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Evaluation of indigenous and introduced bivoltine silkworm hybrids

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Abstract
The present investigation was carried out to evaluate thirty-one silkworm bivoltine hybrids including control by involving full diallel set of six bivoltine breeds (ND_2, ND_3, NSP, U_1, CSR_2 and JD_6) in a complete randomized design (CRD) along with ruling bivoltine hybrid, $CSR_2 \times CSR_4$. Thirty-one treatments including control were replicated thrice with 200 worms per replicate post IIIrd moult. Observations were made on fifteen economically important traits namely; fecundity, hatching percentage, brushing percentage, weight of 10 mature larvae, larval survival, cocoon yield per 10,000 larvae (by weight and by number), good cocoon, pupation, single cocoon weight, single shell weight, shell ratio, total filament length, non-breakable filament length and filament size. Based on the cumulative E.I. values for fifteen commercial characters, ranking of hybrids was conducted and eight hybrids viz. $ND_2 \times CSR_2$, $ND_2 \times$ NSP, $ND_3 \times$ NSP, $ND_2 \times ND_3$, $ND_3 \times CSR_2$, NSP $\times JD_6$, $ND_3 \times$ JD6 and NSP $\times CSR_2$ qualified E.I. value > 50. Three hybrids viz., ND2 × CSR2 ranked 1st (55.53) followed by $ND_3 \times$ NSP (55.33) and $ND_2 \times$ NSP (53.93) are recommended as promising and heterotic hybrids to be exploited at commercial level after multi location trials.

Keywords: *Bombyx mori* l., bi × bi hybrids, evaluation index

1. Introduction

Silk is the most elegant textile in the world with unparalleled grandeur, natural sheen and inherent affinity for dyes, high absorbance, light weight, soft touch and high durability and known as the "Queen of Textiles" the world over. Sericulture is rearing of silkworm for the production of cocoons which is the raw material for the production of silk (Kamili *et al.*, 2000) [10]. Sericulture industry provides employment to approximately 8 million persons in rural and semi-urban areas in India (Masrat and Tripathi, 2017) [19]. The bivoltine cocoons are superior in comparison to multivoltine with higher silk content, longer filament, higher neatness, cleanness, low boil off loss ratio, higher tensile strength and less variation in evenness (Dandin *et al*., 2003) [1]. India is now on the threshold of further vitalizing the silk industry focusing attention on to realize the dream of producing large quantity of bivoltine silk. Dandin *et al.* (2006) [2] emphasized the necessity of developing and popularizing the location specific silkworm breeds/hybrids to suit to the varied agro-climatic conditions prevailing in India and this could be accomplished by mobilization of genetic resources across the institutes and through the combining ability studies of breeds evolved in different institutes.

The state of Jammu and Kashmir with diverse climatic conditions *viz.*, sub-tropical in Jammu plains, warm temperate in Jammu hills and temperate in Kashmir valley makes it ideally suitable to rear bivoltine races for the production of quality bivoltine silk. From time to time, various bivoltine silkworm hybrids evolved by the southern states of the country have been recommended by 'Central Silk Board' for commercial exploitation (Rajalakshmi *et al.*, 1998) [23] and have been tried in J&K state also but the performance at state level has not yielded much results. The required goal of increasing the bivoltine cocoon productivity in the quickest possible time frame can be achieved through identification of heterotic season and region specific bivoltine hybrids. The northern states of India, such as Jammu & Kashmir, Himachal Pradesh, Uttra khand and some pockets of Punjab assumes special significance due to its salubrious climate congenial for rearing of bivoltine silkworms and these states has observed an increasing trend in cocoon production and has a high potential for bivoltine sericulture activities (Datta *et al*., 2001) [3]. The state produces quality bivoltine cocoons for the production of silk yarn and has the potential to increase the raw silk provided locally developed region and season specific hybrids are commercially exploited. Considering the economic importance of silkworm rearing as an employment and income generating activity, therefore, the present investigation was aimed to develop and evaluate indigenous silkworm hybrids for springsea season that can results in better yield, adaptability and quality for successful commercial exploitation of bivoltine crop.

2. Methodology

The present investigation was conducted during spring 2018 at Division of Sericulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu with an intention to develop, evaluate and identify new bivoltine hybrid combinations suitable for rearing during spring season in sub-tropical conditions of northern India. For this purpose, six bivoltine silkworm breeds (ND_2, ND_3, NSP, U_1, CSR_2 and JD_6) evolved at Division of Sericulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu were taken to prepare bivoltine hybrids by employing full diallel method (Table 1) and studied along with ruling bivoltine hybrid, $CSR_2 \times CSR_4$ in order to identify the adaptable, high yielding bi × bivoltine silkworm hybrids. These hybrids along with the control were reared in the completely randomized block design (CRBD) with three replications each. Standard rearing techniques as suggested by Dandin *et al*. (2003) [1] were followed. Data was recorded replication- wise for all the treatments viz., fecundity, hatching percentage, brushing percentage, larval weight, larval survival percentage, cocoon yield per 10,000 larvae (by weight and by number), good cocoon percentage, pupation percentage, single cocoon weight, single shell weight, shell ratio, average filament length, non-breakable filament length and filament size and the data was analyzed using multiple trait index (Evaluation index) method. The Evaluation Index method developed by Mano *et al*. (1993) [18] was found to be very useful in selecting potential hybrids. Data on the economically important traits was collected, pooled and analyzed. The Evaluation Index (E.I.) was calculated as per the procedure

$$\mathrm{E.I.} = \frac{\mathrm{A-B}}{\mathrm{C}} \times 10 + 50$$

Where, A = Value obtained for a particular trait of a particular hybrid combination

B = Mean values of a particular trait of all the hybrid combinations

C = Stand deviation of a particular trait of all the hybrid combinations

10 = Standard Unit

50 = Fixed Value

The E.I. value fixed for the selection of hybrid is 50 or >50 for the traits. The hybrid which scored above the limit is considered to possess greater economic value.

3. Results and Discussion

Selection, evaluation and synthesis of productive breeds is an important component in the development of sericulture. The main objective of any breeding programme is to develop new breeds as well as to identify promising hybrids for commercial exploitation with consistent performance with desired environmental conditions (Hallauver, 1987) [7]. Hybridization of silkworm hybrids with different genetic constitutions can be made by crossing different breeds depending upon the character that the breeders desire to introduce for improvement of productivity (Mano *et al*., 1988) [17]. Malik *et al*. (2001 and 2002) [15] and Ram *et al*. (2003) [25] suggested that the superiority and the potential of breeds and hybrids among depends on the ranking and considering all the major cocoon yield and silk contributing parameters. In silkworm (*Bombyx mori* L.) even though the parental strains are superior, they do not have much value if the same is not refuted in the hybrids. The ultimate results in silk worm breeding are judged by the Excellency of commercial traits that appear in the hybrids (Reddy *et al*. 2012) [26]. Therefore, large number of hybrids are tested and promising ones are selected based on the economic traits (Seshagri *et al*., 2009; Kumar and Naik, 2011) [29, 11]. Evaluation of different breed/hybrids is undoubtedly the most important method to identify their superiority. This could be achieved precisely by adopting a common index giving adequate weightage to all the commercially important traits (Islam *et al*., 2005; Seidevi, 2010 and Reddy *et al*., 2012) [9, 26].

In present study, an attempt has been made to evaluate various bivoltine silkworm hybrids in order to identify their superiority for commercial exploitation. The results show high degree of variability by different hybrids with regard to various economically important characters.

Fecundity is an important trait for variability of a commercial grainage. Variation in fecundity was found in different breeds and hybrids, which resulted in fluctuation of egg number per brood. Among hybrids, maximum Evaluation Index value of 64.50 was recorded in hybrid combination $ND_3 \times JD_6$ and $JD_6 \times NSP$ followed by $ND_2 \times JD_6$ (64.22) whereas minimum E.I. value was recorded for $ND_2 \times ND_3$ (38.10). The control hybrid recorded an E.I. value 53.38 (Table 2&3). Eleven hybrids surpassed the E.I. value greater than control hybrid $CSR_2 \times CSR_4$. According to Tazima (1957), fecundity mainly depends upon genotype of mother moth and environmental conditions at the time of oviposition. Higher fecundity registered in F1 hybrids can be attributed to heterotic effect prevailing in hybrids.

Hatching and brushing being two important seed parameters, commercially show direct co-relation to number of worms brushed and larval population reared that ultimately contribute for cocoon yield. Out of thirty hybrids, E.I. value was maximum in NSP × ND_3 (59.84) followed by $ND_2 \times CSR_2$ (59.04) (Table 2&3). Eighteen hybrids recorded an E.I. value more than the check hybrid. High hatching percentage observed in bivoltine breeds also reflects the high value for number of eggs hatched, number of warms brushed and brushing percentage which are important characters of quality silkworm seed and breed. For brushing character, only six hybrid combinations surpassed the E.I. value of 56.51 (control) for this character with $ND_3 \times JD_6$ (59.78) having the maximum E.I. Among thirty hybrids, the average E.I. value for three commercially important egg parameters ranged between 35.46 (U_1 × NSP) to 60.82 ($ND_3 \times JD_6$). Nineteen hybrid combinations *viz.*, $ND_3 \times JD_6$ (60.82), NSP × U_1(58.86), $ND_2 \times JD_6$ (58.68), ND_2 × NSP (58.45), $ND_3 \times ND_2$ (56.84), $ND_2 \times U_1$ (56.49), JD_6 × NSP (54.72), $ND_3 \times CSR_2$ (54.15), $JD_6 \times ND_3$ (54.04), $ND_3 \times U_1$ (53.86), JD6 × U_1(53.35), NSP × JD_6 (53.20), NSP × ND_2 (53.17), NSP × ND_3 (52.92), NSP × CSR_2 (52.56), $CSR_2 \times U_1$(51.34), $ND_2 \times CSR_2$ (51.24), ND_3 × NSP(50.79) and $CSR_2 \times ND_2$ (50.73) scored E.I. value > 50 (Table 2&3).

Silkworms are voracious eaters of mulberry during its larval stages and around 80 percent leaf is consumed in the last two instars (Fukuda, 1960) [5]. Highlighting the importance of food intake, Horie *et al*. (1978) [8] reported that for the production of 1g larval dry weight, requirement of ingestion and digestion of food is 4.2 mg and 1.8 mg respectively. The intake of food during total larval life is also reflected by the larval weight and is a cocoon and shell contributing parameter. Among 30 hybrids, maximum E.I. value of 66.80 was achieved by ND_3 × NSP and CSR2 x ND3 for weight of 10 mature larvae and a minimum value of 35.88 in hybrid ND_2 × NSP, $ND_2 \times JD_6$ and $JD_6 \times CSR_2$ (Table 2 & 3). The present study reveals that the bivoltine worms which consumed more mulberry leaves and attained robust growth at larval stage resulted in the higher larval weight and ultimately cocoon weight, shell weight and raw silk production. Present finding is supported by Kumar *et al*. (2013) [13] who found similar results. Commercially larval survival constitutes an important character for reader's point of view that contributes to produce a more number of cocoons for better crop production. Hybrid $ND_2 \times ND_3$ scored maximum E.I. value of 64.25 for larval survival percentage followed by $ND_2 \times CSR_2$, NSP × JD_6 (62.79) and minimum E.I. value of 31.96 was recorded in $U_1 \times CSR_2$. The insignificant variation for larval survival can be attributed to uniform rearing condition non-occurrence of disease. Ohi *et al.* (1970) [22] worked out multiple co-relations between yield components and found larval survival directly co-related to number of cocoons harvested. Among hybrids, the cumulative E.I. observation made for weight of 10 mature larvae and larval survival revealed that seventeen hybrid combinations *viz.* ND_3 × NSP (63.32), $ND_2 \times CSR_2$ (62.21), $ND_2 \times ND_3$ (57.79), $ND_3 \times CSR_2$ and $CSR_2 \times ND_2$ (57.07), $ND_3 \times ND_2$ (56.33), NSP × ND_3 (55.96), $ND_3 \times JD_6$ (54.86), NSP × ND_2 (54.50), U_1 × NSP (54.12), $U_1 \times JD_6$ (53.75), NSP × CSR_2 (53.39), $CSR_2 \times ND_3$ (53.05), CSR_2 × NSP (51.94), NSP × JD_6 (51.91), $U_1 \times ND_3$ (51.19) and $ND_2 \times U_1$ (51.18) scored E.I. value > 50. The control hybrid scored 42.74 only (Table 2&3).

Minagava and Otsuka (1975) [21] have reported inter relationship between multiple characters in silkworm. Silkworm cocoon is important commercial and economic product of rearing. Malik *et al*. (2006) [16] suggested that cocoon yield/10,000 larvae by weight and by number, good cocoon percentage, pupation percentage, single cocoon weight, shell weight and shell ratio percentage are important parameter for quality cocoon crop as well as potential hybrid. In the present study, a great deal of variability was observed in the expression of cocoon yield (by weight and by number). Out of 30 hybrid combinations, $ND_2 \times ND_3$ achieved highest E.I. value of (68.20) while as the control hybrid $CSR_2 \times CSR_4$ depicted E.I. value of (39.12). Cocoon yield by number is an important parameter for contributing viability. Maximum E.I. value for cocoon yield per 10,000 larvae (by number) was recorded in hybrid $ND_2 \times ND_3$ (63.20) while as hybrid $JD_6 \times ND_3$ scored lowest E.I. value of 35.60 (Table 2&3). Eighteen hybrids recorded greater E.I. value than check hybrid. Saratchandra *et al*. (2002) reported mulberry varietal effect on cocoon yield by weight and number.

For good cocoon percentage, maximum E.I. value of 66.13 was observed in hybrids $ND_2 \times ND_3$ and a minimum E.I. value of 32.36 was observed in $ND_2 \times JD_6$. The control hybrid recorded E.I. value of 37.76 (Table 2&3). For good cocoon, sixteen hybrid combinations exhibited > 50 E.I. value than control. Good cocoon and pupation percentage is a positive sign for cocoon reeling performance as well as seed production. These are generally influenced by rearing environment and other abiotic factors. Pupation rate is one of the important economic characters to determine the variability of a breed/hybrid. The genetic and environment interaction gets more reflected in this character. Among hybrids, maximum E.I. value of 63.70 was recorded by $ND_2 \times ND_3$ followed by $ND_2 \times CSR_2$ with E.I. value 62.10. Hybrid $CSR_2 \times JD_6$ recorded lowest E.I. value of 34.17 for pupation character. The control hybrid had E.I. value of 38.16 for pupation percentage (Table 2&3). Sixteen hybrids recorded higher pupation E.I. in comparison to control. Major factors among these include spacing, hygiene, seriposition material and appropriate time for picking of mature larvae for seriposition. The observations are in accordance with the findings at Kato *et al*. (1989) [12] and Gowda *et al*. (2013) [6].

The cocoon weight, shell weight and shell ratio are important commercial parameters of cocoon for yield and silk reeling performance. The cocoon weight has a negative correlation with shell ratio but positive correlation with shell weight whereas, shell weight has positive correlation with shell ratio. Seventeen hybrids including control recorded E.I. value > 50. Maximum E.I. value of 64.46 was observed in $ND_3 \times CSR_2$ followed by ND_2 × NSP with the E.I. value of (63.53) whereas lowest E.I. value of (36.31) was observed in hybrid $ND_2 \times CSR_2$. The control hybrid had E.I. value of 50.76 for single cocoon weight (Table 2&3).

Shell weight has a positive co-relation with cocoon shell ratio. It contributes to the silk content. Maximum E.I. value of 85.00 was displayed by the combination ND_2 × NSP followed by $ND_2 \times JD_6$ (77.00) whereas the control hybrid scored E.I. value of 52.00. Similar trend with respect to shell weight was observed by Maqbool *et al*. (2008) [20]. Shell ratio is an important parameter of quality depicting actual silk content of a cocoon. Hybrid NSP × ND_2 scored maximum E.I. value of 71.60 followed by $ND_2 \times CSR_2$ with the value of 67.15 whereas the hybrid U_1 × NSP scored minimum E.I. value of (32.93). The control hybrid remained at E.I. value of 49.44 (Table 2&3). Fifteen hybrids scored E.I. value greater than 50. The average cumulative E.I. values for the cocoon parameters recorded for 30 silkworm hybrids ranged between 42. 07 to 59. 90. Fifteen hybrids *viz.*, $ND_2 \times CSR_2$ (59.90), ND_2 × NSP (57.86), $ND_2 \times ND_3$ (54.84), ND_3 × NSP (54.39), NSP × ND_3 (54.00), $ND_3 \times ND_2$ (53.59), NSP × ND_2 (53.07), NSP × JD6 (53.03), NSP × CSR_2 (52.42), $CSR_2 \times ND_2$ (52.70), $ND_3 \times JD_6$ (52.22), $ND_3 \times CSR_2$ (51.30), $CSR_2 \times ND_3$ (51.09), $JD_6 \times ND_2$ (50.43) and$U_1 \times JD_6$ (50.01). The control hybrid $CSR_2 \times CSR_4$ remained at E.I. value of 48.78 only (Table 2&3).

Post cocoon characters have greater significance not only from reeler's point of view but also from industrial point of view. Three post-cocoon parameter viz. total filament length, non-breakable filament length and filament size mainly contribute for silk, the end product. Maximum E.I. value for total filament length was achieved in hybrid $U_1 \times JD_6$ (66.47) followed by NSP × U_1 (66.03) and minimum value was recorded in hybrid $U_1 \times ND_2$ (30.53). The control hybrid recorded an E.I. value of 45.22 for total filament length (Table 2&3). Out of thirty hybrids, sixteen hybrids recorded E.I. value >50 than the check hybrid. Rajalakshmi *et al*. (2000) [24] opines that the quality of a good hybrid is to have minimum or no breaks during reeling. Fifteen hybrids recorded >50 E.I. value than control for non-breakable filament length (Table 2&3). Filament size denotes thinness/thickness of the filament and an E.I. value of 69.16 in combination $JD_6 \times ND_3$ followed by $CSR_2 \times ND_2$ (65.00) and minimum in $ND_2 \times ND_3$ (30.00). The filament size of control hybrid calculated was 58.33 (Table 2&3). Among hybrids, the average cumulative E.I. value for post cocoon parameters ranged from 34.07 to 63.74. Twelve hybrids scored E.I. value > 50. These hybrids include $U_1 \times JD_6$ (63.74), $CSR_2 \times ND_2$ (61.91),$U_1 \times CSR_2$ (61.70), NSP x $U_1$and $CSR_2 \times U_1$ (61.00), JD6 × NSP (59.19), NSP × CSR_2 (57.65), NSP × ND_3 (56.30), $ND_2 \times CSR_2$ (54.09), ND_3 ×JD_6 (53.60), ND_2 x NSP (53.00), $CSR_2 \times ND_3$ (52.80), and. Control hybrid attained the E.I. value of (51.47) only (Table 5). The results are in accordance with the findings of Dayananda *et al*. (2011) [4]. Among hybrids, the overall average E.I. value for fifteen quantitative and qualitative traits ranged between 39.77($CSR_2 \times JD_6$) to 57.59 ($ND_2 \times NSP$) (Table 2) and from 43.80 ($U_1 \times ND_2$) to 55.53 ($NSP \times ND_3$) (Table 3). In case of genuine cross, ten hybrids surpassed E.I. values >50. These include, $ND_2 \times NSP$ (57.59), $ND_2 \times CSR_2$ (55.46), $ND_3 \times JD_6$ (55.26), $ND_3 \times NSP$ (55.13), $NSP \times CSR_2$ (54.83), $NSP \times U_1$ (53.26), $NSP \times JD_6$ (53.15) $ND_2 \times ND_3$ (51.78), $U_1 \times JD_6$ (52.37) and $ND_3 \times CSR_2$ (52.14) while in reciprocal cross, six hybrids scored E.I. values of >50. The hybrids are $CSR_2 \times ND_2$ (55.61), $NSP \times ND_3$ (55.53), $ND_3 \times ND_2$ (53.90), $CSR_2 \times U_1$ (50.86), $JD_6 \times NSP$ (50.69) and $NSP \times ND_2$ (50.27) (Table 2 and 3).

On the basis of cumulative E.I. value of fifteen commercial characters, ranking of hybrids was done and three hybrids *viz.*, hybrids $ND_2 \times CSR_2$, $ND_3 \times NSP$ and $ND_2 \times NSP$ scored E.I. Value 55.53, 55.33 and 53.93 respectively are identified as promising hybrids for further rearing trials at field level (Table 4).

Table 1: Full Diallel crossing chart of six parental breeds

Breeds	**ND_2**	**ND_3**	**NSP**	**U_1**	**CSR_2**	**JD_6**
ND_2	$ND_2 \times ND_2$	$ND_2 \times ND_3$	$ND_2 \times NSP$	$ND_2 \times U_1$	$ND_2 \times CSR2$	$ND_2 \times JD_6$
ND_3	$ND_3 \times ND_2$	$ND_3 \times ND_3$	$ND_3 \times NSP$	$ND_3 \times U_1$	$ND_3 \times CSR_2$	$ND_3 \times JD_6$
NSP	$NSP \times ND_2$	$NSP \times ND_3$	$NSP \times NSP$	$NSP \times U_1$	$NSP \times CSR_2$	$NSP \times JD_6$
U_1	$U_1 \times ND_2$	$U_1 \times ND_3$	$U_1 \times NSP$	$U_1 \times U_1$	$U_1 \times CSR_2$	$U_1 \times JD_6$
CSR_2	$CSR_2 \times ND_2$	$CSR_2 \times ND_3$	$CSR_2 \times NSP$	$CSR_2 \times U_1$	$CSR_2 \times CSR_2$	$CSR_2 \times JD_6$
JD_6	$JD_6 \times ND_2$	$JD_6 \times ND_3$	$JD_6 \times NSP$	$JD_6 \times U_1$	$JD_6 \times CSR_2$	$JD_6 \times JD_6$

Control: $CSR_2 \times CSR_4$ Dialled formula = n (n-1); where n = no. of parents = 6(6-1) = 6(5) = 30

Table 2: Evaluation Index values of bivoltine silkworm hybrids for commercial traits (Genuine cross)

Parameters		**$ND_2 \times ND_3$**	**$ND_2 \times NSP$**	**$ND_2 \times U_1$**	**$ND_2 \times CSR_2$**	**$ND_2 \times JD6$**	**$ND_3 \times NSP$**	**$ND_3 \times U_1$**	**$ND3 \times CSR_2$**	**$ND3 \times JD_6$**	**$NSP \times U_1$**	**$NSP \times CSR_2$**	**$NSP \times JD_6$**	**$U_1 \times CSR2$**	**$U_1 \times JD_6$**	**$CSR_2 \times JD_6$**	**$CSR_2 \times CSR_4$***
Fecundity		38.10	61.44	56.99	45.88	64.22	48.94	45.33	49.50	64.50	63.94	41.71	45.05	56.16	44.21	44.77	53.38
Hatching		55.02	57.61	53.68	59.04	55.23	55.55	57.41	57.50	58.18	59.75	57.77	55.76	29.17	41.18	46.28	50.54
Brushing		47.66	56.30	58.80	48.82	56.61	47.90	58.84	55.46	59.78	52.91	58.22	58.80	39.27	48.60	28.28	56.61
Wt. of 10 mature larvae		51.34	35.88	41.04	61.64	35.88	66.80	46.19	61.64	51.34	51.34	51.34	41.04	46.19	46.19	41.04	46.19
Larval Survival		64.25	58.38	61.32	62.79	36.36	59.85	49.58	52.51	58.38	48.11	55.44	62.79	31.96	61.32	33.43	39.30
Cocoon yield/10,000 larvae	By wt.	68.20	62.75	47.61	57.00	33.37	54.57	43.07	54.88	60.02	55.79	61.24	57.60	45.80	35.19	39.12	29.43
	By no.	63.20	58.26	59.91	61.56	36.01	59.49	48.37	51.67	57.85	47.56	54.97	61.15	34.36	60.73	39.72	36.01
Good cocoon		66.13	58.02	59.37	63.43	32.36	62.08	49.92	51.26	58.02	45.87	55.32	64.78	35.06	59.37	36.41	37.76
Pupation		63.70	58.51	59.31	62.10	36.16	60.10	49.33	51.32	58.11	47.35	55.31	61.71	35.37	60.91	34.17	38.16
Single cocoon weight		44.00	63.53	36.77	36.31	56.92	54.30	38.70	64.46	49.39	54.30	47.54	47.62	58.76	51.38	40.54	50.76
Single shell weight		53.00	85.00	10.00	44.00	77.00	63.00	35.00	57.00	45.00	47.00	55.00	47.00	54.00	42.00	38.00	52.00
Shell ratio		59.90	49.25	46.23	67.16	53.96	50.28	57.92	34.53	47.65	42.08	55.66	51.22	39.91	43.31	56.79	49.44
Total filament length		30.80	53.54	38.86	50.47	53.54	43.03	39.96	55.07	48.07	66.03	62.97	50.25	64.28	66.47	43.47	45.22
Non-breakable filament length		41.43	56.32	46.73	54.31	35.41	49.45	47.44	36.27	52.74	64.49	62.48	54.17	63.34	64.77	49.74	50.87
Filament size		30.00	49.16	56.66	57.50	59.16	51.66	45.83	49.16	60.00	52.50	47.50	38.33	57.50	60.00	38.33	58.33
Total		776.73	863.95	733.28	832.01	722.19	827.00	712.89	782.23	829.03	799.02	822.47	797.27	691.13	785.63	596.69	707.40
Av. E.I.		51.78	57.59	48.88	55.46	48.14	55.13	47.52	52.14	55.26	53.26	54.83	53.15	46.07	52.37	39.77	47.16

*Control

Table 3: Evaluation Index values of bivoltine silkworm hybrids for commercial traits (Reciprocal cross)

Parameters		**$ND_3 \times ND_2$**	**$NSP \times ND_2$**	**$NSP \times ND_3$**	**$U_1 \times ND_2$**	**$U_1 \times ND_3$**	**$U_1 \times NSP$**	**$CSR_2 \times ND_2$**	**$CSR_2 \times ND_3$**	**$CSR_2 \times NSP$**	**$CSR_2 \times U_1$**	**$JD_6 \times ND_2$**	**$JD_6 \times ND_3$**	**$JD_6 \times NSP$**	**$JD_6 \times U_1$**	**$JD_6 \times CSR_2$**	**$CSR_2 \times CSR_4$***
Fecundity		57.27	58.38	50.88	40.04	48.94	38.65	48.94	41.98	42.55	49.22	54.21	52.82	64.50	56.16	49.22	53.38
Hatching		56.98	49.24	59.84	41.76	30.00	33.08	51.27	50.50	43.03	52.58	39.97	55.75	54.56	49.65	44.88	50.54
Brushing		56.29	51.89	48.04	42.73	37.49	34.65	52.00	48.27	40.19	52.22	43.89	53.55	45.12	54.85	48.94	56.61
Wt. of 10 mature larvae		51.34	56.49	56.49	51.34	51.34	51.34	61.64	66.80	61.64	41.04	46.19	51.34	51.34	41.04	35.88	46.19
Larval Survival		61.32	52.51	55.44	39.30	51.04	56.91	52.51	39.30	42.24	42.24	42.24	33.43	40.77	52.51	49.58	39.30
Cocoon yield/10,000 larvae	By wt.	53.36	49.43	54.27	50.33	53.36	53.06	64.27	50.02	57.00	50.33	58.20	28.52	42.16	38.82	41.25	39.12
	By no.	59.91	51.67	55.78	40.55	51.67	56.20	53.31	40.14	43.43	44.26	44.66	35.60	41.38	51.67	50.02	39.72
Good cocoon		60.72	48.57	56.67	41.82	53.97	55.32	53.97	39.11	40.46	43.17	43.17	35.06	41.82	52.62	48.57	37.76
Pupation		59.71	47.35	56.51	40.95	52.52	56.51	52.13	40.16	43.35	44.95	45.35	36.96	42.56	52.13	49.74	38.16
Single cocoon weight		40.62	38.54	48.39	55.38	55.23	53.30	54.76	53.38	60.00	47.00	57.69	44.00	54.15	50.84	37.24	50.76
Single shell weight		54.00	58.00	63.00	46.00	52.00	27.00	57.00	64.00	47.00	56.00	58.00	48.00	57.00	31.00	29.00	52.00

Shell ratio	65.84	71.60	58.77	40.10	43.40	32.93	46.61	52.07	33.68	56.98	43.31	57.07	47.46	38.12	56.79	49.44
Total filament length	45.87	32.73	59.02	30.53	52.66	55.29	60.12	47.63	42.15	60.99	46.97	47.63	62.75	39.74	53.98	45.22
Non-breakable filament length	31.25	42.71	59.90	41.28	55.75	36.41	60.62	52.45	48.88	61.19	52.02	32.25	62.34	47.30	35.69	50.87
Filament size	54.16	45.00	50.00	55.00	22.50	35.00	65.00	58.33	46.66	60.83	45.00	69.16	52.50	40.83	60.00	58.33
Total	808.64	754.11	833.00	657.11	711.87	675.65	834.15	744.14	692.26	763.00	720.87	681.14	760.41	697.28	690.78	707.40
Average E.I.	53.90	50.27	55.53	43.80	47.45	45.04	55.61	49.60	46.15	50.86	48.05	45.40	50.69	46.48	46.05	47.16

*Control

Table 4: Ranking of hybrids as per E.I. values.

Hybrids	Genuine cross (A)	Reciprocal cross (B)	E.I. Value (A+B/2)	RANKING
ND_2 × CSR_2	55.46	55.61	111.07/2=55.53	01
ND_3 × NSP	55.13	55.53	110.66/2=55.33	02
ND_2 × NSP	57.59	50.27	107.86/2 =53.93	03
ND_2 × ND_3	51.78	53.90	105.68/2=52.84	04
NSP × JD_6	53.15	50.69	103.84/2=51.92	05
ND_3 × CSR_2	52.14	49.60	101.74/2 =51.28	06
ND_3 ×JD_6	55.26	45.40	99.92/2 = 50.87	07
NSP × CSR_2	54.83	46.15	100.98/2 =50.49	08

Cumulative E.I. score for control CSR_2 × CSR_4 = 47.16

4. Conclusion

Thus based on the investigation, it can be concluded that hybrid, ND_2 × CSR_2 (55.53), ND_3 × NSP (55.33), ND_2 × NSP (53.93), ND_2 × ND_3 (52.84), NSP × JD_6 (51.92), ND_3 × CSR_2 (51.28), ND_3 ×JD_6 (50.87) and NSP × CSR_2 (50.49) surpassed the E.I. bench mark value >50. Hence, based on the Evaluation Index values for qualitative and quantitative three hybrids *viz*. hybrids ND_2 × CSR_2, ND_3 × NSP and ND_2 × NSP scored E.I. Value 55.53, 55.33 and 53.93 and were identified as potential hybrids both by evaluation and ranking through E.I. values respectively. These hybrids can be commercially exploited for sub-tropics for spring season after multi locational trials.

5. References

1. Dandin SB, Basavaraja HK. and Suresh Kumar N. Factors for success of Indian bivoltine sericulture. Indian Silk. 2003; 41(9):5-8.
2. Dandin SB, Suresh Kumar N, Basavaraja HK, Mal Reddy N, Kalpana GV, Joge PG. *et al*. Development of new bivoltine silkworm hybrid, Chamaraja (CSR-50 x CSR-51) of *Bombyx mori* L. for tropics. Indian Journal of Sericulture. 2006; 45:35-44.
3. Datta RK, Basavaraja HK, Mal Reddy N, Nirmal Kumar S, Suresh Kumar N, Ramesh Babu M *et al*. Evaluation and identification of promising bivoltine hybrid, CSR-12 x CSR-6 of silkworm, *Bombyx mori* L. International Journal of Industrial Entomology. 2001; 3(2):127-133.
4. Dayananda Kulkarni BS, Rao MRP, Gopinath KO, Kumar NS. Evaluation and selection of superior bivoltine hybrids of the silkworm, *Bombyx mori* L. for tropics through large scale inhouse testing. In: Proceedings of Golden Jubilee Conference - Sericulture Innovations: Before and Beyond, 28-29th January, 2011, CSR&TI, Mysore. 2011; 199-203.
5. Fukuda S. Biochemical studies on the formulation of silk protein. Par IX. The direct and indirect formulations of silk protein during the growth of silkworm larvae. Bulletin Agricultural Chemical Society, Japan, 1960; 24:296-401.
6. Gowda V, Kalpana GV and Ashwath SK. Evaluation and identification of potential bivoltine silkworm hybrids of *Bombyx mori* L. Journal of Entomology and Zoology. 2013; 1(6):39-43.
7. Hallauver AR, Weir BS, Eisen EJ, Goodman MM and Namkoong G. Proceedings of 2nd International Conference on Quantitative Genetics. Sinaver Associates, Inc. Publishers, Sunderland, Massachusetts. 1987; 488-491.
8. Horie Y, Inokuchi T and Watanabe K. Quantitative studies of food utilization by the silkworm *Bombyx mori* L. through the life cycle II. Economy of nitrogen and amino acids. Bulletin of Sericultural Experimental Station. 1978; 27(2):531-578.
9. Islam MI, Ali IA, Haque T. Combining ability estimation in popular bivoltine mulberry silkworm, *Bombyx mori* L. Pakistan Journal of Biological Sciences. 2005; 8(1):68-72.
10. Kamili AS, Malik GN, Trag AR, Kukiloo FA and Sofi AM. Development of new bivoltine silkworm (*Bombyx mori* L.) genotypes with higher commercial characters. Journal of Research, SKUAST. 2000; 2:66-69.
11. Kumar KP and Naik S. Development of polyvoltine x bivoltine hybrids of mulberry silkworm, *Bombyx mori* L. tolerant to BmNPV. International Journal of Zoological Research. 2011; 7:300-309.
12. Kato M, Nagayasu K, Ninaki O, Hara W and Watanabe A. Studies on resistance of the silkworm *Bombyx mori* L. to high temperature. In: Proceedings of the 6th International Congress of SABRAO. 1989; 953-95.
13. Kumar R, Singh A and Sharma J. Comparative performance of two different mulberry varieties on silkworm rearing in spring season. International Journal of Science and Nature. 2013; 4(4): 651-653.
14. Malik GN, Kamili AS, Wani Shafiq A, Munshi NA and Tariq A. Performance of some bivoltine silkworm *Bombyx mori* L. hybrids. Sericologia. 2001; 6:105-111.
15. Malik GN, Kamili AS, Wani SA, Dar HL, Ahmed R and Sofi AM. Evaluation of some bivoltine silkworm, *Bombyx mori* L. genotypes. SKAUST Journal of Research. 2002; 4:83-87.
16. Malik GN, Massoodi MA, Kamili AS, Sofi AM. Studies on heterosis in some bivoltine silkworm (*Bombyx mori* L.) crosses. Journal of Sericulture. 2006; 6(1-2):47-49.
17. Mano Y. Nishimura M, Kato M, Nagayasu K. Breeding of an autosexing silkworm race N140 × C145. Bulletin of Sericultural Experimental Station. 1988; 30: 753-785.

18. Mano Y, Kumar NS, Basavaraja HK, Mal Reddy N, Datta RK. A new method to select promising silkworm breeds/combinations. Indian Silk. 1993; 31:53.
19. Masrat S, Tripathi AK. Sericulture Industry in India A comparative study of Jammu and Kashmir and Madhya Pradesh, International Journal of Business and Administration Research Review. 2017; 1(18):81.
20. Maqbool A, Malik GN, Dar HV, Kamili AS and Gulzaffar. Evaluation of some bivoltine silkworm (*Bombyx mori* L.) genotype under different seasons. Indian Journal of Sericulture. 2008; 4(2):147-155.
21. Minagava I, Otsuka Y. Relationships of actual performance of double cross hybrids and predicted value based on the mean value of the single crosses concerned in the silkworm *Bombyx mori* (L.). Japanese Journal of Breeding. 1975; 25:251-257.
22. Ohi H, Miyahara T, Yamashita A. Analysis of various practically important characteristics in the silkworm in early breeding generations of hybrids, variation among strains, correlations between parents. and offspring as well as relationship between each character. Technical Bulletin of Sericultural Experimental Station. 1970; 93:9-49.
23. Rajalakshmi E. Chauhan TPS, Kamble CK. Hybrid vigour among newly evolved bivoltine hybrids of silkworm, *Bombyx mori* L. under hill conditions. Indian Journal of Sericulture. 1998; 68:620-624.
24. Rajalakshmi E, Chauhan TPS, Kamble CK, Sreenivas BT, Mahadevaiah BM. Evaluation of newly evolved bivoltine hybrids of *Bombyx mori* L. for silk yield contributing traits under hill condition. Indian Journal of Sericulture. 2000; 39(1):21-23.
25. Ram K, Bali RK, Koul A. Seasonal Evaluation of various cross combinations in Bivoltine Silkworm *Bombyx mori* L. Journal of Research SKUAST – J. 2003; 2(2):169-177.
26. Reddy MN, Begum AN, Shekar KBC, Kumar SN, Qadri SMH. Expresssion of hybrid vigour in different crossing pattern involving the bivoltine silkworm *Bombyx mori* L. parents. Indian Journal of Sericulture. 2012; 51(1):2631.
27. Saratchandra B, Rajanna L, Philomena KL, Paramesh C, Ramesh SP, Jayappa T. An evaluation of elite mulberry varieties for good yield and quality through bioassay. Sericologia. 2002; 32(1):127-134.
28. Seidavi A. Estimation of genetic parameters and selection effect on genetic and phenotype trends in silkworm commercial pure lines. Asian Journal of Animal and Veterinary Advances. 2010; 5:1-12.
29. Seshagiri SV, Ramesha C, Rao CGP. Genetic manifestation of hybrid vigor in cross breeds of mulberry silkworm, *Bombyx mori* L. International Journal of Zoological Research. 2009; 5 (2):150-160.
30. Tazima Y. Report on Sericulture Industry in India. Central Silk Board, Bombay, India, 1957, 29-37.