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Evaluation of different larval stages of silkworm hybrids in Jammu division of Jammu and Kashmir

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Abstract
Data on six commercial economic characters was recorded during the rearing. The recorded data was computed and analyzed by analysis of variance and heterotic crosses were screened by using a multiple trait index method. The data revealed that the larval duration depicted non-significant results; however U6×ND3 and CC1×U1 recorded shorter larval life of 23.17 days. Significantly higher weight gain and growth rate were recorded by the hybrid U6×ND3 whereas maximum larval weight was achieved by the hybrid JD6×U6. It can be concluded that hybrid U6×ND3 can be utilized for field rearing after validating the results through multi location traits at the farmer's level.

Keywords: silkworm, larval stages, weight, hybrid, rearing

1. Introduction

Silk has played an important role in the economic life of humans since its discovery. Fabulous silks from China and India were carried to Europe along the famous 6000 miles Silk Road and it has been traditionally associated with the socio-economic upliftment of many Asian and Central Asian countries. Even today, despite the onslaught of manmade fibers, silk continues to reign supreme as "Queen of Textiles'' (Anonums 2013). The productivity and quality of silk produced in India need further improvement and silkworm breeds/ hybrids have to contribute so significantly that it becomes the world leader. The limitations in achieving the goal are varied agro climatic conditions of the country which spells the need for identification of different season and region specific silkworm races /hybrids. Further, the silk reeling industry is very diverse employing traditional and primitive appliances like charkha to produce silk yarn for the handlooms and also the modern multi end reeling machines. These reeling appliances require various graded qualities of cocoons to meet the purpose which means that different silkworm breeds/hybrids are required to produce cocoons for charkha and multi end reeling machines. The mulberry silk production in India is mainly concentrated in the states of Karnataka, West Bengal, Andhra Pradesh, Tamil Nadu and Jammu and Kashmir. Presently the mulberry silkworm in India has several races/ hybrids having distinct nutritional, developmental and cocoon characteristics. The races/ hybrids of silkworm are known not only for their significant differences in the yield and quality characters of silk but also for the response of the silkworms to physical environment and food quality [8, 4] observed that the cocoon productivity is dependent on multiple factors mulberry leaf quality (38.2%), climate (37%), silkworm rearing technique (9.3%) silkworm race/hybrids (4.2%), silkworm eggs (3.1%) and other factors (8.2%). Evidently two factors that affect the successful cocoon crop production are environment and leaf quality, contributing around 75.2 percent. The relationship between the environment and genes varies depending on the genetic background of the silkworm [5]. Some crosses between genetically dissimilar parents results in the production of F1's that are sturdier and vigorous than either of the parents. This superiority of F1 (in terms of yield or some other trait) over their parent may either be positive or negative in terms of hetrosis. Heterosis is the phenomenon of superiority or inferiority of F1's over the parent and hybrid vigour has been used as a synonym for F1offspring over the parents but heterosis includes other conditions as well. In the few cases where F_1 off spring are inferior to their parents and is regarded as hybrid vigour in a negative direction. For example: Short larval duration in silkworm is a desirable trait.

The state of Jammu and Kashmir presents an ideal environment for the growth and development of bivoltine silkworm and mulberry cultivation.

Sericulture has an important place in the economy of landless to marginal farmers of J&K with an annual turnover of 937MT cocoon production (Sericulture development department J&K Govt. 2016). The attempts to spread temperate silkworm strains throughout the sericulture belt of India results in crop failures especially during hot and humid seasons under rain fed conditions

2. Materials and Methods

The experimental research material for the proposed study comprised of nine bivoltine silkworm hybrids CSR2×PO3, CSR4 × PO1, CSR5 × SPO, KA × ND5, CC1 × U1, NSP × U1, JD6 × U6, U1 × NSP, U6 × ND3, (evolved at Division of Sericulture, SKUAST-J, Udheywalla) and the popular commercial hybrid CSR2 × CSR4 was also included in the study as a check.

The varieties studied are maintained in the germplasm of the Division of Sericulture, Udheywala, Jammu as bush plants at a distance of 1x1 m. The experiment was laid in Complete Randomized Block Design with three replicates. Each variety was taken as treatment and observations were recorded after 15 days interval up to 75th day after sprouting. The morphological and physical characters of the mulberry varieties were evaluated as under.

Following observations were made for different parameters of the larval stage:

2.1 Larval duration of each instar (D: H) It was recorded as the duration of larval age of each instar (I, II, III, IV and V) including moulting period in days and hours.

2.1.1 I age larval duration it was recorded as the larval duration from the day of brushing till the end of I moult and was calculated in days and hours.

2.1.2 II age larval duration it was recorded as the larval duration from the end of I moult till the end of II moult and was calculated in days and hours.

2.1.3 III age larval duration it was recorded as the larval duration from the end of II moult till the end of III moult and was calculated in days and hours.

2.1.4 IV age larval duration it was recorded as the larval duration from the resumption in IV age till the end of IV moult and was calculated in days and hours.

2.1.5 V age larval duration it was recorded as the larval duration from the end of IV moult till the pre-spinning stage and was calculated in days and hours.

2.2 Total Larval Period (D: H) it was recorded as the total duration of larval age of each instar (I, II, III, IV and V) excluding moulting period in days and hours.

2.3 Moulting duration of each instar (Hours) It was recorded as the duration of moulting of each instar (I, II, III and IV) in hours.

2.3.1 I age moulting duration. it was recorded as the duration from the time of feed stoppage of I instar till the resumption of feed from end of I moult and was calculated in hours.

2.3.2 II age moulting duration it was recorded as the duration from the time of feed stoppage of II instar till the resumption of feed from end of II moult and was calculated in hours.

2.3.3 III age moulting duration it was recorded as the duration from the time of feed stoppage of III instar till the resumption of feed from end of III moult and was calculated in hours.

2.3.4 IV age moulting duration it was recorded as the duration from the time of feed stoppage of IV instar till the resumption of feed from end of IV moult and was calculated in hours.

2.4 Total Moulting Period (Hours) it was recorded as an average of moulting duration in hours in each instar of each replicate.

2.5 Growth Rate (g) Growth rate explains the weight gain per day per gram of mean body weight during larval stages. The relative growth rate was calculated as:

$$\text{Growth Rate} = \frac{G}{TA}$$

Where,
G = Fresh weight gain of larvae during feeding period (g)
T = Duration of feeding period (days)
A = Mean fresh weight of larvae during the feeding period (g)

2.6 Weight gain (g) In order to work out the weight gain, ten randomly selected larvae were weighed daily at 9 am in the morning from beginning of the instar till the completion of each instar.

2.7 Weight of 10 mature larvae (g) ten mature larvae were picked randomly from each replicate from fourth to sixth day of final instar and weighed on digital balance. Maximum larval weight was recorded in each hybrid combination

The data presented in the thesis are the mean values. All the observations obtained for various parameters were tabulated and subjected to statistical analysis, following Analysis of Variance techniques. The results were tested for the treatments mean by applying F- test of significance (ANOVA) on the basis of null hypothesis as mentioned by [1].

3 Results

3.1 Larval Duration (Days: Hours) the observations were recorded for larval duration at each instar including moulting period (Table 3).

3.1.1 I instar larval duration (Days: Hours). Among different hybrids studied. I instar larval duration remained non-significant and was same (4:00) for all the hybrids. (Table 1).

Table 1: Performance of different bi × bi silkworm hybrids for larval instar (feeding) duration (days and hours)

Hybrid	Larval Duration (D:H)					
	1st Instar	2nd Instar	3rd Instar	4th Instar	5th Instar	Total
CSR2 x PO3	4	3	4.10	4.20	7.14	23.20
CSR4 x PO1	4	3	4.10	4.22	7.14	23.22
CSR5 X SPO	4	3	4.10	4.20	7.16	23.22
KA X ND5	4	3	4.10	4.21	7.15	23.22
CC1 x U1	4	3	4.16	4.20	7.04	23.16
NSP X U1	4	3	4.16	4.20	7.08	23.20
JD6 X U6	4	3	4.16	4.20	7.10	23.22
U1 X NSP	4	3	4.16	4.20	7.10	23.22
U6 X ND3	4	3	4.17	4.20	7.04	23.17
CSR2 X CSR4	4	3	4.10	4.20	7.14	23.20
CD5%	NS	NS	NS	NS	NS	NS

3.1.2 II Instar larval duration (Days: Hours). Among different hybrids studied, II instar larval duration remained non-significant and was same (3:00) for all the hybrids.

3.1.3 III Instar larval duration (Days: Hours). Among different hybrids studied, III instar larval duration remained non-significant. However, larval duration for III instar was found maximum in U6×ND3 (4:17) closely followed by CC1 × U1, NSP × U1, JD6 × U6 and U1 × NSP (4:16). It was found less in hybrids CSR2 × PO3, CSR4 × PO1, CSR5 × SPO, KA × ND5 and control CSR2 × CSR4 (4:10).

3.1.4 IV Instar larval duration (Days: Hours). Among different hybrids, IV instar larval duration again remained non-significant. However, larval duration for IV instar was found maximum in CSR4×PO1 (4:22)followed by KA × ND5 (4:21) and minimum in CSR2×PO3, CSR5×SPO, CC1×U1,NSP×U1, JD6×U6, U1×NSP, U6×ND3 and CSR2 × CSR4 (4:20).

3.1.5 V Instar larval duration (Days: Hours). Among different hybrid combinations studied, V instar larval duration again remained non-significant. However, larval duration for V instar was maximum in CSR5×SPO (7:16) followed by KA × ND5 (7:15) and CSR2 × PO3, CSR4 × PO1, and control hybrid CSR2 × CSR4 (7:14). It was found less in hybrids JD6 × U6, U1 × NSP (7:10) followed by NSP × U1 (7:08), CC1 × U1 and U6 × ND3 (7:04).

3.2 Total larval duration (Days: Hours). Among different hybrids studied, the total larval duration remained non-significant. The longest total larval life was found in CSR4×PO1, CSR5×SPO, KA×ND5, JD6×U6 and U1×NSP(23:22) followed by CSR2 × PO3, NSP × U1 and control CSR2 × CSR4 (23:20). Shortest larval life was observed in hybrids CC1 ×U1 (23:16).

3.3 Moulting Duration (Hours). The observations were recorded for the moulting duration at each instar (Table 2).

Table 2: Performance of different bi × bi silkworm hybrids for moulting period (hours)

Hybrid	Moult (Hours)				
	1st	2nd	3rd	4th	Total
CSR2 x PO3	24	23	24	30	101
CSR4 x PO1	24	23	24	29	100
CSR5 X SPO	24	23	24	28	99
KA X ND5	24	23	24	29	100
CC1 x U1	24	23	24	28	99
NSP X U1	24	23	24	26	97
JD6 X U6	24	21	24	25	94
U1 X NSP	24	22	24	26	96
U6 X ND3	24	22	24	28	98
CSR2 X CSR4	24	23	24	30	101
CD5%	NS	NS	NS	NS	NS

3.3.1 I instar moulting duration (Hours). Among different hybrids studied, I instar moulting duration remained non-significant and was same (24) for all the hybrids.

3.3.2 II Instar moulting duration (Hours). Among different hybrids, II instar moulting duration remained non-significant. However, moulting duration for II instar was found maximum in CSR2 × PO3, CSR4 × PO1, CSR5 × SPO, KA × ND5, CC1 × U1, NSP×U1andcontrol CSR2 × CSR4 (23) closely followed by U1 × NSP, U-6 × ND3 (22). It was found less in hybrid, JD6 ×U6 (21).

3.3.3 III Instar moulting duration (Hours). Among different hybrids studied, III instar moulting duration remained non-significant and was same (24) for all the hybrids.

3.3.4 IV Instar moulting duration (Hours). Among different hybrids, the IV instar moulting duration again remained non-significant. However, moulting duration for IV instar was found maximum in CSR2×PO3 and control CSR2×CSR4 (30) followed by CSR4 × PO1, KA × ND5 (29), CSR5 × SPO, CC1 × U1, U6 × ND3 (28) and was minimum in hybrid JD6 × U6 (25).

3.4 Total moulting duration (Hours). Among different hybrids studied, total moulting duration remained non-significant. The longest total moulting duration was found in CSR2 × PO3 and control CSR2 × CSR4 (101) closely followed by CSR4 × PO1, KA × ND5 (100) and CSR5×SPO, CC1×U1 (99). Shortest moulting duration was observed in hybrid JD6 × U6 (94).

3.5 Weight gain

3.5.1 IV Instar Weight gain for IV instar observed significant results for the hybrids studied and was significantly maximum in U6×ND3 (0.73) closely followed by control CSR2×CSR4 (0.72) and CSR5×SPO (0.70) and least in KA×ND5 (0.59). The other significant hybrids found for this parameter were JD6×U-6(0.69), CSR2×PO3 (0.68), NSP×U1 (0.67) CSR4×PO1 (0.63) and CC1× U-1 (0.61) respectively (Table 5). The results regarding E.I values for weight gain revealed that for IV instar hybrid U6×ND3 exhibited highest E.I. value of 62 followed by control CSR2 × CSR4 (60.00) and CSR5 × SPO (56.00). The minimum E.I. value of 34.00 was recorded in KA×ND5 (Table 3).

Table 3: Evaluation Index values of different bi × bi silkworm hybrids for larval characters.

Hybrid	Weight gain(g)		Average of weight gain	Growth rate(g)		Average of growth rate	Wt. of 10 mature larvae(g)
	4th Instar	5th Instar		4th Instar	5th Instar		
CSR2 x PO3	52.00	43.92	47.96	50.00	45.00	47.50	44.08
CSR4 x Po1	42.00	43.57	42.78	40.00	45.00	42.50	44.08
CSR5 X SPO	56.00	57.85	56.92	60.00	57.50	58.75	56.63
KA X ND5	34.00	52.85	43.42	30.00	52.50	41.25	51.94
CC1 x U1	38.00	44.28	41.14	40.00	45.00	42.50	40.60
NSP X U1	50.00	33.92	41.96	50.00	35.00	42.50	35.18
JD6 X U6	54.00	62.14	58.07	60.00	50.00	55.00	62.30
U1 X NSP	52.00	50.35	51.17	50.00	40.00	45.00	49.91
U6 X ND3	62.00	50.35	56.17	70.00	60.00	65.00	64.61
CSR2 X CSR4	60.00	50.71	55.35	60.00	50.00	55.00	50.44

3.5.2 V Instar

Weight gain for V instar observed significant results for the hybrids studied and was significantly maximum in JD6 × U6 (3.47) closely followed by U6 × ND3 (3.41) and CSR5 × SPO (3.35) and least in NSP×U1 (2.68). The other significant hybrids found for this parameter were KA × ND5 (3.21), CSR2 × CSR4 (3.15), U1 × NSP (3.14), CC1 × U1 (2.97), CSR2 × PO3 (2.96) and CSR4 × PO1 (2.95) respectively (Table5). The result regarding E.I values for V instar weight gain revealed that, hybrid JD6 × U6 exhibited the highest E.I. value of 62.14 followed by CSR5 × SPO (57.85) and KA × ND5 (52.85). The minimum E.I. value of 33.92 was recorded in hybrid NSP×U1 (Table 3).

The average E.I. value of hybrids for weight gain during IV and V instar ranged from 41.14 to 58.07. Five hybrid combinations viz., JD6 × U6, CSR5 × SPO, U6 × ND3, CSR2 × CSR4 (control) and U1 × NSP scored E.I. value > 50 for weight gain (Table 3).

3.6 Growth rate

3.6.1 IV Instar. Growth rate for IV instar observed significant results for the hybrids studied and was significantly maximum in U-6 × ND3 (0.18) closely followed by CSR5 × SPO, JD6 × U-6, CSR2 × CSR4 (0.17), CSR2 × PO3, NSP × U1, U1 × NSP (0.16) and least in KA × ND5 (0.14). The other significant hybrids found for this parameter were CSR4 × PO1 (0.15) and CC1 × U-1 (0.15) respectively (Table5). The results regarding E.I values for growth rate revealed that for IV instar hybrid U6 × ND3 exhibited the highest E.I. value of 70 followed by control CSR5 × SPO, JD6 × U6 and control hybrid CSR2 × CSR4 (60.00). The minimum E.I. value of 30 was recorded in KA × ND5 (Table 3).

3.6.2 V Instar. The growth rate for V instar observed significant results for the hybrids studied and was significantly maximum in JD6 × U6 (0.49) closely followed by U6 × ND3 (0.48) and CSR5 × SPO (0.47) and least in NSP × U-1 (0.38). The other significant hybrids found for this parameter were KA × ND5 (0.45), U-1 × NSP and control CSR2 × CSR4 (0.44) while as hybrids CSR2 × PO3, CSR4 × PO1 and CC1 × U1 recorded (0.42) respectively (Table 5). The results regarding E.I values for growth rate revealed that for V instar hybrid U-6 × ND3 exhibited highest E.I. value of 60 followed by CSR5 × SPO (57.50) and KA × ND5 (52.50) the control hybrid CSR2×CSR4 remains at 50.. The minimum E.I. value of 35.00 was recorded in NSP × U1 (Table 3).

The average E.I. value of hybrids for growth rate during IV and V instar ranged from 41.25 to 65.00. Four hybrid combinations viz., U6 × ND3, CSR5 × SPO, JD6 × U6 and CSR2 × CSR4 (control) scored E.I. value > 50 for growth rate (Table 3).

3.7 Weight of 10 mature larvae

Weight of 10 mature larvae is a cocoon and a shell contributing parameter. Weight of 10 mature larvae observed significant results for the hybrids studied.It was significantly maximum in JD6×U6 (44.83) followed by U6 × ND3 (44.26) and CSR5 × SPO (42.86) and the minimum in NSP ×U-1 (37.56). The other significant hybrids found for this parameter were KA × ND5 (41.70), control CSR2 × CSR4 (41.33), U1 × NSP (41.20), CSR2 × PO3, CSR4 × PO1 (39.76) and CC1 × U-1 (38.90) respectively (Table 5). The results regarding E.I values for weight of 10 mature larvae, exhibited highest E.I. value of 64.61 for U6 × ND3 followed by JD6 × U6 (62.30) and CSR5 × SPO (56.63). The minimum E.I. value of 35.18 was recorded in NSP× U1 (Table 3).

4. Dissuasion

Larval stage influence rearing duration, labour input and leaf consumption and are directly related to the cost of production and silk productivity. In the present study, total larval duration did not exhibit significant differences among the hybrids studied. Significant decrease in larval duration which is a desirable character, for per se performance was observed for hybrids CC1 x U1 followed by U6 X ND3, CSR2 x PO3,NSP X U1 and CSR2×CSR4. The reduced larval duration may be attributed to the better nutritional value given to the hybrid. In this study, decreased moulting period was again found to be non- significant among hybrids studied. It was shorter for hybrid JD6 X U6 followed by U1 X NSP and NSP X U1. In hybrids, the robustness of larval characters got reflected in uniform growth and moulting. Less larval and moulting duration indicates less intake of mulberry leaf and is considered to possess greater economic value [16]. It also supports the concept of genetic homeostasis [9] i.e. heterozygous population is less influenced by the environmental factors than the homozygous population. Longer larval duration in hybrids studied may be due to slow growth and reduced rate of metabolism due to associated environmental conditions [10]. Fluctuations observed in larval duration in various breeds and hybrids can be interpreted to the variable level of heterozygosity attained at some loci as observed by [18, 7] observed that the increase in larval duration in silkworm from 3 to 24 hr a day resulted in decrease in consumption rate, assimilation rate and metabolic rate but an increase in conversion rate and gross net conversion efficiencies. The results are in accordance with the findings of [13, 11, 8]. Silkworms being voracious eaters of mulberry during its larval stages and around 80 percent leaf are consumed in the last two instars [4]. Highlighting the importance of food intake [6] reported that for the production of 1 g larval dry weight, requirement of ingestion and digestion of food is 4.2 mg and 1.8 mg respectively. In the present study, weight gain was significant among the hybrids studied during IV and V instar. In IV instar, U6 X ND3 recorded highest weight gain for the worms followed by CSR2 X CSR4 and CSR5 X SPO, whereas; in V instar JD6 X U6 recorded a highest weight gain followed by U6 X ND3 and CSR5 X SPO. This variation might be due to the biochemical constituents of mulberry varieties fed, which play a major role in body weight gain of silkworm. The results are in accordance with the findings of [3, 14]. Growth rate exhibited significant differences between the hybrids studied for IV and V instar. In the IV instar, hybrid U6 X ND3 recorded the highest growth rate followed by CSR5 X SPO, JD6 X U6, CSR2 X CSR4 (control) and CSR2 x PO3, NSP X U1, U1 X NSP. In the V instar, hybrid JD6 X U6 exhibited highest growth rate followed by U6 X ND3 and CSR5 X SPO. This suggests that worms were robust and were having lower ingestion and consumption index or it might be due to shorter larval duration [15]. Similar were the findings of [2, 14]. The intake of food during total larval life is also reflected by the weight of 10 mature larvae. The maximum weight of the larvae indicates the robustness of particular breed/hybrids. In the present study, different hybrids exhibited significant difference for weight of 10 mature larvae. Hybrid U6×ND3 depicted significantly higher value closely followed by JD6×U6 and CSR5 X SPO. This may be attributed to higher consumption of mulberry leaves and prolonged larval duration with higher digestibility of food leading to higher weight gain during V instar. The present study revealed that the bivoltine worms which consumed more mulberry leaves attain robust growth resulting into higher larval weight, cocoon weight, shell weight and raw silk production. [19] Reported a positive correlation between food ingestion and weight of mature larvae. The present results are in close conformity with those reported by [11, 17].

5. Conclusion

From cumulative analysis of six commercial economic traits two hybrids viz.U6×ND3 (EI 59.20) and CSR4×PO_1 (EI 54.59) were found heterotic, crossing the bench mark of 51.10 scored by the check hybrid CSR2×CSR4. On the basis of six dynamic characters viz. larval duration, moulting duration, total moulting Period, growth rate, weight gain and weight of 10 mature larvae hybrid U6×ND3 and JD6×U6 were found to be potential crosses and can be recommended for field utilization after multi locational traits at farmers level.

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