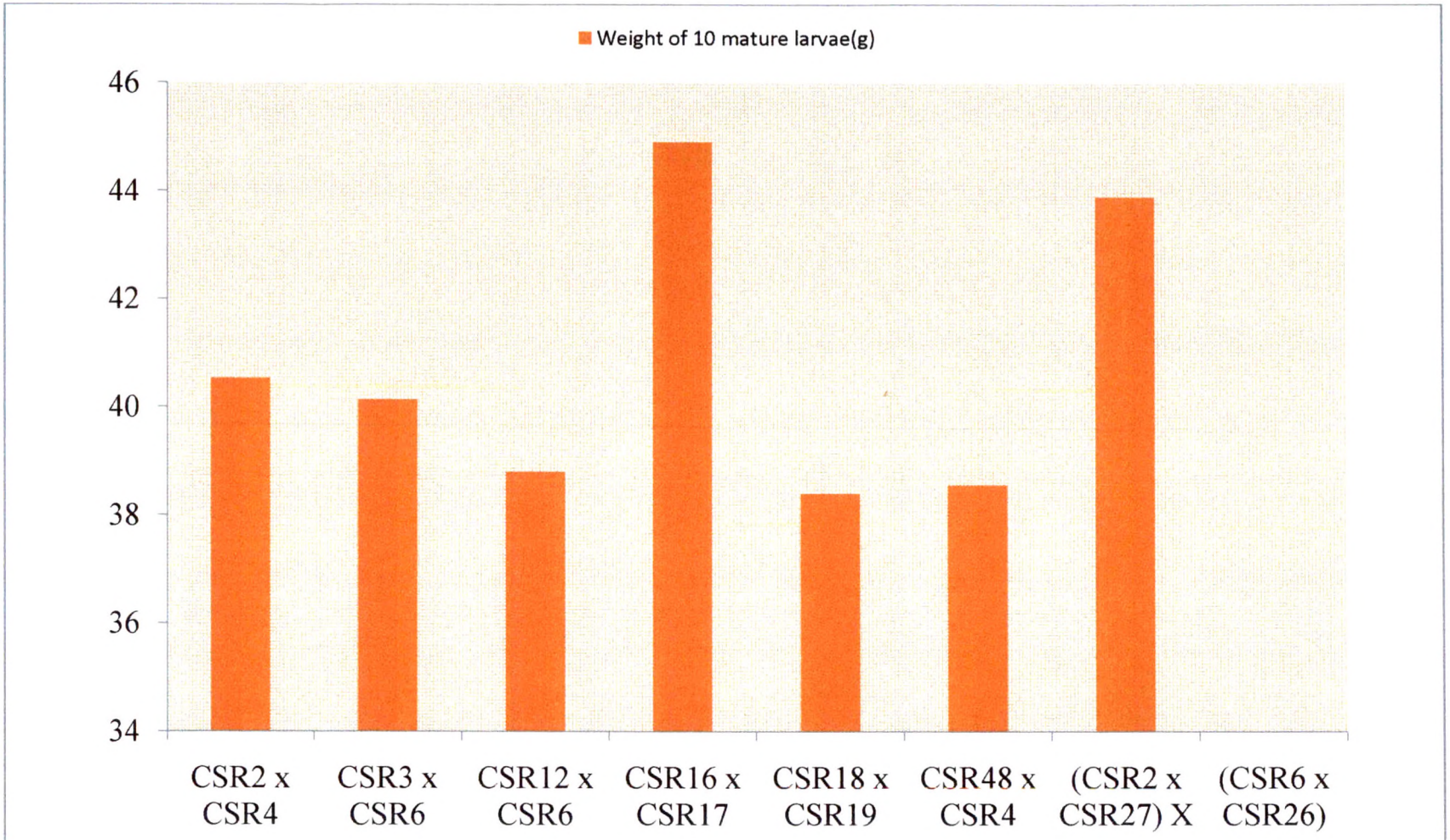


Fig.3 Performance of different bivoltine silkworm hybrids for weight of ten larval.

4.4 Performance of different bivoltine silkworm hybrids for single cocoon weight (g)

Data presented in Table no. 4 revealed that, the cocoon weight was recorded in the range of 1.74 to 1.96 g.

Table no. 4. Performance of different bivoltine silkworm hybrids for single cocoon weight (g)

Sr. No.	Treatment	Single cocoon weight (g)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	1.83	1.85	1.87	5.55	1.85
2	CSR_3 x CSR_6	1.77	1.89	1.86	5.52	1.84
3	CSR_{12} x CSR_6	1.81	1.78	1.87	5.46	1.82
4	CSR_{16} x CSR_{17}	2.08	1.97	1.90	5.98	1.96
5	CSR_{18} x CSR_{19}	1.71	1.73	1.78	5.22	1.74
6	CSR_{48} x CSR_4	1.76	1.84	1.80	5.40	1.80
7	(CSR_2 x CSR_{27}) X (CSR_6 x CSR_{26})	1.94	1.92	1.90	5.76	1.92
	SE $\pm$					0.025
	CD at 5%					0.078

The highest significant cocoon weight was recorded by CSR_{16} x CSR_{17} (1.96 g) over the rest of silkworm hybrids tested followed by double hybrid (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (1.92 g) which was at par with CSR_{16} x CSR_{17} (1.96 g).Whereas, the lowest cocoon weight was recorded by the hybrid CSR_{18} x CSR_{19} (1.74 g).

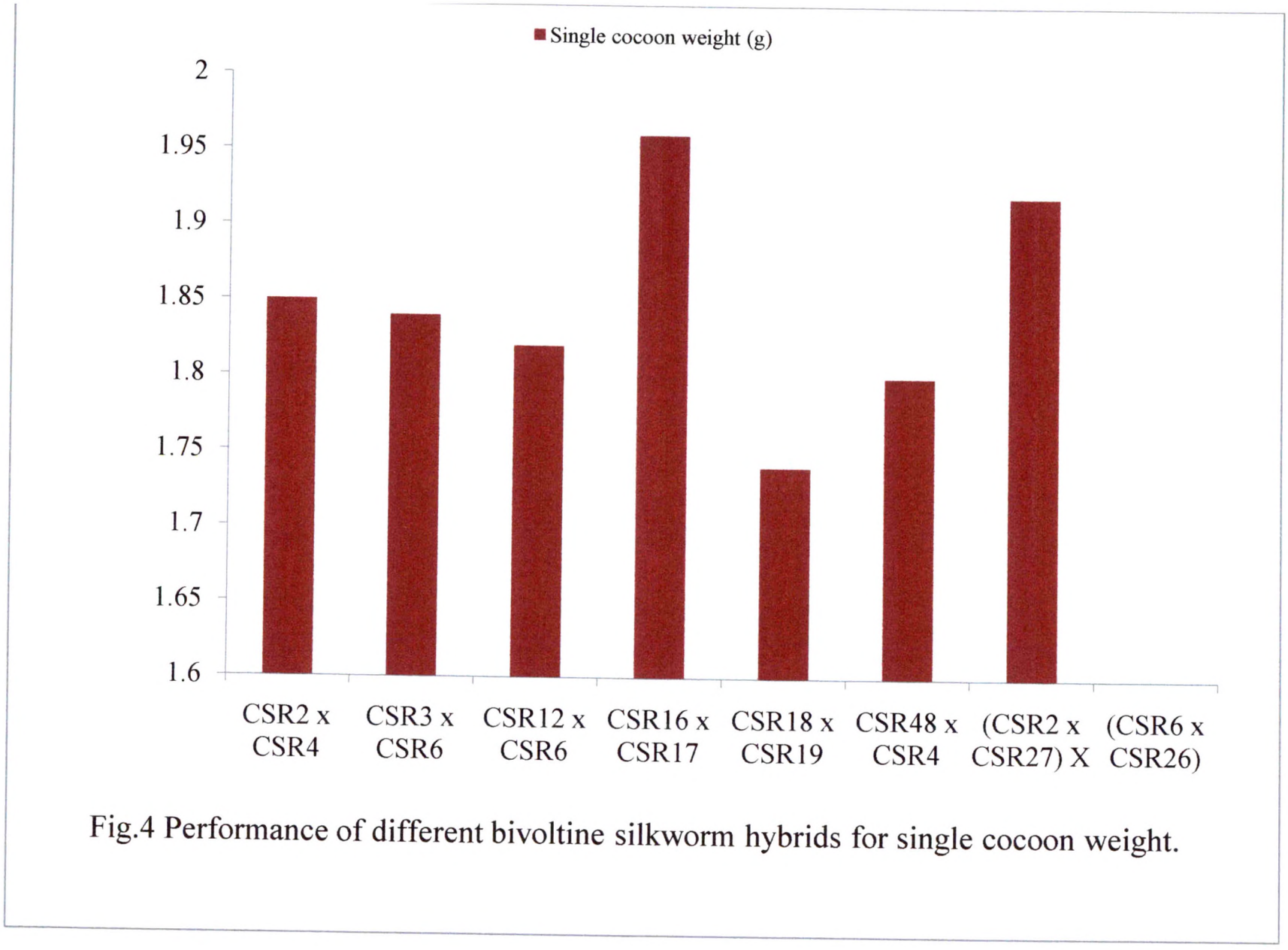


Fig.4 Performance of different bivoltine silkworm hybrids for single cocoon weight.

4.5 Performance of different bivoltine silkworm hybrids for single shell weight (g)

Data on single shell weight presented in Table no. 5. The data revealed that, maximum shell weight was recorded by CSR_{16} x CSR_{17} (0.391 g) and found significantly superior over rest of the hybrids followed by (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (0.384 g). Whereas, the minimum shell weight was recorded by CSR_{18} x CSR_{19} (0.354 g).

Table no. 5. Performance of different bivoltine silkworm hybrids for single shell weight (g)

Sr. No.	Treatment	Single shell weight (g)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	0.367	0.376	0.361	1.104	0.368
2	CSR_3 x CSR_6	0.363	0.356	0.358	1.077	0.359
3	CSR_{12} x CSR_6	0.361	0.365	0.363	1.089	0.363
4	CSR_{16} x CSR_{17}	0.385	0.394	0.394	1.173	0.391
5	CSR_{18} x CSR_{19}	0.357	0.362	0.343	1.062	0.354
6	CSR_{48} x CSR_4	0.371	0.362	0.365	1.098	0.366
7	(CSR_2 x CSR_{27}) X (CSR_6 x CSR_{26})	0.390	0.387	0.375	1.152	0.384
	SE ±					0.003
	CD at 5%					0.010

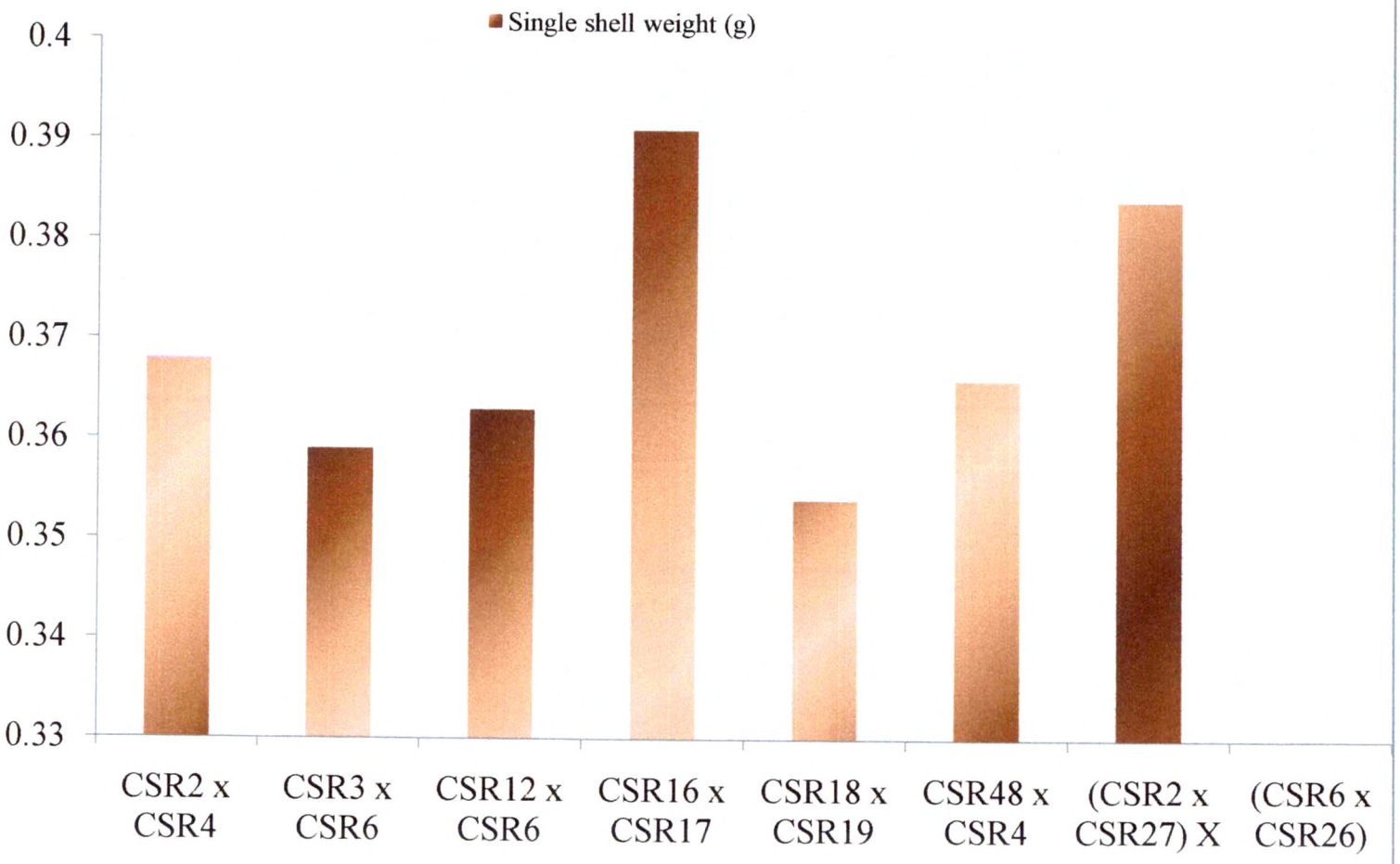


Fig.5 Performance of different bivoltine silkworm hybrids for single shellweight.

4.6 Performance of different bivoltine silkworm hybrids for shell ratio (%)

The data presented in Table no. 6 revealed that maximum shell percentage was recorded CSR_{48} x CSR_4 (20.53 per cent) followed by CSR_{18} x CSR_{19} (20.35 per cent) and (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (19.99 per cent). Whereas CSR_3 x CSR_6 recorded (19.52 per cent) showed lowest shell ratio.

Table no. 6. Performance of different bivoltine silkworm hybrids for shell ratio (%)

Sr. No.	Treatment	Shell ratio (%)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	20.05	20.32	19.30	59.67	19.89
2	CSR_3 x CSR_6	20.50	18.83	19.24	58.57	19.52
3	CSR_{12} x CSR_6	19.94	20.50	19.41	59.85	19.95
4	CSR_{16} x CSR_{17}	19.15	20.00	20.73	59.88	19.96
5	CSR_{18} x CSR_{19}	20.87	20.92	19.26	61.05	20.35
6	CSR_{48} x CSR_4	21.07	19.67	20.27	61.61	20.53
7	(CSR_2 x CSR_{27}) X (CSR_6 x CSR_{26})	20.10	20.15	19.73	59.98	19.99
	SE ±					0.296
	CD at 5%					0.882

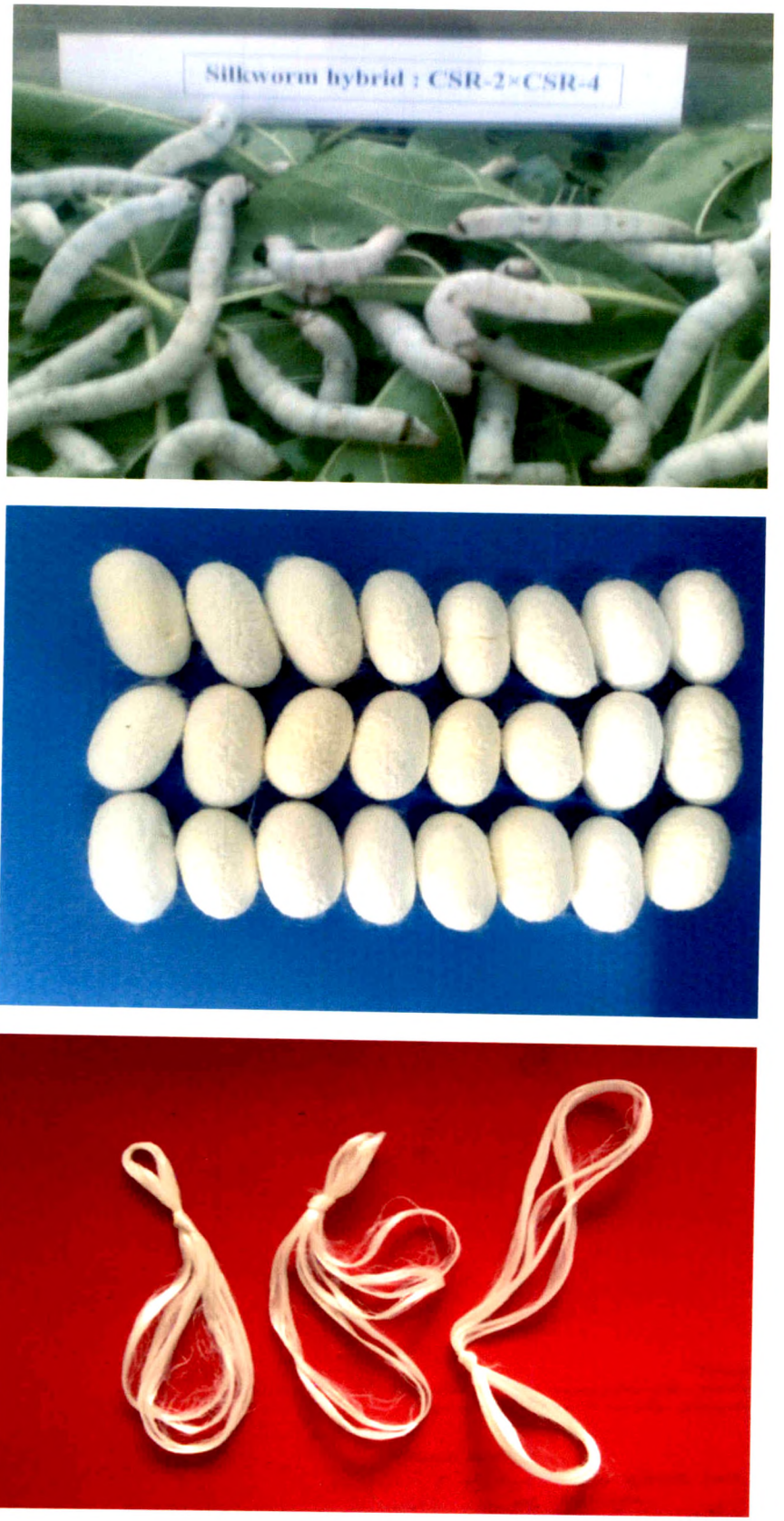


Plate 1. Larvae, cocoon and filament of CSR_2 x CSR_4

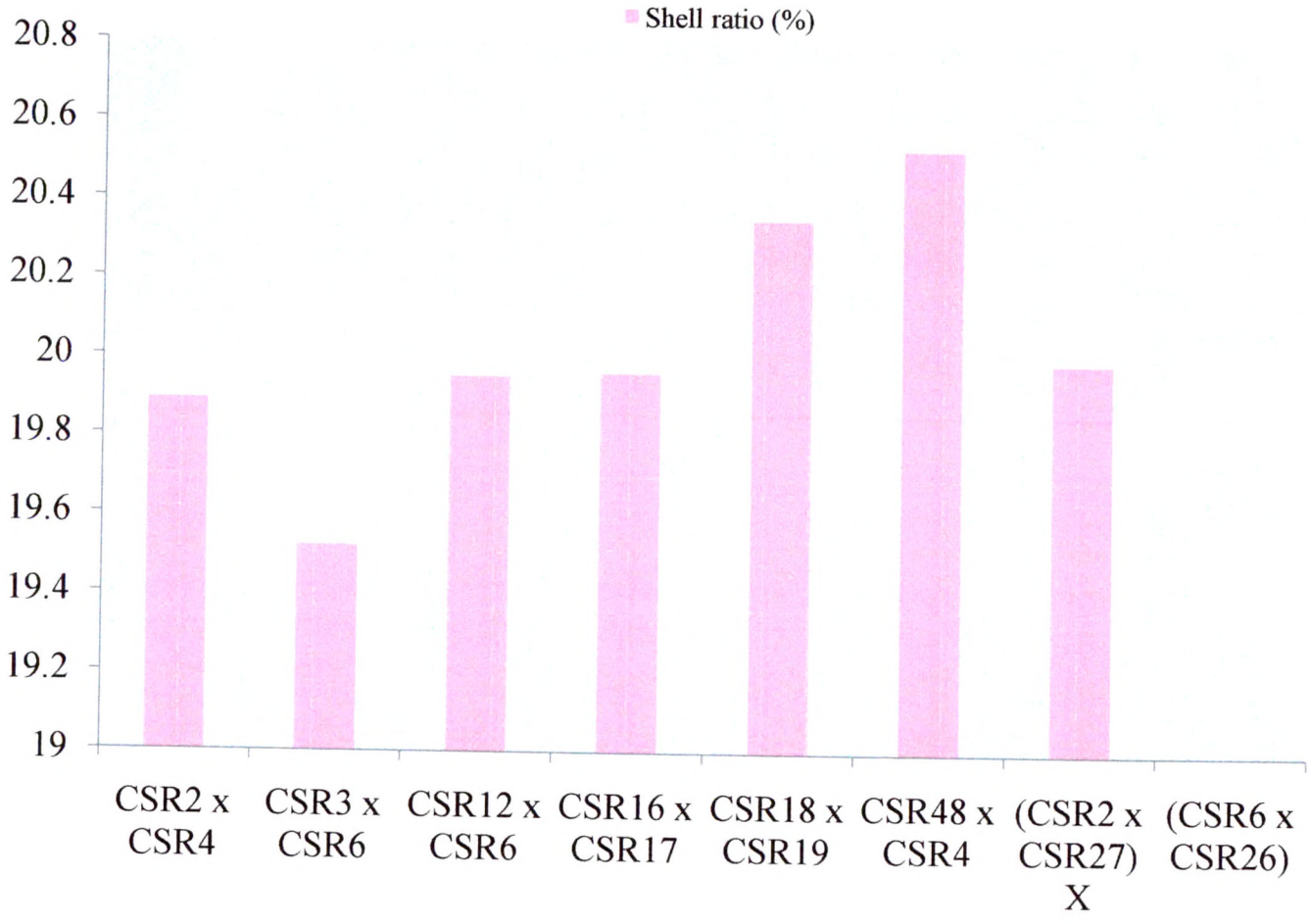


Fig.6 Performance of different bivoltine silkworm hybrids for shell ratio

4.7 Performance of different bivoltine silkworm hybrids for filament length (m)

Data on the performance of silkworm hybrids under study for filament length are presented in Table no. 7 revealed that filament length was recorded significantly superior by CSR_{16} x CSR_{17} (1010 m.) over rest of the hybrids followed by double hybrid (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (1004 m) which was at par with other hybrids tested. Whereas, CSR_{18} x CSR_{19} (925 m) was showed lowest filament length.

Table no. 7. Performance of different bivoltine silkworm hybrids for filament length (m)

Sr. No.	Treatment	Filament length (m)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	970	950	966	2886	962
2	CSR_3 x CSR_6	930	948	972	2850	950
3	CSR_{12} x CSR_6	946	963	965	2874	958
4	CSR_{16} x CSR_{17}	986	1004	1040	3030	1010
5	CSR_{18} x CSR_{19}	940	915	920	2775	925
6	CSR_{48} x CSR_4	928	942	935	2805	935
7	(CSR_2 x CSR_{27}) X (CSR_6 x CSR_{26})	1012	1008	992	3012	1004
	SE $\pm$					9.18
	CD at 5%					28.26

Plate 2. Larvae, cocoon and filament of CSR_3 x CSR_6

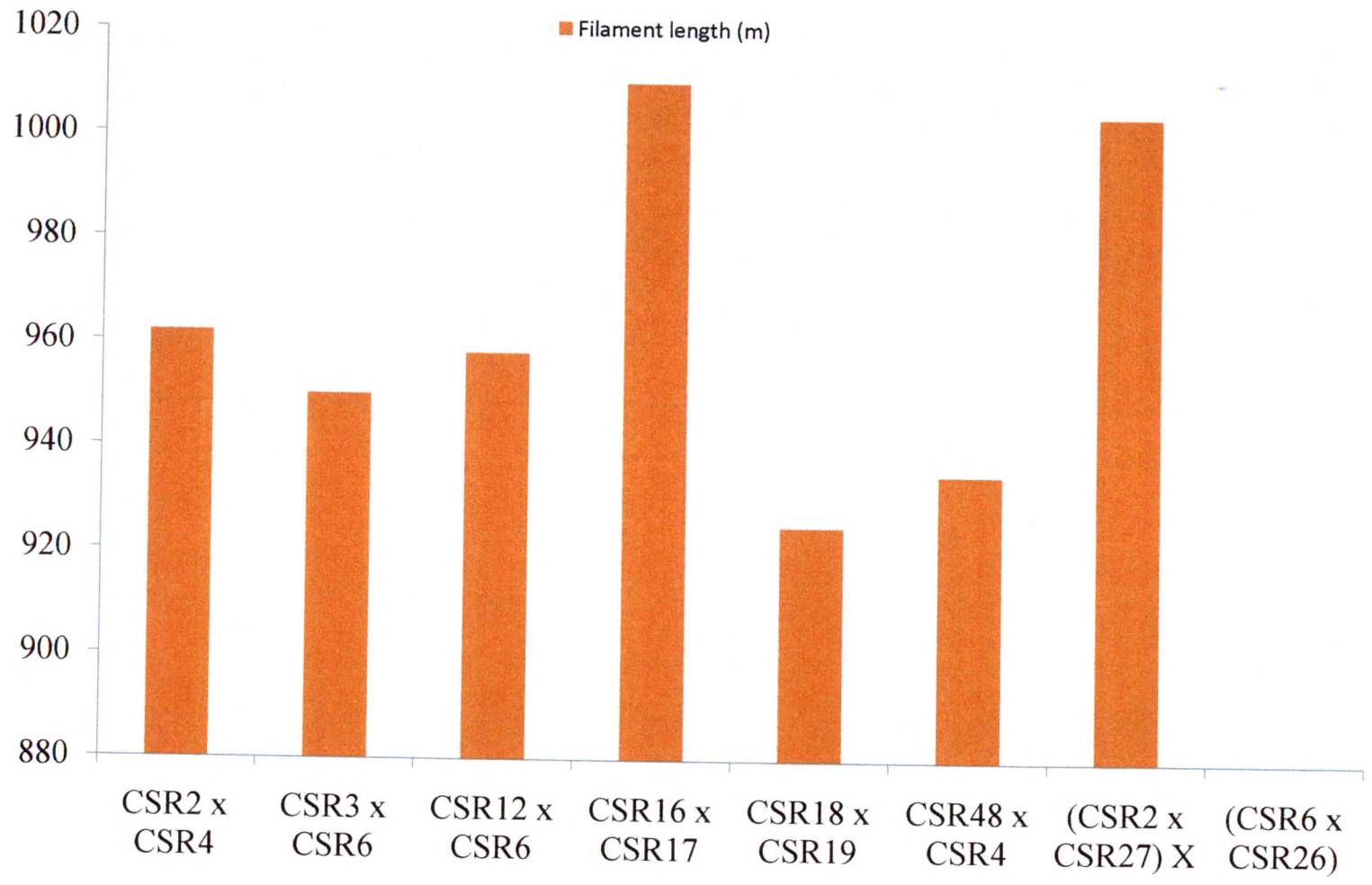


Fig.7 Performance of different bivoltine silkworm hybrids for filament length

4.8 Performance of different bivoltine silkworm hybrids for cocoon yield/10000 larvae brushed (kg)

The observation on cocoon yield/10,000 larvae brushed (kg) were recorded and presented in Table no. 8 revealed that cocoon yield/10,000 larvae brushed varies from 17.12 kg to 18.60 kg.

Table no. 8. Performance of different bivoltine silkworm hybrids for cocoon yield/10000 larvae brushed (kg)

Sr. No.	Treatment	Cocoon yield/10000 larvae brushed (kg)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	17.96	18.10	17.88	53.94	17.98
2	CSR_3 x CSR_6	17.70	17.78	18.22	53.70	17.90
3	CSR_{12} x CSR_6	17.19	17.29	17.42	51.90	17.30
4	CSR_{16} x CSR_{17}	18.80	18.60	18.40	55.80	18.60
5	CSR_{18} x CSR_{19}	17.20	17.09	17.07	51.36	17.12
6	CSR_{48} x CSR_4	17.40	17.12	17.08	51.60	17.20
7	(CSR_2 x CSR_{27}) X (CSR_6 x CSR_{26})	18.70	18.90	18.05	55.65	18.55
	SE ±					0.138
	CD at 5%					0.426

Maximum cocoon yield was noticed by CSR_{16} x CSR_{17} (18.60 kg) which was significantly superior over rest of hybrids followed by (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (18.55 kg). The minimum cocoon yield was noticed by CSR_{18} x CSR_{19} (17.12 kg) followed by CSR_{48} x CSR_4 (17.20 kg).

Plate 3. Larvae, cocoon and filament of CSR_{12} x CSR_6

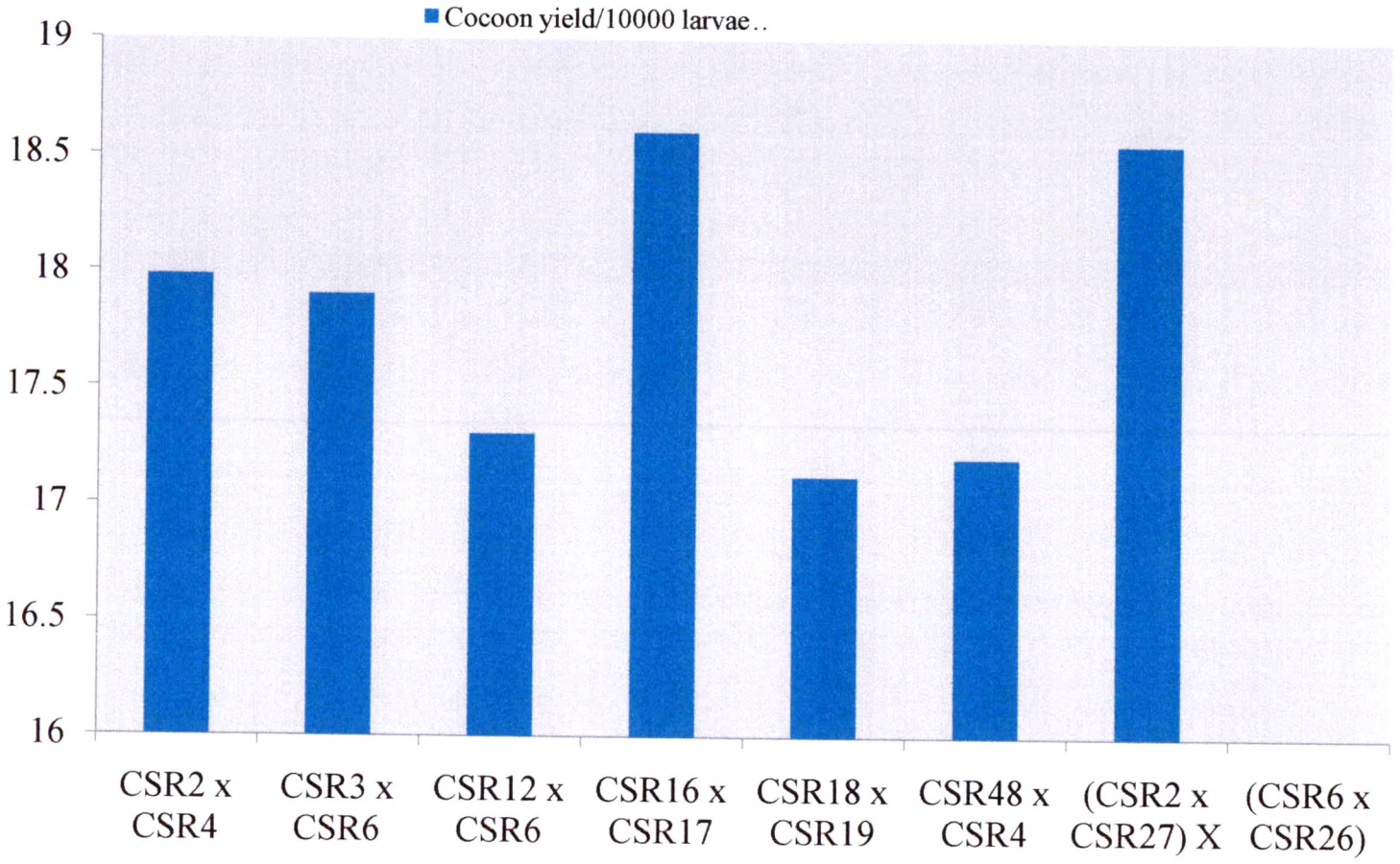


Fig.8 Performance of different bivoltine silkworm hybrids for cocoon yield/10000 larvae

4.9 Performance of different bivoltine mulberry silkworm hybrids for denier

Data presented in Table 9 revealed that, the hybrid CSR_{16} x CSR_{17} (3.725) showed lowest denier value and found significantly superior over the rest of hybrids, followed (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (3.733) and CSR_3 x CSR_6 (3.736) which are at par with each other. The highest denier value was recorded by CSR_{48} x CSR_4 (3.844).

Table no. 9. Performance of different bivoltine silkworm hybrids for denier

Sr. No.	Treatment	Denier			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	3.762	3.778	3.732	11.272	3.757
2	CSR_3 x CSR_6	3.704	3.737	3.769	11.210	3.736
3	CSR_{12} x CSR_6	3.735	3.722	3.769	11.226	3.742
4	CSR_{16} x CSR_{17}	3.660	3.786	3.731	11.177	3.725
5	CSR_{18} x CSR_{19}	3.838	3.742	3.701	11.281	3.760
6	CSR_{48} x CSR_4	3.702	3.918	3.913	11.533	3.844
7	(CSR_2 x CSR_{27}) X (CSR_6 x CSR_{26})	3.832	3.672	3.696	11.200	3.733
	SE $\pm$					0.042
	CD at 5%					0.132

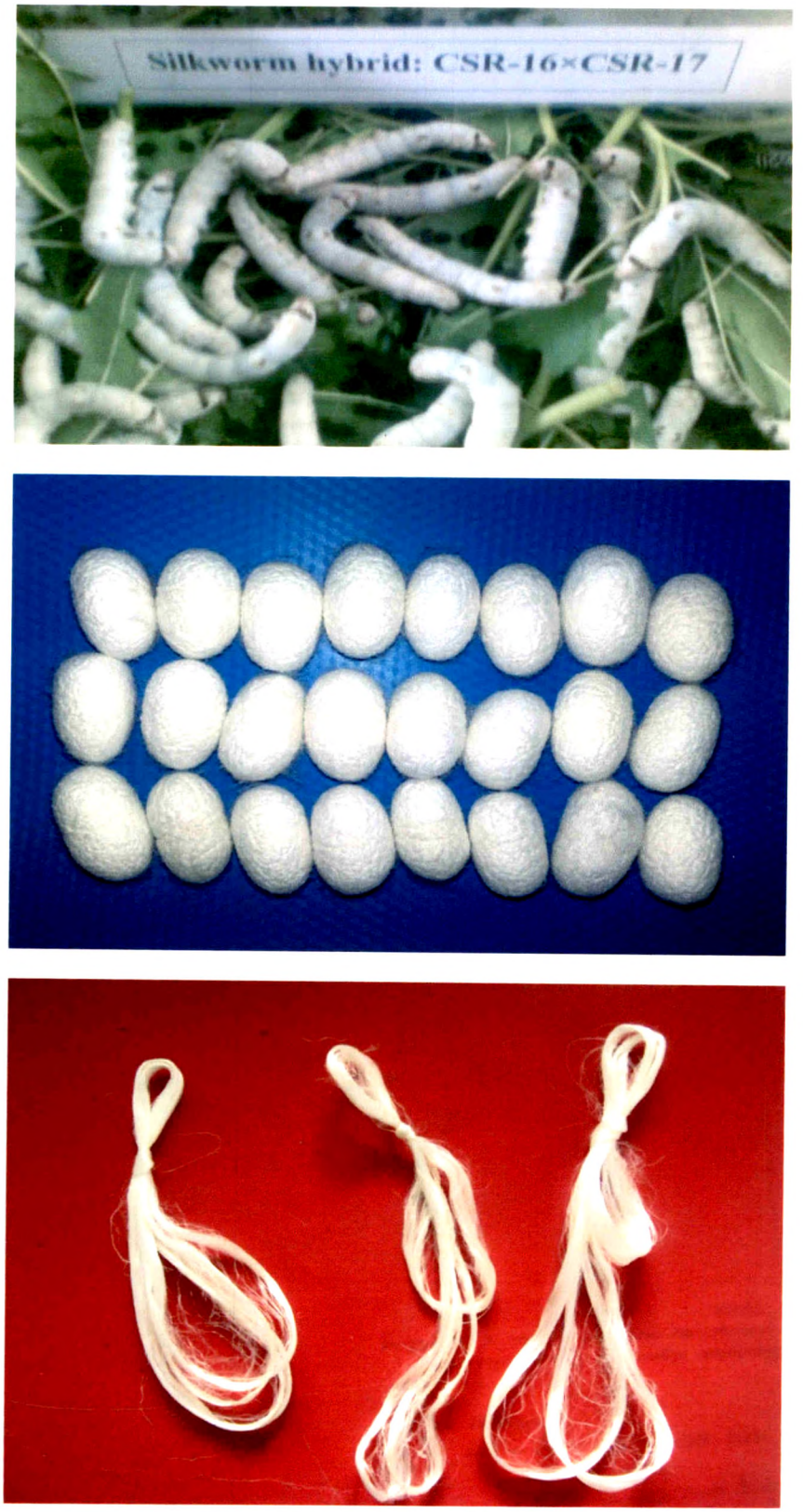


Plate 4. Larvae, cocoon and filament of CSR_{16} x CSR_{17}

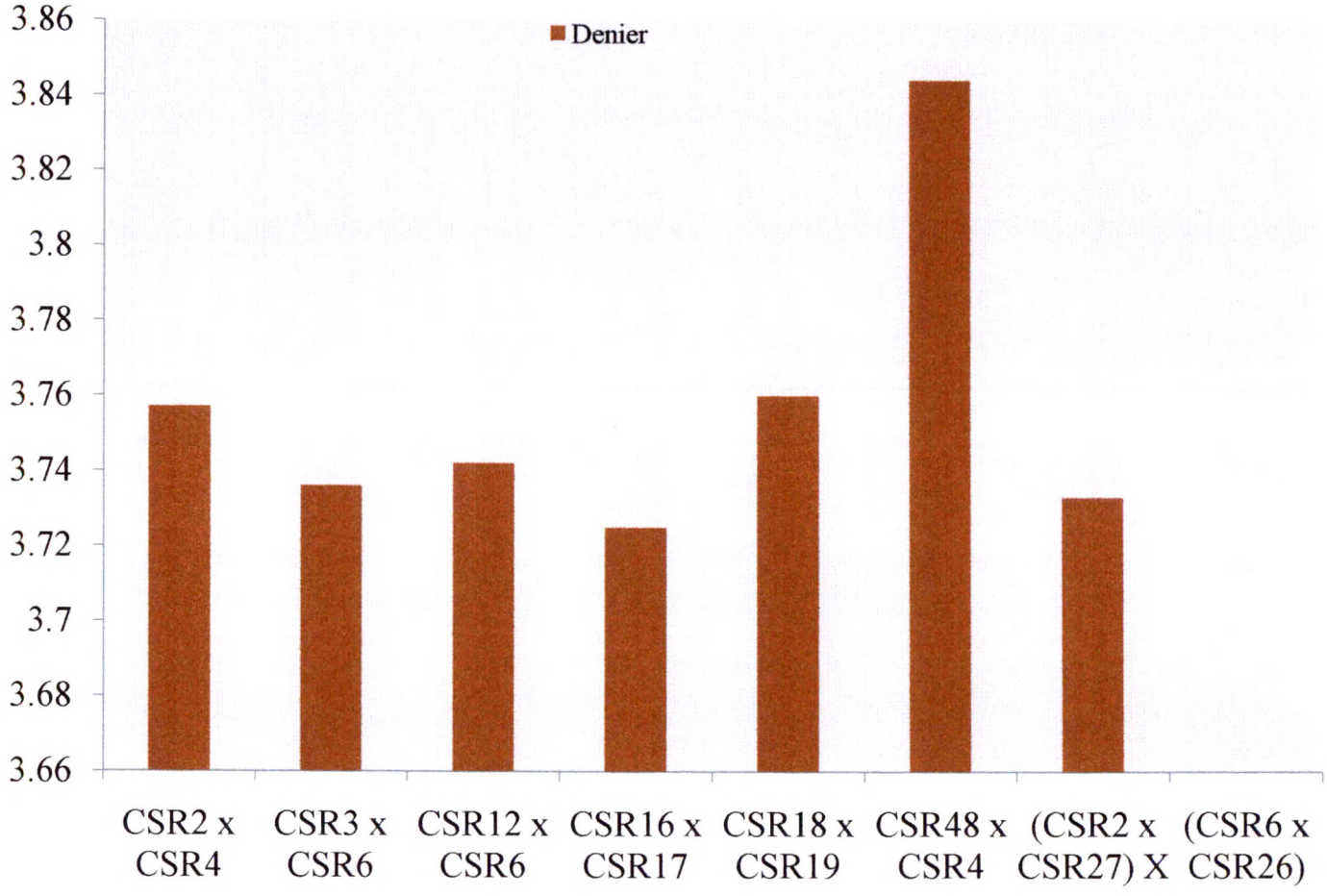


Fig.9 Performance of different bivoltine silkworm hybrids for denier

4.10 Performance of different bivoltine silkworm hybrids for disease incidence

Data on performance of bivoltine hybrids under study for disease incidence is presented in Table no. 10 revealed that the disease per cent varies in the range of 2.32 to 5.08 per cent.

Table no. 10. Performance of different bivoltine silkworm hybrids for disease incidence (%)

Sr. No.	Treatment	Disease incidence (%)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	3.75	3.96	3.99	11.70	3.90
2	CSR_3 x CSR_6	3.77	3.81	3.85	11.43	3.81
3	CSR_{12} x CSR_6	3.60	3.65	3.88	11.13	3.71
4	CSR_{16} x CSR_{17}	5.40	5.13	4.63	14.76	4.92
5	CSR_{18} x CSR_{19}	5.30	5.07	4.87	15.24	5.08
6	CSR_{48} x CSR_4	2.20	2.40	2.36	6.96	2.32
7	(CSR_2 x CSR_{27}) X (CSR_6 x CSR_{26})	4.72	4.93	4.96	14.61	4.87
	SE $\pm$					0.165
	CD at 5%					0.510

The bivoltine hybrid CSR_{48} x CSR_4 recorded significantly less disease incidence (2.32 per cent) than all other treatments. Treatment CSR_{18} x CSR_{19} recorded significantly high disease incidence (5.08 per cent) than rest of the treatments.

Plate 5. Larvae, cocoon and filament of CSR_{18} x CSR_{19}

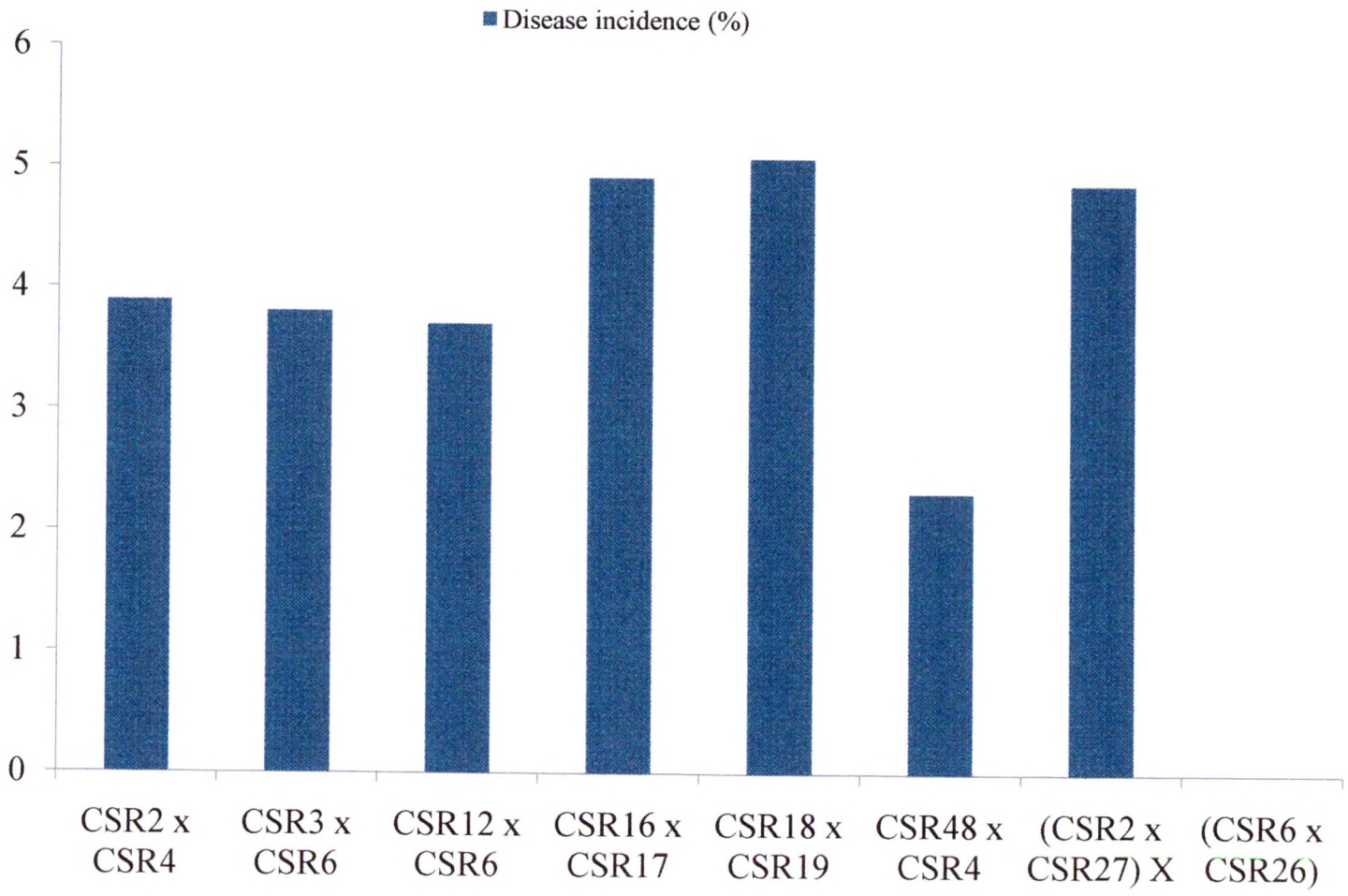


Fig.10 Performance of different bivoltine silkworm hybrids for disease incidance

4.11 Performance of different bivoltine silkworm hybrids for filament weight (g)

The observation on filament weight in gram was recorded and presented in Table no. 11 revealed that filament weight was varied from 0.386 g to 0.417 g. The performance of CSR_{16} x CSR_{17} (0.417 g) observed significantly superior over all the other hybrids. The hybrid (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (0.416 g) and CSR_2 x CSR_4 (0.401 g) were at par with each other. The lowest filament weight was recorded by CSR_{18} x CSR_{19} (0.386 g).

Table no. 11. Performance of different bivoltine silkworm hybrids for filament weight (g)

Sr. No.	Treatment	Filament weight (g)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	0.405	0.398	0.400	1.203	0.401
2	CSR_3 x CSR_6	0.382	0.393	0.407	1.182	0.394
3	CSR_{12} x CSR_6	0.392	0.398	0.404	1.194	0.398
4	CSR_{16} x CSR_{17}	0.400	0.422	0.431	1.253	0.417
5	CSR_{18} x CSR_{19}	0.400	0.380	0.378	1.158	0.386
6	CSR_{48} x CSR_4	0.381	0.410	0.406	1.197	0.399
7	(CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26})	0.430	0.411	0.407	1.248	0.416
	SE $\pm$					0.007
	CD at 5%					0.022

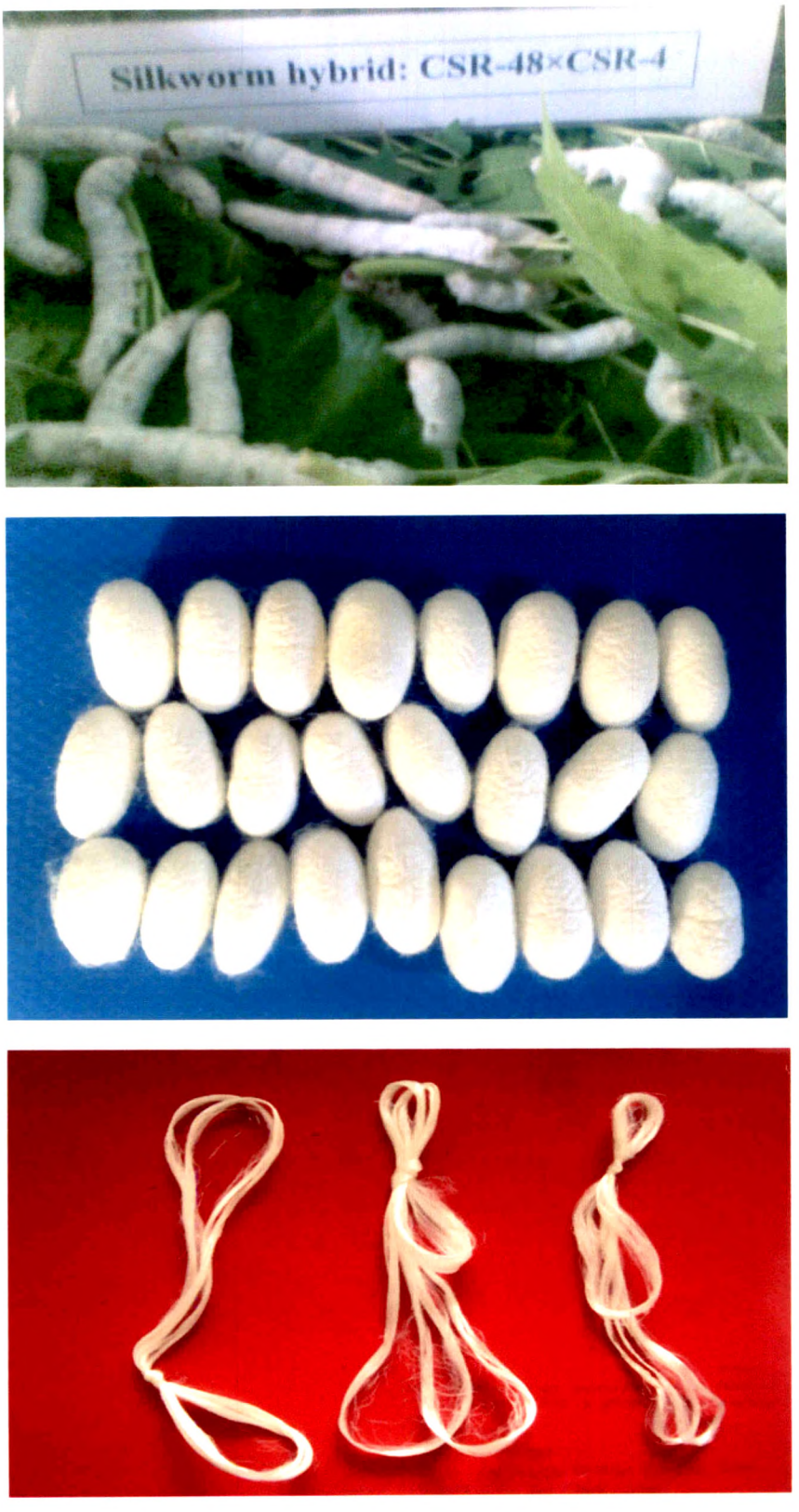


Plate 6. Larvae, cocoon and filament of CSR_{48} x CSR_4

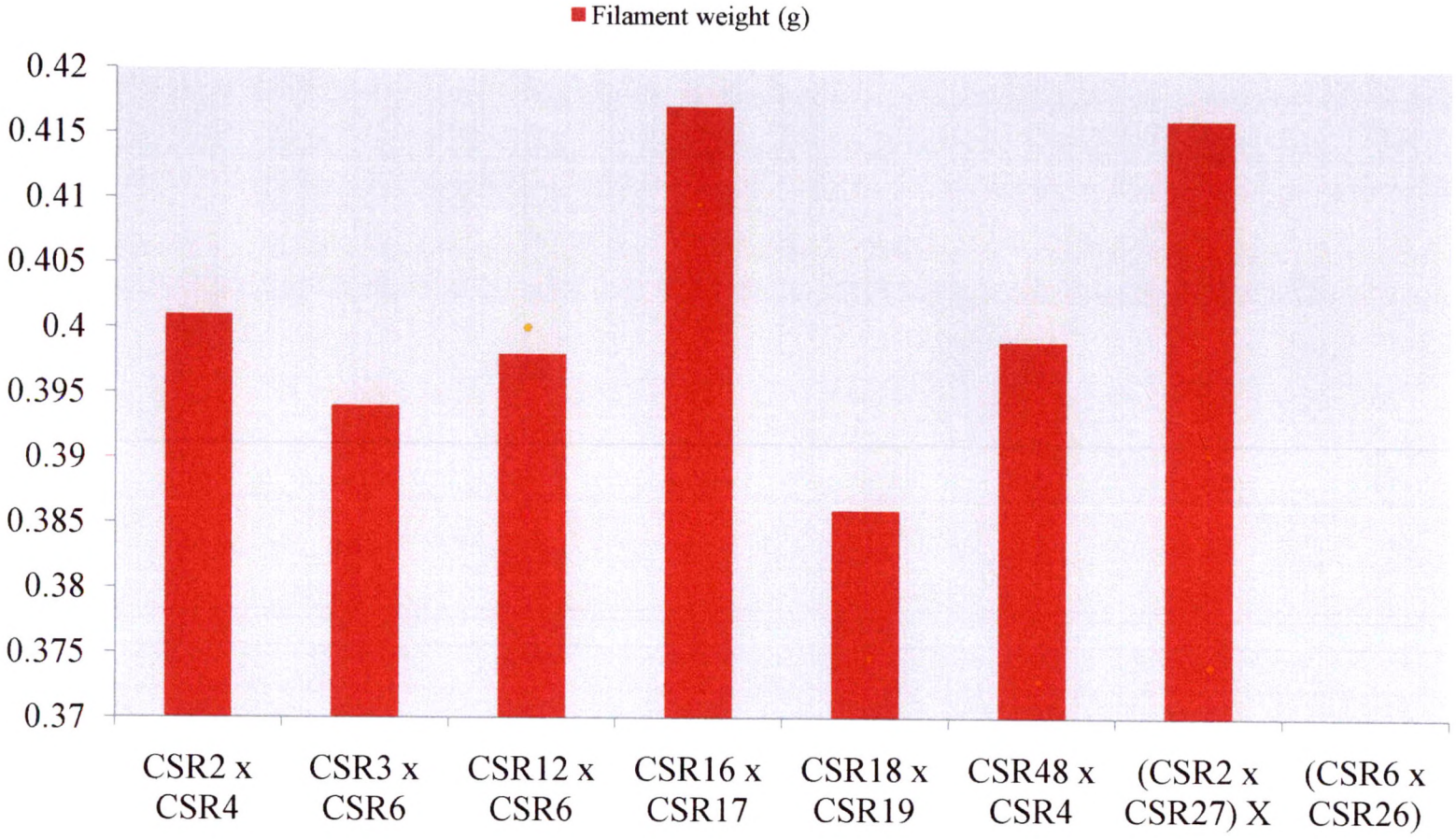


Fig.11 Performance of different bivoltine silkworm hybrids for filament weight

4.12 Performance of different bivoltine silkworm hybrids for moth emergence percentage .

The data on moth emergence percentage was recorded and presented in Table no. 12. This data clearly shows that moth emergence percentage varies between 95.33 % to 84 %.

Table no. 12. Performance of different bivoltine silkworm hybrids for moth emergence percentage.

Sr. No.	Treatment	Moth emergence (%)			Total	Mean
		R-I	R-II	R-III		
1	CSR_2 x CSR_4	88	92	90	270	90
2	CSR_3 x CSR_6	90	94	92	276	92
3	CSR_{12} x CSR_6	92	96	94	282	94
4	CSR_{16} x CSR_{17}	84	88	90	262	87.33
5	CSR_{18} x CSR_{19}	86	84	82	252	84
6	CSR_{48} x CSR_4	96	96	94	286	95.33
7	(CSR_2 x CSR_{27}) X (CSR_6 x CSR_{26})	88	90	82	260	86.66
	SE $\pm$					1.81
	CD at 5%					3.634

The highest moth emergence percent was recorded by the hybrid CSR_{48} x CSR_4 (95.33 %), which was significantly superior over the rest of the hybrids followed by CSR_{12} x CSR_6 (94 %) and CSR_3 x CSR_6 (92 %). The lowest moth emergence percentage was observed by CSR_{18} x CSR_{19} (84.00 %).

Plate 7.Larvae, cocoon and filament of (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26})

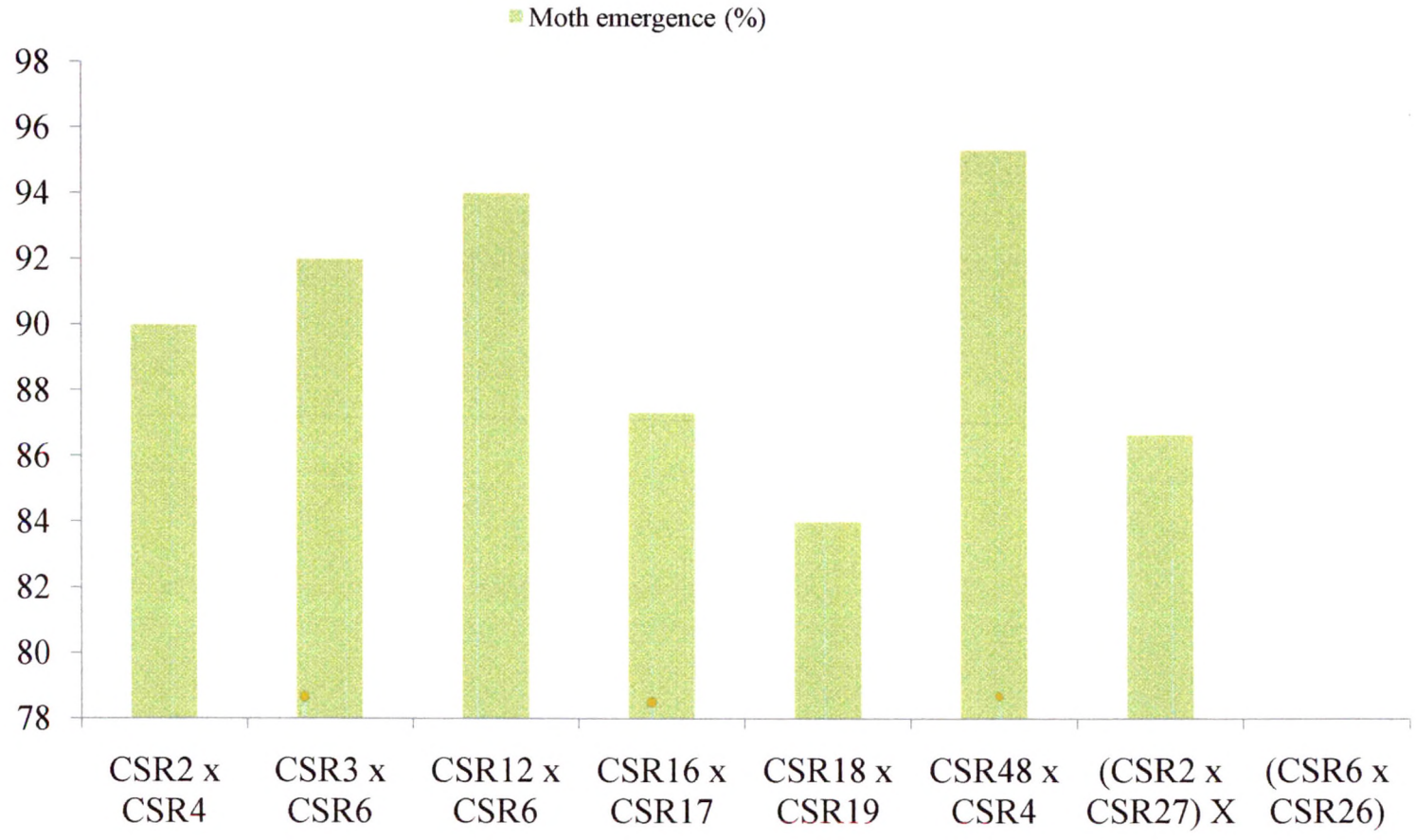


Fig.12 Performance of different bivoltine silkworm hybrids for moth emergance.

DISCUSSION

Chapter-V

DISCUSSION

Widespread utilization of hybrids towards achieving sustainability and quality oriented increased production is well established in plants and animals in general and silkworm in particular as it is the only animal where hybrids are used compulsorily (Yokoyama, 1976). In spite of quantitative increase in the overall silk production in India over years through the development and use of productive silkworm hybrids on commercial scale (Sengupta *et al.*, 1971;), there remains a wide quantitative and qualitative yield gap than is mainly attributed to the dearth for potential silkworm hybrids suitable for Indian tropical conditions necessitating the need for more potential silkworm hybrids. Realizing the need for increased qualitative silk production, due emphasis is being laid towards the development of suitable and qualitatively superior bivoltine hybrids. Tropical conditions of the country in general and region and season specific in particular likewise the present research was conducted to study the performance of bivoltine silkworm hybrids at Latur condition.

The persual of literature revealed that very meager information is available on the mulberry silkworm hybrids under Latur conditions. Hence, the results obtained are discussed in the light of available literature on the other related hybrids.

5.1 Per cent hatching

The hybrid CSR_{16} x CSR_{17} (94.08 per cent) recorded higher per cent hatching, at par with CSR_3 x CSR_6 (93.17 per cent).

The pooled data (Table no.1) revealed that the bivoltine hybrid CSR_{16} x CSR_{17} recorded significantly more hatching than all the other hybrids tested except CSR_3 x CSR_6.

Salunke (2003) observed 97.22 per cent hatching in bivoltine hybrid CSR_{16} x CSR_{17} and which was also significantly superior in his experiment. Whereas, per cent hatching of 96.82 per cent to 97.5 per cent has been reported by Nahar *et al.*, (1989). The present results are in conformity with previous workers.

5.2 Larval duration (days) of silkworm

Among all the silkworm hybrids, the bivoltine hybrid CSR_{18} x CSR_{19} recorded significantly minimum larval duration (22.20 days) followed by (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (22.70 days). The larval duration contribute little in the yield of cocoons. Salunke (2003) reported that under favourable condition the bivoltine hybrid CSR_{18} x CSR_{19} recorded significantly shortest larval duration (21.43 days) than all other bivoltine hybrids tested. Vidhate (2003) had recorded CSR_{18} x CSR_{19} (21.68 days) significantly superior larval duration than other hybrids tested.

5.3 Weight of ten mature larvae

The bivoltine hybrid CSR_{16} x CSR_{17} (44.90 g) recorded significantly superior larval weight than all other hybrids tested.

Salunke (2003) reported that maximum ten mature larval weight was recorded in bi x bi hybrids compared to multi x bi hybrids and also CSR_{16} x CSR_{17} showed best result in that experiment (52.33 g) ten larvae which recorded significantly high than all other hybrids tested in favorable season Oct-Nov 2002.

5.4 Single cocoon weight

The bivoltine hybrid CSR_{16} x CSR_{17} showed maximum single cocoon weight (1.96 g) and found significantly superior over rest of hybrids tested.

The performance of bivoltine hybrids was evaluated at Central Sericulture Research & Training Institute, Mysore. The result showed that CSR_{16} x CSR_{17} had shown single cocoon weight 2.13 g.

Akio (2000) reported CSR_{16} x CSR_{17} has shown superior single cocoon weight (2.13 g). Vidhate (2003) recorded CSR_{16} x CSR_{17} (1.975 g) significantly superior cocoon weight.

5.5 Single shell weight

The results on the single shell weight of different silkworm hybrids are presented in Table no. 5. The observations revealed that the bivoltine hybrid CSR_{16} x CSR_{17} (0.391 g) had shown significantly highest single shell weight. Whereas, lowest single shell weight was recorded in the bivoltine hybrid CSR_{18} x CSR_{19}.

Akio (2000), Vidhate (2003) and Salunke (2003) reported the highest shell weight of CSR_{16} x CSR_{17} bivoltine hybrid. The present findings are in conformity with the results of above workers.

5.6 Per cent shell ratio

The data on shell ratio are presented in Table no. 6. The data revealed that, the highest shell ratio was recorded by bivoltine hybrid CSR_{48} x CSR_4 (20.53 per cent), whereas the bivoltine hybrid CSR_3 x CSR_6 showed lowest shell ratio (19.52 per cent).

Vidhate (2009) reported the highest shell ratio of the bivoltine hybrid CSR_{48} x CSR_4 (20.98 per cent). The present findings are in confirmative with the result of above worker.

5.7 Filament length (m)

The observations on filament length per cocoon are presented in Table no. 7. It was observed that, the longest filament length was observed in the bivoltine hybrid CSR_{16} x CSR_{17} (1010 m). However, the bivoltine hybrid CSR_{18} x CSR_{19} (925 m) recorded lowest filament length.

Present findings are in agreement with above workers record more filament length in bi x bi hybrids over multi x bi hybrids. This may be due to bivoltine hybrid possessing high potential for yield and higher cocoon shell weight. These findings are supported by Narayanaswami *et al.*, (1999).

5.8 Cocoon yield/10000 larvae brushed

Observations on cocoon yield in kg/10000 larvae brushed are presented in Table no. 8. It has been found that significantly highest cocoon yield was recorded by CSR_{16} x CSR_{17} (18.60 kg) followed by double hybrid (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (18.55 kg). The lowest yield was recorded by bivoltine hybrid CSR_{18} x CSR_{19} (17.12 kg)

followed by CSR_{48} x CSR_4 (17.20kg). This character is directly related to the weight of mature larvae, hence it has been observed that the bivoltine hybrid CSR_{16} x CSR_{17} recorded the highest cocoon yield than CSR_{18} x CSR_{19} (17.12kg).

Vidhate (2003) recoreded significantly highest cocoon yield in hybrid CSR_{16} x CSR_{17} (18.05 kg). the present findings recorded significant cocoon yield in bivoltine hybrid CSR_{18} x CSR_{19} (17.07 kg). Basavaraja (2002a) also reported less cocoon weight of CSR_{18} x CSR_{19}.

5.9 Denier

As denier is the thickness of silk thread, higher the denier value coarse the filament while lower the denier value fine the filament.

The hybrid CSR_{16} x CSR_{17} (3.725) recorded significantly lowest and finer denier followed by (CSR_2 x CSR_{27}) x (CSR_6 x CSR_{26}) (3.733), CSR_3 x CSR_6 (3.742).

Akio (2000) recorded the denier value of CSR_{16} x CSR_{17} (3.44) which was significantly superior. Better performance of bi x bi hybrids for filament denier has been reported by Rayar *et al.,* (1987).The present findings in conformity with earlier worker.

5.10 Incidence of disease

The bivoltine hybrid CSR_{48} x CSR_4 (2.32 per cent) recorded significantly less disease incidence than other hybrids tested followed by CSR_{12} x CSR_6 (3.71 per cent) showed less disease incidence.

5.11 Filament weight (g)

The observations on filament weight per cocoon are presented in Table no. 11. It was observed that, the highest filament

weight was observed in the bivoltine hybrid CSR_{16} x CSR_{17} (0.417 g). However, the bivoltine hybrid CSR_{18} x CSR_{19} (0.386 g) recorded lowest filament weight.

Present findings are in agreement with above workers recording more filament weight in bi x bi hybrids over multi x bi hybrids.

5.12 Moth emergence (%)

The data on moth emergence percentage was observed and presented in Table no.12. It was observed that the highest moth emergence percentage was observed in the bivoltine hybrid CSR_{48} x CSR_4 (95.33) per cent. However the bivoltine hybrid CSR_{18} x CSR_{19} (84) per cent. recorded lowest moth emergence percentage.

Tayade (1983a) reported that the highest per cent emergence in Pure Mysore (80 per cent) and Kalimpong-A (80 per cent) during September-October.

The present findings are in close agreement with Tayade (1983a).

SUMMARY AND CONCLUSION

Chapter VI

SUMMARY

The experiment was conducted at Department of Agricultural Entomology, College of Agriculture Latur, during 2009-2010, in randomized block design with seven treatments and three replications.

The variety of mulberry, S-1635 were utilized. The treatments were CSR_2xCSR_4, CSR_3xCSR_6, $CSR_{12}xCSR_6$, $CSR_{16}xCSR_{17}$, $CSR_{18}xCSR_{19}$, $CSR_{48}xCSR_4$, double hybrid (CSR_2xCSR_{26}) x (CSR_6xCSR_{26}). The observations were recorded on the performance of different bivoltine mulberry silkworm hybrids for economic traits of silkworm (*B. mori* L.). The findings of the present investigation are summarized below.

6.1 The hatching percentage, larval duration, larval weight, single cocoon and single shell weight, shell ratio, filament length, cocoon yield per 10,000 larvae brushed, denier, disease incidence, filament weight, moth emergence per cent of mulberry silkworm varied from 72.17 to 94.08 per cent, 22.20 to 24.28 days, 38.40 to 44.90 g, 1.74 to 1.96 g, 0.354 to 0.391 g, 19.52 to 20.53 per cent, 925 to 1010 m, 17.12 to 18.60 kg, 3.725 to 3.844, 2.32 to 5.8 per cent, 0.386 to 0.417 g, 84 to 95.33 per cent, respectively.

6.2 Significantly highest hatching percentage, larval weight, single cocoon and single shell weight, filament length, cocoon yield per 10,000 larvae brushed, denier, filament weight to the extent of 94.08 per cent, 44.90 g, 1.96 g, 0.391 g, 1010 m, 18.60 kg, 3.725, 0.417 g, respectively were recorded by $CSR_{16}xCSR_{17}$.

6.3 Significantly the lowest larval duration of mulberry silkworm hybrid was recorded by $CSR_{18}xCSR_{19}$ (22.20 days).

6.4 significantly highest shell ratio and moth emergence percentage were recorded by silkworm hybrid $CSR_{48}xCSR_4$ whose corresponding values were 20.53 per cent and 95.33 per cent, respectively.

6.5 Significantly the lowest incidence of silkworm diseases were recorded by $CSR_{48}xCSR_4$ (2.32 per cent).

Based on the above findings of bivoltine hybrids, it is concluded that the overall performance of bivoltine hybrid CSR_{16} x CSR_{17} showed superior for different economic traits when reared on mulberry variety S-1635 at Latur condition.

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LITERATURE CITED

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ANNEXURE

APPENDIX I

Weekwise meteorological data during the period of investigation

Year	:	2008	Latitude	:	18^0 24'N
State	:	Maharashtra	Longitude	:	76^0 36'
District	:	Latur	Altitude	:	633.85 m.
Locations			Soil type	:	Vertisol
Zone	:	Deccan platau Zone			

Month	Met. week No.	Temp. (^{0}C)		Rainfall (mm)	Number of rainy days	Relative humidity	
		Mean Max.	Mean Min.			BN (%)	AN (%)
1	2	3	4	5	6	7	8
Aug.	33	33.1	21.7	9.00	1	78.1	74.4
	34	33.2	18.8	8.00	1	70.6	67.8
	35	32.9	19.7	72.00	2	81.5	78.2
Sept.	36	31.2	21.0	112.8	4	82.6	79.1
	37	31.4	22.3	268.8	3	86.4	82.4
	38	31.7	22.2	47.6	1	85.9	80.7
	39	31.2	22.3	0.00	0	78.6	73.4
Oct.	40	31.9	18.7	0.00	0	63.5	59.9
	41	31.7	18.5	52.6	3	77.8	73.8
	42	32.7	18.2	0.00	0	68.3	65.1
	43	32.5	18.5	0.00	0	76.2	72.9
Nov.	44	31.9	17.0	0.00	0	64.3	61.5
	45	31.4	14.7	0.00	0	59.4	55.4
	46	30.3	15.7	0.00	0	59.9	55.6
	47	30.5	14.9	4.00	1	64.1	61.2
Dec.	48	31.3	12.3	0.00	0	60.2	57.3
	49	31.7	13.0	0.00	0	70.4	67.1

ABBREVIATIONS

%	-	Per cent
B. mori	-	*Bombyx mori*
Bi.	-	Bivoltine
C.D.	-	Critical difference
C.V.	-	Coefficient of variation
cm	-	Centimeter(s)
Dec.	-	December
Edn.	-	edition
et al	-	*Et alia,* and others
Fig	-	Figure
hr	-	hour(s)
i.e.	-	*Id est,* that is
m	-	meter
Max.	-	Maximum
Met .	-	Meterological
mg	-	Miligram
Min	-	Minimum
mm	-	Milimeter(s)
N.S.	-	Non-significant
No.	-	number(s)
Nov.	-	November
^{0}C	-	degree celcious
Oct.	-	October
pp	-	pages
S.D.	-	Standard deviation from mean
S.E.	-	Standard error
Sept.	-	September
sp.	-	species
Temp.	-	Temperature
viz.	-	Videlicet, namely

Dissertation Abstract

Title : - Performance of bivoltine hybrids of silkworm (*Bombyx mori* L.) on mulberry.

Name of student : - Chavan Sandeep Laxman

Reg.No : - 2008A/31ML.

Name of research guide : - Dr. Latpate C.B.

The experiment was conducted at Department of Agricultural Entomology, College of Agriculture Latur, during 2009-2010, in randomized block design with seven treatments and three replications. The variety of mulberry, S-1635 was utilized. The bivoltine hybrids CSR_2xCSR_4, CSR_3xCSR_6, $CSR_{12}xCSR_6$, $CSR_{16}xCSR_{17}$, $CSR_{18}xCSR_{19}$, $CSR_{48}xCSR_4$, double hybrid (CSR_2xCSR_{27}) x (CSR_6xCSR_{26}) were used as treatments. The observations were recorded on the performance of different bivoltine mulberry silkworm hybrids for economic traits of silkworm (*B. mori* L.).

Out of seven bivoltine hybrids, $CSR_{16}xCSR_{17}$, $CSR_{18}xCSR_{19}$, $CSR_{48}xCSR_4$ was found superior for economic traits studied. $CSR_{16}xCSR_{17}$ recorded significantly superior for hatching percentage (94.08 per cent), larval weight (44.90 g), single cocoon weight (1.96 g), single shell weight (0.391 g), filament length (1010 m), cocoon yield per 10,000 larvae brushed (18.60 kg), denier (3.725) and filament weight (0.417 g). $CSR_{18}xCSR_{19}$ hybrid recorded significantly superior for economic trait, larval duration (22.20 days). The hybrid $CSR_{48}xCSR_4$ was recorded significantly superior for the characters shell ratio, moth emergence and minimum disease incidence 20.53, 95.33 and 2.32 per cent respectively.