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Expression of crop yield attributes of promising bivoltine hybrids of silkworm, *Bombyx mori* L

Monika Attri, RK Gupta and Kamlesh Bali

Abstract
The nature of performance of any silkworm hybrid depends on various aspects but most importantly on the climatic conditions prevailing in a particular area. Thus, the need of identification and evaluation of region and season specific hybrids attracts the attention of silkworm researchers. The present investigation was undertaken to assess the performance of indigenous silkworm hybrids on various important economic traits for their evaluation as potential bivoltine hybrids suitable for subtropical conditions of Jammu Division. Among twelve selected hybrids, FC1×FC2, PO3×ND5, U-3×U-1, U-4×U-6, JD6× U6, ND3x NSP have been recognized as superior bivoltine hybrids in term of various commercial parameters. Additionally, the silkworm hybrid FC1×FC2 exhibited maximum total filament length of 1029 meters followed by PO3×ND5 and U-4×U-6 (969, 961 and 933 mts resp.) and filament size FC1×FC2 followed by U-3×U-1 (2.50 and 2.55) which proves the economic viability of these hybrids. Therefore, the current findings will provide an insight to the future aspects of silkworm breeding for development of region and season specific hybrids with improved qualitative and quantitative characters.

Keywords: Silkworm hybrids, developmental traits, cocoon yield

Introduction
Sericulture is one of the important agro-based, economy generating industry as it contributes great economy to the country and also offers great opportunities to the farming community including women and the farmers with small land holdings in the rural areas for their livelihood (Trivedi and Sarkar, 2015) [24]. Silk is a multifunctional material both for textile and non-textile uses and is as precious as gold due to its excellent and attractive properties including graceful luster, rich dyeing capacity, moderate elasticity as well as elegancy in wear ability (Tsukada, 2005) [25]. In silkworm, the biology and cocoon character are greatly influenced by the temperature, humidity, silkworm hybrids (Rajesh *et al.*, 2010) [14] and influence of season on the performance silkworm breeds/hybrids are prominent which may affect the genotypic expression which in turn affects the phenotypic expression including cocoon weight, shell weight, shell ratio etc. of the silkworm (Nacheva *et al.*, 1989) [10]. In India, the requirement and production of silk is increasing day by day with time and total production of silk accounts 35,468 MT whereas, the raw silk production in J&K was recorded to be about 16 MT of raw silk during 2019-2020 (Anonymous, 2020) [1] which is low when compared to other advanced states of the country, urgent attention needed to be taken for strengthening the progress of sericulture industry in J&K so as to achieve the target unit production of silk. Contribution of multivoltine hybrids is comparatively more than bivoltine hybrids but mostly multi×bivoltine hybrids are reared in tropical areas and the silk produced by these hybrids are not so superior and cannot be sold in the international market whereas only bivoltine hybrids can meets the international standards. Thus, considering the demand of high quality bivoltine silk in national and global silk market, double hybrids have been evolved by Central Sericulture Research and Training Institute, Mysore, which were recorded to yield good results when provided with adequate leaf supply, rearing space and improved rearing technologies. However, these double hybrids continue to suffer due to poor maintenance of recommended rearing practices and is the most common problem with the small and marginal farmers of Jammu and Kashmir. The main aim of this study was to adjudicate the potential or promising bivoltine silkworm hybrids by the comparative evaluation of the bivoltine single hybrids with double hybrid (check) for commercial exploitation to increase the bivoltine cocoon productivity in the region.

Materials and Methods

The present investigation was performed to identify potential bivoltine silkworm hybrids suitable for rearing under subtropical conditions of Jammu Division of Jammu and Kashmir. For identification, ten indigenous bivoltine silkworm single hybrids were evolved at Division of Sericulture, SKUAST-Jammu namely U-8×PO1, ND3×PO1, PO1×U-8, U-3×U-1, JD6×U-6, U-4×U-6, PO3×ND5, U-6×ND3, ND3×NSP, ND2×NSP along with one single cross hybrid SH6×NB4D2 and one double cross hybrid namely FC1×FC2 as check from Regional Sericulture Research Station (RSRS), Dehradun were selected and reared as per standard rearing techniques as recommended by Krishnaswami (1978) [9] and Dandin *et al.*, (2003) [4] under Completely Randomized Design (CRD) with three replications each. In order to maintain hygienic conditions, incubation room, rearing room and rearing appliances were disinfected by Sanitech.

All the selected hybrids were evaluated for sixteen different commercial parameters. For egg parameter, fecundity was calculated by counting total number of eggs laid by a single mother moth whereas hatching and brushing percent was calculated by taking into consideration the ratio between the average number of eggs hatched and brushed and total number of eggs laid by moth. For larval parameters, larval duration was calculated by measuring the time taken by larval feeding from Ist instar to Vth instar in days as well as in hours and larval weight was taken by randomly selecting ten mature larvae of all selected hybrids and weighed whereas larval survivability was observed by calculating the ratio between number of larvae survive at pre-spinning stage and total number of larvae retained after third moult. Different cocoon parameters were calculated by using suitable formula which are represented as follows:

Cocoon yield by weight (kg)

$$\text{By weight} = \frac{\text{Cocoon yield in kg}}{\text{Total number of larvae retained after III moult}} \times 10{,}000$$

Cocoon yield by number:

$$\text{By number} = \frac{\text{Cocoon yield by number}}{\text{Total number of larvae retained after III moult}} \times 10{,}000$$

Pupation per cent:

$$\frac{\text{Number of live pupae in harvested cocoon}}{\text{Total number of larvae retained after III moult}} \times 100$$

Good cocoon per cent:

$$\frac{\text{Number of good cocoons harvested}}{\text{Total number of larvae retained after III moult}} \times 100$$

To determine the average cocoon weight for single cocoon weight (g) twenty-five male and twenty-five female cocoons were randomly selected and the same cocoon shells were used to determine average single shell weight and shell ratio from each replicate and weighed by using the following formulae:

$$\text{Single cocoon weight} = \frac{\text{Weight of 25 male(g)} + \text{25 female cocoon (g)}}{50}$$

$$\text{Single shell weight} = \frac{\text{Weight of 25 male(g)} + \text{25 female cocoon shells (g)}}{50}$$

$$\text{Shell ratio} = \frac{\text{Average weight (g)of 25 cocoon shells of each sex}}{\text{Average weight of same no. of cocoons of each sex}} \times 100$$

For post cocoon assessment, cocoons were stifled in hot air oven at 90- 60 ^{0}C for six hours and different post cocoon parameters were executed at Demonstration Cum Technical Service Centre (DC &TSC) of Central Silk Board, Miran Sahib, Jammu. In order to estimate the significant difference, the data thus generated was subjected to analysis of variance techniques by using statistical package (SPSS 16.0) and differences between means were tested by using Tukey's HSD (P<0.05).

Results

Silkworm hybrids plays most influential factor in the development of sericulture industry. J&K has different agro-climatic conditions as compared to the different parts of the country and it requires special diligence to develop and evaluate specific hybrids suitable for J&K. In above context an attempt was made to study the performance of all the selected single hybrids along with double hybrid and the experimental results of all the selected hybrids for different parameters are presented in Table 1, 2 and 3, Fig. 1&2. Fecundity, the egg laying capacity which denotes the productivity from industrial aspects was reported to be highest in silkworm hybrid FC1×FC2 as 595 eggs followed by PO3×ND5 as 589 eggs while lowest in ND3×PO1 as 478 eggs. The data also reveals that the maximum hatching and brushing percentage was noticed in FC1×FC2 as 96.11 and 94.89 per cent followed by PO3×ND5 as 95.07 and 93.46 per cent and minimum in SH6×NB4D2 as 90.2 and 87.92 per cent (Table 1). Larval duration of first instar was observed to be shorter in FC1×FC2 and U-3×U-1 as 4 days. Similarly, FC1×FC2 and JD6×U-6 (3 days) in second instar, U-8×PO1 (4.08±0.01) followed by U-3×U-1 (4.09±0.01) in third instar, FC1×FC2 (5.06±0.02) followed by PO3×ND5 (5.09±0.01) and U-3×U-1 (5.09±0.01) in fourth instar, PO3×ND5 (6.22±0.01) and FC1×FC2 (6.23±0.02) in fifth instar. Above all the hybrid FC1×FC2 (23.18±0.02) and PO3×ND5 (24.03±0.04) depicted superiority in terms of total larval duration. FC1×FC2 again surpassed all the selected hybrids with respect to weight of 10 mature larvae and larval survival percent (Fig.1), as 42.29±1.27g and 96.28±0.16 per cent followed by PO3×ND5 (41.85±0.85and 95.71±0.35) while minimum for the hybrid ND3×PO1 as 31.95±0.59g and 82.57±0.32 per cent.

Cocoon yield per 10000 larvae by weight and by number among the hybrids tested and highest values were recorded in FC1×FC2 (16.19±0.04 and 8657±5.55) followed by U-3×U-1 (15.59±0.65 and 8600± 1.36) and least in SH6×NB4D2 (12.33±0.69 and 7771±1.74). The highest pupation rate was observed in hybrid FC1×FC2 (94.86±1.24) followed by PO3×ND5 (93.71±0.45) in comparison to hybrids ND3×PO1 (81.43±1.31) and SH6×NB4D2 (84.28±1.46) having lowest rate. The weight of single cocoon and single shell weight was observed higher in hybrids FC1×FC2 (1.87±0.05and 0.41±0.01), U-3×U-1 (1.82±0.03 and 0.38±0.01) while the lower was observed in hybrid U-8×PO1 (1.61±0.02 and 0.25±0.02) whereas, the highest shell ratio per cent was obtained in hybrids FC1×FC2 (23.2±0.86), U-4×U-6 (23.11±0.26) while the lowest was obtained in hybrid ND3×PO1 (17.62±1.02). The maximum percentage of good cocoons was recorded in FC1×FC2 as 85.71 per cent followed by U-3×U-1 with 85.14 per cent and minimum in

SH6×NB4D2 as 74.85 per cent and U-8×PO1 74.93 per cent. On the same hand, maximum total filament length was recorded in FC1×FC2 as 1029.00±15.13 meters followed by U-3×U-1 (969.00±5.85) and minimum in ND3×PO1 (715.00±4.04) whereas, the finest silk filament was observed in silkworm hybrid FC1×FC2 (2.50±0.05) followed by U-3×U-1 (2.55±0.08) as represented in Fig. 2.

Table 1: Performance of bivoltine silkworm hybrids for different egg traits

Hybrid	Fecundity*	Hatching%*	Brushing%*
U-8×PO1	495±8.50abc	90.5±1.46a	88±0.57ab
ND3×PO1	478±21.45a	90.03±0.51a	85.66±0.67a
PO1×U-8	539±5.50bcd	91.11±0.43ab	88.33±0.33ab
U-3×U-1	569±12.34de	94.96±0.57cd	90.14±0.56bc
JD6×U-6	558±10.26de	94.82±0.41cd	90±0.58b
U-4×U-6	570±5.85de	94.21±0.40bcd	91±0.58bcd
PO3×ND5	589±4.61de	95.07±0.46cd	93.46±0.31cd
U-6×ND3	547±10.14cd	92.23±0.96abc	88.79±1.09ab
ND3×NSP	553±6.08cd	94.25±0.03bcd	89.49±0.83b
ND2×NSP	551±11.50cd	93.92±0.47bcd	89.16±0.61b
SH6×NB4D2	483±18.03ab	90.2±0.75a	87.92±0.58ab
FC1×FC2	595±9.07e	96.11±0.44d	94.89±0.84d

*Values are Means ± SE
Means within a column followed by different letters are significantly different at $P<0.01$

Table 2: Performance of bivoltine silkworm hybrids for different larval trait {Days: Hours (D:H)}

Hybrid	Ist Instar* (D:H)	IInd Instar* (D:H)	IIIrd Instar* (D:H)	IVth Instar* (D:H)	Vth Instar* (D:H)	Total Larval Duration* (D:H)
U-8×PO1	4.09±0.00bc	3.16±0.03e	4.08±0.01a	5.11±0.01abc	7.13±0.01bc	25.09±0.05bc
ND3×PO1	4.12±0.03c	3.11±0.01de	4.15±0.01ab	5.19±0.01c	7.2±0.01cd	25.21±0.05d
PO1×U-8	4.06±0.01abc	3.09±0.01cde	4.13±0.01ab	5.14±0.01abc	7.11±0.01b	24.23±0.01b
U-3×U-1	4±0.00a	3.08±0.01bcd	4.09±0.01a	5.09±0.01ab	7.15±0.02bc	24.17±0.02b
JD6×U-6	4.02±0.01ab	3±0.00ab	4.12±0.02ab	5.16±0.01bc	7.13±0.01bc	24.19±0.04b
U-4×U-6	4.05±0.01abc	3.03±0.01abc	4.1±0.03ab	5.1±0.01ab	7.1±0.00b	24.14±0.03b
PO3×ND5	4.01±0.00a	3±0.00a	4.19±0.01b	5.09±0.01ab	6.22±0.01a	24.03±0.04a
U-6×ND3	4.05±0.02abc	3.09±0.01cde	4.12±0.01ab	5.13±0.01abc	7.13±0.01bc	25.04±0.02b
ND3×NSP	4.07±0.01abc	3.08±0.01bcd	4.09±0.01a	5.1±0.00ab	7.11±0.01b	24.21±0.03b
ND2×NSP	4.03±0.01bc	3.12±0.01de	4.14±0.01ab	5.12±0.00abc	7.08±0.02b	25.01±0.03b
SH6×NB4D2	4.11±0.01c	3.13±0.01de	4.18±0.01b	5.1±0.02ab	7.21±0.01d	25.1±0.03cd
FC1×FC2	4±0.00a	3±0.00a	4.13±0.01ab	5.06±0.02a	6.23±0.02a	23.18±0.02a

*Values are Means ± SE
Means within a column followed by different letters are significantly different at $P<0.01$

Table 3: Performance of different silkworm hybrids for cocoon traits

Hybrid	Cocoon yield per 10,000 larvae		Pupation* %	Good cocoon* (%)	Flimsy cocoon* (%)	Double cocoon* (%)	Single cocoon weight* (g.)	Single shell weight* (g.)	Shell ratio* %
	By wt.* (kg)	By No.*							
U-8×PO1	12.51±0.52a	7875± 3.23ab	87.43±1.08bc	74.93± 2.11a	4.67 ± 0.27de	2.39 ± 0.14bcd	1.61±0.02ab	0.25±0.02a	18.49±0.64ab
ND3×PO1	12.37±0.24a	7828± 1.54ab	81.43±1.31a	75.04 ± 0.84a	4.92 ± 0.22e	2.67 ±0 .12cd	1.62±0.03ab	0.29±0.01ab	17.62±1.02a
PO1×U-8	12.92±0.39a	7850± 4.95ab	88.86±1.08bc	76.24 ± 0.61ab	4.33 ± 0.60cde	2.45 ± 0.36cd	1.64±0.01abc	0.28±0.03ab	18.59±0.53ab
U-3×U-1	15.59±0.65cd	8600± 1.36d	91.71±0.59cd	85.14 ± 0.22e	2.00 ± 0.09a	1.71 ± 0.31abc	1.82±0.03de	0.38±0.01ab	21±1.32abc
JD6×U-6	13.49±0.44abc	8228±2.93c	90±1.03bcd	80.86 ± 0.09d	3.81 ± 0.39cde	1.45 ± 0.17ab	1.68±0.01abcd	0.30±0.01ab	20.45±1.67abc
U-4×U-6	14.84±0.18bcd	8542±3.03d	92±1.78cd	84.29 ± 0.22e	2.32 ± 0.19ab	1.37 ± 0.25a	1.78±0.03e	0.36±0.02ab	23.11±0.26c
PO3×ND5	15.24±0.41bcd	8572±1.55d	93.71±0.45d	84.85 ± 0.27e	2.31 ± 0.18ab	1.00 ± 0.08a	1.79±0.03cde	0.37±0.02ab	22.65±0.60bc
U-6×ND3	13.08±0.39ab	7914±1.83ab	89.14±0.87bcd	75.08 ± 1.35a	3.56 ± 0.19cd	2.34 ± 0.13bcd	1.63±0.03abc	0.29±0.02ab	19.63±0.49abc
ND3×NSP	13.47±0.47abc	8142±2.56c	90±0.91bcd	80.00 ± 0.15cd	3.27 ± 0.19bc	2.64 ± 0.20cd	1.76±0.03bcde	0.31±0.01ab	20.19±0.44abc
ND2×NSP	13.28±0.21ab	7971±3.45b	89.71±1.19bcd	78.00 ± 1.35bc	3.78 ± 0.24cde	2.50 ± 0.19cd	1.69±0.04abcd	0.31±0.02ab	19.68±0.39abc
SH6×NB4D2	12.33±0.69a	7771±1.74a	84.28±1.46ab	74.85 ± 0.30a	5.00 ± 0.15e	2.86 ± 0.10d	1.59±0.01a	0.29±0.03ab	17.94±0.61a
FC1×FC2	16.19±0.04d	8657±5.55d	94.86±1.24d	85.71 ± 0.24e	1.71 ± 0.15a	0.86 ± 0.19a	1.87±0.05e	0.41±0.01b	23.2±0.86c

* Values are Means ± SE
Means within a column followed by different letters are significantly different at $P<0.01$

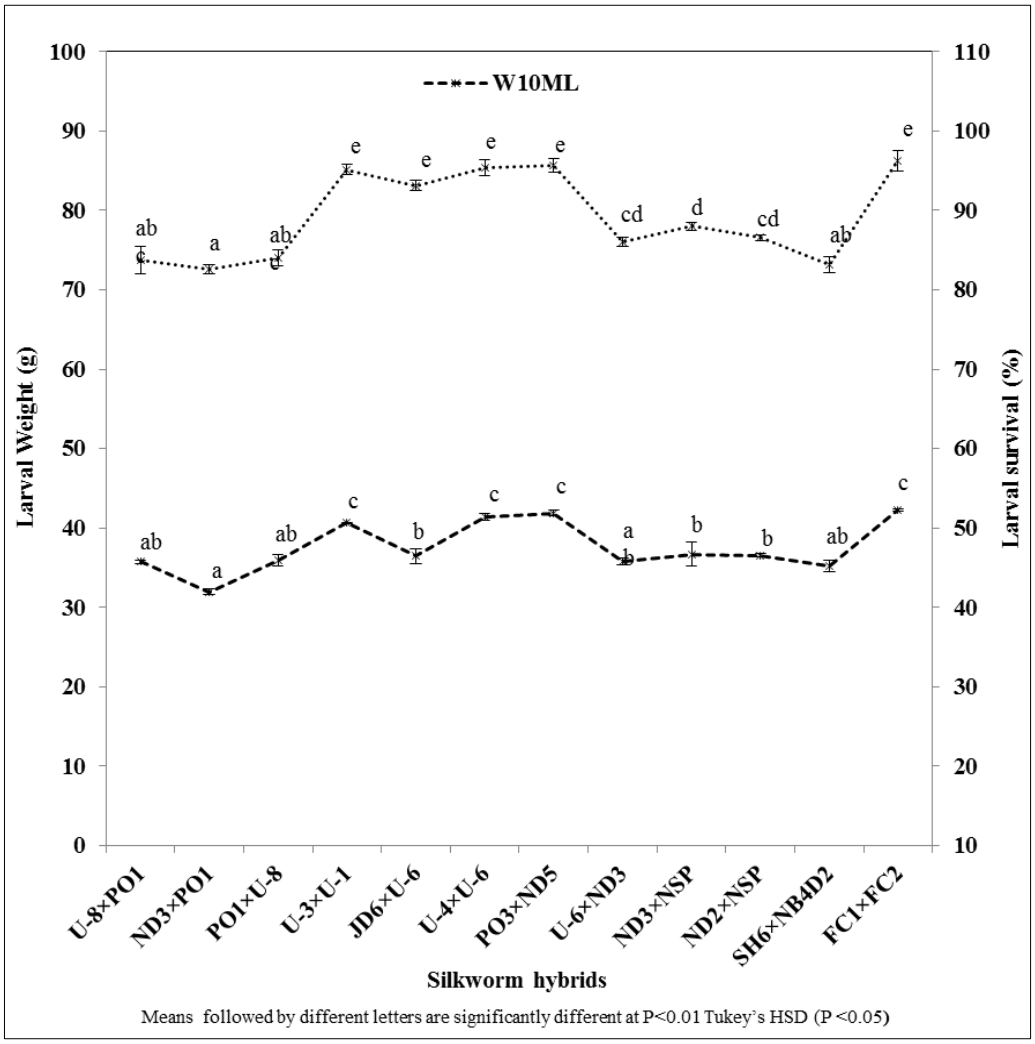

Fig 1: Developmental traits of selected bivoltine silkworm hybrids

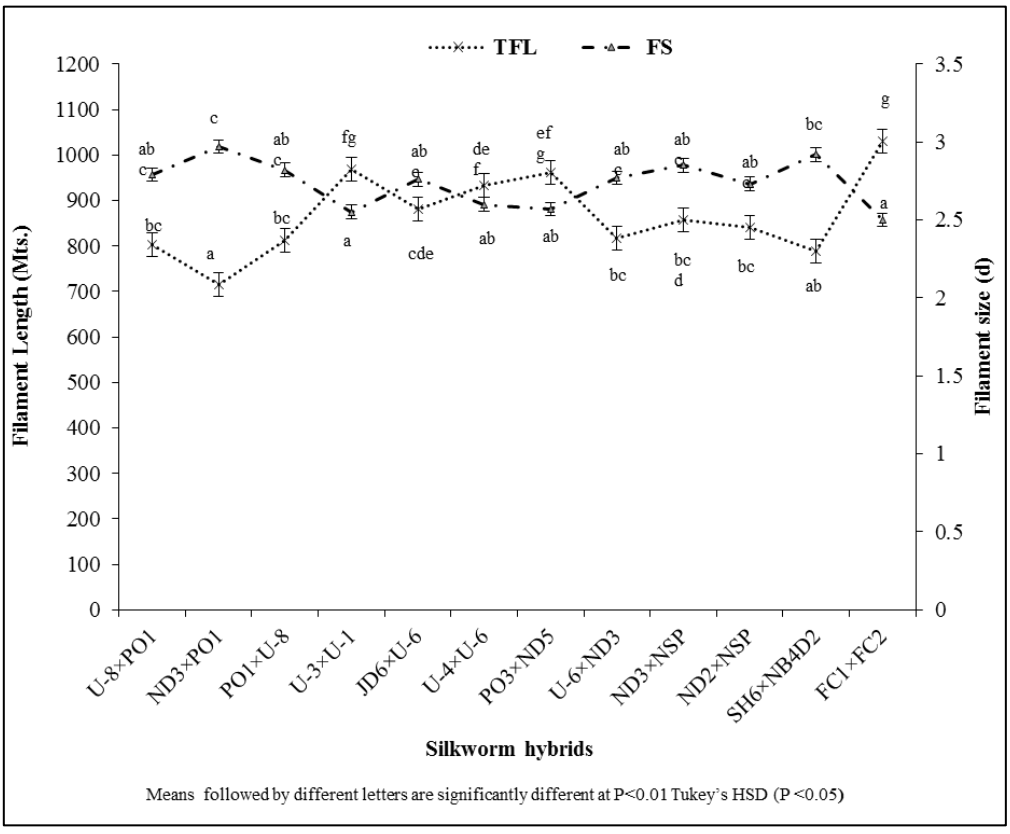

Fig 2: Post cocoon traits of different bivoltine silkworm hybrids

Discussion

The primitive aim of any breeding programme is to develop and identify new promising hybrids for commercial exploitation based on consistent performance under desired environmental conditions and from breeding point of view fecundity plays vital role because it denotes the efficacy of any silkworm hybrid to be selected as a parental breed for grainage purpose. In current study fecundity in case of hybrid FC1×FC2 was recorded to be highest as 595±9.07 followed by PO3×ND5 (589±4.61) and minimum in ND3×PO1 (478±21.45). Hatching percentage is another commercial trait for validation of any hybrid and the present study revealed FC1×FC2 to exhibit maximum hatching percentage of about 96 per cent followed by PO3×ND5 (95.07±0.46), U-3×U-1 (94.96±0.57). Ram *et al.* (2006) [15], Rao *et al*. (2006) [17], Gadgala and Singh (2015) [5], Buhroo *et al.* (2016a and 2016b) [2-3] earlier also have found the similar results depicting the superiority of hybrid combinations for commercial rearing of silkworm under climatic conditions of Jammu. In silkworm *Bombyx mori* L. the duration of larval period although a genetic character is influenced by a variety of factors including macro and micro-environmental conditions and rearing skills of the rearer. In current study 12 bivoltine silkworm hybrids depicted significant variation in duration of the larval period at every instar and in total larval period too. This can be attributed to the responsiveness of each hybrid to the rearing practices and in-vitro conditions maintained during the rearing period. The results depicted more or less coherence with that of the results presented by Ilyas *et al.* (2013) [7] and Panday *et al*. (2012) showing superiority of control hybrid RSJ3xRSJ1 against SH6xNB4D2 under sub-tropical climatic conditions in Jammu & Kashmir.

The mean values for maximum larval weight and highest larval survival percentage were observed in silkworm hybrid FC1×FC2 followed by PO3×ND5 and U-4×U-6 (42.29±1.72 and 96.28±0.16) (41.85±0.85 and 95.71±0.35) and (41.36±1.00 and 95.42±0.38) respectively. The results showed that larval parameters varied among the hybrids which revealed coherence with the earlier reports of Singh *et al.* (2016) [23], Sajgotra *et al.* (2017b) [22] and Raghuvanshi and Bali (2020) [13]. Neelaboina *et al.* (2019a) [11] reported the superiority of FC1×FC2 for larval characters which lies in close conformity with the present record. Among the selected hybrids, FC1×FC2, PO3×ND5 and U-4×U-6 were recorded to exhibit highest pupation rate of above 90 per cent and least in ND3×PO1 as 81.43 per cent. The current findings are strongly supported by the results presented by Jaiswal *et al.* (2003) [8] with some selected hybrids and Rayar (2010 and 2011), Gadgala and Singh (2015) [5] and Sajgotra *et al*. (2016) [20]. Single cocoon weight was observed to be significantly high in FC1×FC2 (1.87±0.05) followed by U-3×U-1 (1.82±0.03) and minimum in U-8×PO1, ND3×PO1 and U-6×ND3. Results and values of cocoon characters including single cocoon weight, single shell weight and shell ratio were found to be in accordance with that of Sajgotra *et al*. (2017a and 2017b) [21-22] with more or less same hybrid stock.

Additionally, the silkworm hybrid FC1×FC2 exhibited finest denier (2.50d) with maximum total filament length of 1029 meters followed by PO3×ND5 and U-4×U-6 (969, 961 and 933 mts resp.). Similar studies have been conducted by Buhroo *et al.* (2016b) [3] on various post cocoon parameters of some selected hybrids and reported significantly higher estimates of all the parameters in case of spring rearing, which supports the present findings of this study.

Conclusion

From the present study, it has been concluded that double hybrid FC1×FC2 showed higher cocoon yield as well as developmental characters *viz*., fecundity, larval duration, larvae survival per cent and post cocoon parameters along with single hybrids, PO3×ND5, U-3×U-1, U-4×U-6, JD6×U6, ND3×NSP have been recognized as superior hybrids, both in quality as well as in quantity parameters and these identified potential single hybrids provides an idea for the future selection of promising parental material for breeding of new silkworm hybrids with improved qualitative and quantitative characters for commercial exploitation.

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