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Studies on Heterosis and Heterobeltiosis in Selected Quantitative Traits during Summer Season in Bivoltine Silkworm, *Bombyx mori* L.

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ABSTRACT

Background: The phenomenon of heterosis has been commercially exploited in agriculture, horticulture, animal husbandry, piggery, poultry and sericulture. Heterosis is the phenotypic result of gene interaction in heterozygotes and the degree of heterosis increases as the genetic similarities between two parent's decreases.
Methods: The present study was carried out at Central Sericultural Research and Training Institute (CSR&TI), Central Silk Board, Gallandar, Pampore during summer 2019 (July-August) and extent of heterosis was studied in six quantitative traits viz., Cocoon yield per 10000 larvae by weight, Single cocoon weight, Single shell weight, Shell ratio, Filament length and Pupation rate in a set of 30 bivoltine silkworm hybrids along with three control hybrids. The data generated were analysed statistically and subjected to multiple trait Evaluation index (E.I).
Results: The average relative heterosis values ranged from-5.59 (DUN6 X DUN22) to 4.94 (S8 X CSR27). Among the 30 hybrids studied only 13 hybrids showed a variable amount of relative heterosis. The average heterobeltiosis values ranged from -6.90 (Pam117 X DUN 22) to 3.08 (S8 X CSR27). Among the 30 hybrids, only 8 hybrids showed a variable amount of heterobeltiosis. Maximum relative heterosis and heterobeltiosis have been observed in filament length (17.14 & 14.73, respectively).
Conclusion: Hybrids having CSR 27, Pam 117, S8 and N5 as one of the parents have shown higher heterosis and heterobeltiosis. Among the hybrids S 8 X CSR27 and CSR27 X Pam117 have shown higher relative heterosis and heterobeltiosis. The results have also been confirmed through evaluation index values calculated on relative heterosis and heterobeltiosis.

Key-words: *Bombyx mori*, Bivoltine silkworm, Evaluation index, Heterobeltiosis, Relative heterosis

INTRODUCTION

The silkworm, *B. mori* L (Lepidoptera: Bombycidae) is an insect of great importance for its production of silk, aptly named the queen of natural fibres [1]. This unique lepidopteran insect completes its life cycle while engineering an economically distinct structure made of silk called cocoon [2].

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The lepidopteran species have been reared for silk production for more than 5000 years [3]. Since then, silkworms have undergone many evolutionary changes due to natural as well as manmade selections after several thousands of generations, thereby creating a wide genetic diversity [4].

Since so many years sericulture has proved to have considerable socio-economic relevance in India due to its suitability to small and marginal farmers and also due to low-cost investment.

The major commercial silkworm rearing is being practised under temperate climatic conditions of Kashmir division of the Union Territory of Jammu & Kashmir during the spring season (May–June) only and

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about 15-20% rearers conduct second rearing during the autumn season (August-September). It has been observed that many rearers due to one reason or the other are unable to conduct rearing during the spring season and are interested in conducting rearing during summer season [5] (July-August) on the left overleaf of the spring season. It is to mention here that from a single set of the mulberry plantation, under recommended pruning schedule for Kashmir climatic conditions, the leaf is available for two rearings in a year i.e., spring and autumn. As summer season can also be exploited for a limited commercial rearing on left overleaf of spring flush or from a separate set of mulberry plantation pruned for harvesting leaf during the summer season[6], need was felt to identify silkworm hybrids suitable for rearing during the summer season. The Kashmir weather averages during summer months are depicted in Table 1.

Table 1: Kashmir Weather Averages for June, July and August 2019

Months	Min. Temp. (^{0}C)	Max. Temp. (^{0}C)	Average Temp. (^{0}C)	Average Precipitation/ Rainfall (mm)	Avg. Sunlight hours/Day	Relative Humidity (%)
June	14.0	29.0	21.5	36	7.5	57
July	18.0	31.0	24.5	61	8.0	62
August	18.0	30.0	24.0	62	7.5	67

METHODS AND METHODS

The present study was carried out at Central Sericultural Research and Training Institute (CSR&TI), Central Silk Board, Gallandar, Pampore during summer, 2019 (July-August). Six silkworm parental races viz., CSR27, Pam 117, S8, N5, DUN22 and DUN6 were selected based on their better performance during the summer season. The six races were crossed (Full diallel) resulting in 30 hybrid combinations. The extent of heterosis was studied in six quantitative traits viz., Cocoon yield per 10000 larvae by weight, Single cocoon weight, Single shell weight, Shell ratio, Filament length and Pupation rate in these 30 bivoltine silkworms (*B. mori* L.) hybrids along with three control hybrids viz., SH6 X NB4D2, CSR6 X CSR26 and CSR2 X CSR27. The standard rearing techniques were followed [7]. The parental races were reared in three replications each and the hybrids were reared in two replications per hybrid. 250 larvae were retained in each replication after 3rd moult.

The data generated for each trait was pooled and analysed to evaluate the performance of the parents as well as the degree of manifestation of heterosis and heterobeltiosis in the hybrids. The heterosis and heterobeltiosis in the F1 crosses were calculated by using the following formula:

$$\textbf{Heterosis} = \frac{\textbf{F1-MPV}}{\textbf{MPV}} \times 10$$

$$\textbf{Heterobeltiosis} = \frac{\textbf{F1-BPV}}{\textbf{BPV}} \times 100$$

Where,
F1= Mean of the hybrid; MPV= Mid parent value
BPV= Better parent value

Evaluation index values were calculated on the values of heterosis and heterobeltiosis obtained for all the traits. The evaluation index (EI) was ca1cuated as per the below-mentioned procedure [8].

$$\textbf{Evaluation Index} = \frac{\textbf{A} - \textbf{B}}{\textbf{C}} \times 10 + 50$$

Where,
A= Value obtained for a trait in a breed; B = Mean value of a trait of all the breed; C= Standard deviation of a trait of all the breeds; 10 = Standard unit; 50= Fixed value

The index value obtained for all the traits was combined and the average EI values were obtained. The EI value fixed for the selection of a line is 50 or >50. The genotype, which scored above the limit, is considered to possess greater economic value.

RESULTS

The average rearing and reeling performance of the parental races and the F1 crosses are presented in Table 2 and 3.

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Table 2: Average rearing and reeling performance of the parental races during summer, 2019

S.No.	Race	Cocoon Yield/10000 larvae by wt. (kg)	Single Cocoon Weight(g)	Single Shell Weight(g)	Shell Ratio (%)	Filament Length (m)	Pupation rate (%)
1	CSR 27	13.17	1.63	0.33	20.21	768	88.00
2	Pam 117	13.87	1.67	0.34	20.14	855	92.00
3	S 8	13.24	1.55	0.32	20.32	860	89.00
4	N 5	13.80	1.64	0.33	20.07	859	85.00
5	DUN 22	14.90	1.62	0.32	19.81	801	86.00
6	DUN 6	14.18	1.69	0.33	19.22	776	89.00
7	CSR 2	13.70	1.65	0.34	20.30	835	85.00
8	CSR 6	12.52	1.63	0.32	19.81	784	84.00
9	CSR 26	13.84	1.63	0.33	19.99	862	87.00
10	SH 6	14.20	1.70	0.31	17.96	744	92.00
11	NB4D2	13.80	1.56	0.29	18.26	776	92.00
MEAN		13.75	1.63	0.32	19.64	810.91	88.09
SD		0.62	0.05	0.01	0.82	44.09	2.98

Table 3: Average rearing and reeling performance of hybrids during summer, 2019

S.No.	Hybrid	Cocoon Yield/10000 larvae by wt.(kg)	Single Cocoon Weight (g)	Single Shell Weight (g)	Shell Ratio (%)	Filament Length (m)	Pupation rate (%)
1	CSR 27 X Pam 117	15.38	1.63	0.34	20.57	869	92.00
2	CSR 27 X S 8	13.84	1.57	0.30	19.06	813	85.00
3	CSR 27 X N 5	14.74	1.60	0.29	18.17	844	92.00
4	Pam 117 X CSR 27	14.44	1.60	0.34	20.97	859	95.00
5	Pam 117 X S 8	13.84	1.65	0.32	19.43	809	86.00
6	Pam 117 X N 5	14.50	1.67	0.35	20.92	904	91.00
7	S 8 X CSR 27	14.18	1.59	0.33	20.71	914	94.00
8	S 8 X Pam 117	14.60	1.69	0.35	20.66	839	90.00
9	S 8 X N 5	13.78	1.56	0.30	18.87	842	91.00
10	N 5 X CSR 27	13.08	1.55	0.29	18.41	851	92.00
11	N 5 X Pam 117	13.30	1.50	0.32	20.96	927	93.00
12	N 5 X S 8	13.90	1.62	0.32	19.50	847	94.00
13	Pam 117 X DUN 22	14.50	1.58	0.29	18.01	805	90.00
14	Pam 117 X DUN 6	14.64	1.55	0.32	20.27	896	93.00
15	CSR 27 X DUN 22	14.26	1.51	0.31	20.50	919	93.00
16	CSR 27 X DUN 6	14.06	1.58	0.30	18.63	817	85.00
17	DUN 22 X Pam 117	14.42	1.55	0.29	18.38	820	92.00
18	DUN 22 X CSR 27	14.40	1.69	0.34	19.83	812	88.00
19	DUN 22 X DUN 6	13.44	1.63	0.32	19.31	821	85.00
20	DUN 22 X S 8	14.28	1.67	0.33	19.51	840	90.00
21	DUN 22 X N 5	13.60	1.63	0.32	19.34	827	88.00
22	DUN 6 X Pam 117	14.28	1.68	0.33	19.39	790	85.00
23	DUN 6 X CSR 27	13.84	1.63	0.31	18.99	774	87.00
24	DUN 6 X DUN 22	12.56	1.56	0.30	18.94	756	88.00

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25	DUN 6 X S 8	13.30	1.49	0.30	19.73	903	94.00
26	DUN 6 X N 5	14.66	1.62	0.32	19.54	803	91.00
27	S 8 X DUN 22	14.68	1.56	0.29	18.64	803	93.00
28	S 8 X DUN 6	14.70	1.55	0.32	20.27	801	94.00
29	N 5 X DUN 22	14.90	1.62	0.33	20.07	819	90.00
30	N 5 X DUN 6	14.20	1.54	0.30	19.10	798	91.00
Control 1	SH6XNB4D2	14.90	1.55	0.29	18.73	818	95.00
Control 2	CSR6XCSR26	12.27	1.55	0.31	19.74	876	88.00
Control 3	CSR2XCSR27	12.80	1.58	0.32	20.00	878	89.00
	MEAN	14.07	1.59	0.31	19.55	839.21	90.42
	SD	0.71	0.05	0.02	0.85	43.52	3.09

Heterosis- Perusal of data reveals that the extent of heterosis in cocoon yield ranged from -13.62 (DUN6 X DUN22) to 13.76 (CSR27 X Pam 117). The heterosis ranged from -9.37 (N5 X Pam 117) to 5.36 (DUN22 X S8) in single cocoon weight; -12.12 (N5 X CSR27 & DUN22 X Pam 117) to 6.06 (S8 X Pam 117) in single shell weight; -9.84 (Pam 117 X DUN22) to 4.25 (N5 X Pam 117) in shell ratio; -5.66 (Pam 117 X S8) to 17.14 (CSR27 X DUN22) in filament length and -6.08 (DUN6 X Pam 117) to 8.05 (N5 X S8) in pupation rate. The average relative heterosis values ranged from-5.59 (DUN6 X DUN22) to 4.94 (S8 X CSR27) (Table 4). Evaluation index was also calculated on the values of relative heterosis (Table 5). Data reveals that the same hybrids ranked in the first six positions based on the values of average relative heterosis as well as the evaluation index values.

Table 4: Heterosis values of the hybrids during summer, 2019

Hybrids	Cocoon Yield by wt.	Single Cocoon Weight	Single Shell Weight	Shell Ratio	Filament Length	Pupation rate	Avg. Heterosis
CSR 27 X Pam 117	13.76	-1.21	1.49	1.96	7.09	2.22	4.22
CSR 27 X S 8	4.81	-1.26	-7.69	-5.95	-0.12	-3.95	-2.36
CSR 27 X N 5	9.31	-2.14	-12.12	-9.78	3.75	6.36	-0.77
Pam 117 X CSR 27	6.80	-3.03	1.49	3.94	5.85	5.56	3.44
Pam 117 X S 8	2.10	2.48	-3.03	-3.95	-5.66	-4.97	-2.17
Pam 117 X N 5	4.81	0.91	4.48	4.05	5.48	2.82	3.76
S 8 X CSR 27	7.38	0.00	1.54	2.20	12.29	6.21	4.94
S 8 X Pam 117	7.71	4.97	6.06	2.13	-2.16	-0.55	3.03
S 8 X N 5	1.92	-2.19	-7.69	-6.56	-2.04	4.60	-1.99
N 5 X CSR 27	-3.00	-5.20	-12.12	-8.59	4.61	6.36	-2.99
N 5 X Pam 117	-3.87	-9.37	-4.48	4.25	8.17	5.08	-0.04
N 5 X S 8	2.81	1.57	-1.54	-3.44	-1.45	8.05	1.00
Pam 117 X DUN 22	0.80	-3.95	-12.12	-9.84	-2.78	1.12	-4.46
Pam 117 X DUN 6	4.39	-7.74	-4.48	3.00	9.87	2.76	1.30
CSR 27 X DUN 22	1.60	-7.08	-4.62	2.45	17.14	6.90	2.73
CSR 27 X DUN 6	2.82	-4.82	-9.09	-5.50	5.83	-3.95	-2.45
DUN 22 X Pam 117	0.24	-5.78	-12.12	-7.98	-0.97	3.37	-3.87
DUN 22 X CSR 27	2.60	4.00	4.62	-0.90	3.51	1.15	2.50
DUN 22 X DUN 6	-7.57	-1.51	-1.54	-1.05	4.12	-2.86	-1.74
DUN 22 X S 8	1.49	5.36	3.13	-2.77	1.14	2.86	1.87
DUN 22 X N 5	-5.23	0.00	-1.54	-3.01	-0.36	2.92	-1.20
DUN 6 X Pam 117	1.82	0.00	-1.49	-1.47	-3.13	-6.08	-1.73

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DUN 6 X CSR 27	1.21	-1.81	-6.06	-3.68	0.26	-1.69	-1.96
DUN 6 X DUN 22	-13.62	-5.74	-7.69	-2.95	-4.12	0.57	-5.59
DUN 6 X S 8	-2.99	-8.02	-7.69	-0.20	10.39	5.62	-0.48
DUN 6 X N 5	4.79	-2.70	-3.03	-0.53	-1.77	4.60	0.23
S 8 X DUN 22	4.34	-1.58	-9.38	-7.10	-3.31	6.29	-1.79
S 8 X DUN 6	7.22	-4.32	-1.54	2.53	-2.08	5.62	1.24
N 5 X DUN 22	3.83	-0.61	1.54	0.65	-1.33	5.26	1.56
N 5 X DUN 6	1.50	-7.51	-9.09	-2.77	-2.39	4.60	-2.61
SH6XNB4D2	6.43	-4.91	-3.33	3.42	7.63	3.26	2.08
CSR6XCSR26	-6.90	-4.91	-4.62	-0.80	6.44	2.92	-1.31
CSR2XCSR27	-4.76	-3.66	-4.48	-1.26	9.54	2.89	-0.29
MEAN	1.77	-2.48	-3.89	-1.80	2.71	2.60	-0.18
MAXIMUM	13.76	5.36	6.06	4.25	17.14	8.05	4.94
MINIMUM	-13.62	-9.37	-12.12	-9.84	-5.66	-6.08	-5.59
SD	5.49	3.73	5.18	4.18	5.55	3.72	2.64

Table 5: Evaluation Index on Heterosis values of the hybrids during summer, 2019

Hybrid	Cocoon Yield by wt.	Single Cocoon Weight	Single Shell Weight	Shell Ratio	Filament Length	Pupation rate	Avg. Heterosis
CSR 27 X Pam 117	71.84	53.40	60.39	61.39	57.89	48.98	66.66
CSR 27 X S 8	55.54	53.27	42.66	42.46	44.90	32.39	41.74
CSR 27 X N 5	63.73	50.91	34.11	33.30	51.87	60.11	47.77
Pam 117 X CSR 27	59.16	48.53	60.39	66.12	55.66	57.96	63.69
Pam 117 X S 8	50.60	63.30	51.66	47.25	34.92	29.65	42.46
Pam 117 X N 5	55.54	59.09	66.16	66.39	54.99	50.59	64.92
S 8 X CSR 27	60.22	56.65	60.48	61.96	67.26	59.70	69.38
S 8 X Pam 117	60.82	69.97	69.21	61.79	41.23	41.53	62.15
S 8 X N 5	50.27	50.78	42.66	41.00	41.44	55.38	43.13
N 5 X CSR 27	41.31	42.71	34.11	36.15	53.42	60.11	39.36
N 5 X Pam 117	39.73	31.53	48.86	66.87	59.84	56.67	50.54
N 5 X S 8	51.89	60.86	54.54	48.47	42.50	64.65	54.47
Pam 117 X DUN 22	48.23	46.06	34.11	33.16	40.11	46.02	33.78
Pam 117 X DUN 6	54.77	35.90	48.86	63.88	62.90	50.43	55.61
CSR 27 X DUN 22	49.69	37.67	48.59	62.56	76.00	61.56	61.03
CSR 27 X DUN 6	51.91	43.73	39.96	43.54	55.62	32.39	41.40
DUN 22 X Pam 117	47.21	41.15	34.11	37.61	43.37	52.07	36.01
DUN 22 X CSR 27	51.51	67.37	66.43	54.55	51.44	46.10	60.14
DUN 22 X DUN 6	32.99	52.60	54.54	54.19	52.54	35.32	44.11
DUN 22 X S 8	49.49	71.02	63.55	50.07	47.17	50.70	57.76
DUN 22 X N 5	37.25	56.65	54.54	49.50	44.47	50.86	46.12
DUN 6 X Pam 117	50.09	56.65	54.63	53.18	39.48	26.67	44.15
DUN 6 X CSR 27	48.98	51.80	45.81	47.89	45.59	38.47	43.25
DUN 6 X DUN 22	21.97	41.26	42.66	49.64	37.69	44.54	29.50
DUN 6 X S 8	41.33	35.15	42.66	56.22	63.84	58.12	48.86
DUN 6 X N 5	55.50	49.41	51.66	55.43	41.93	55.38	51.54

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S 8 X DUN 22	54.68	52.41	39.40	39.71	39.15	59.92	43.90
S 8 X DUN 6	59.93	45.07	54.54	62.75	41.37	58.12	55.37
N 5 X DUN 22	53.75	55.01	60.48	58.25	42.72	57.15	56.58
N 5 X DUN 6	49.51	36.51	39.96	50.07	40.81	55.38	40.80
SH6XNB4D2	58.49	43.49	51.08	64.88	58.86	51.77	58.57
CSR6XCSR26	34.21	43.49	48.59	54.78	56.72	50.86	45.71
CSR2XCSR27	38.11	46.84	48.86	53.68	62.31	50.78	49.59

Heterobeltiosis- Perusal of data reveals that the extent of heterobeltiosis in cocoon yield ranged from -15.70 (DUN6 X DUN22) to 10.89 (CSR27 X Pam 117). The heterobeltiosis ranged from -11.83 (DUN6 X S8) to 3.68 (DUN22 X CSR27) in single cocoon weight; -14.71 (DUN22 X Pam 117 & Pam 117 X DUN22) to 3.13 (DUN22 X S8) in single shell weight; -10.58 (Pam 117 X DUN22) to 4.07 (N5 X Pam 117) in shell ratio; -7.60 (DUN6 X Pam 117) to 14.73 (CSR27 X DUN22) in filament length and -7.61 (DUN6 X Pam 117) to 5.68 (CSR27 X DUN22) in pupation rate. The average heterobeltiosis values ranged from-6.90 (Pam 117 X DUN22) to 3.08 (S8 X CSR27) (Table 6). Evaluation index was also calculated on the values of heterobeltiosis (Table 7). Data reveals that the same hybrids ranked in the first six positions based on the values of average heterobeltiosis as well as the evaluation index values.

Table 6: Heterobeltiosis values of the hybrids during summer, 2019

Hybrids	Cocoon Yield by wt.	Single Cocoon Weight	Single Shell Weight	Shell Ratio	Filament Length	Pupation rate	Avg. Heterob-eltiosis
CSR 27 X Pam 117	10.89	-2.40	0.00	1.78	1.64	0.00	1.99
CSR 27 X S 8	4.53	-3.68	-9.09	-6.20	-5.47	-4.49	-4.07
CSR 27 X N 5	6.81	-2.44	-12.12	-10.09	-1.75	4.55	-2.51
Pam 117 X CSR 27	4.11	-4.19	0.00	3.76	0.47	3.26	1.24
Pam 117 X S 8	-0.22	-1.20	-5.88	-4.38	-5.93	-6.52	-4.02
Pam 117 X N 5	4.54	0.00	2.94	3.87	5.24	-1.09	2.58
S 8 X CSR 27	7.10	-2.45	0.00	1.92	6.28	5.62	3.08
S 8 X Pam 117	5.26	1.20	2.94	1.67	-2.44	-2.17	1.08
S 8 X N 5	-0.14	-4.88	-9.09	-7.14	-2.09	2.25	-3.52
N 5 X CSR 27	-5.22	-5.49	-12.12	-8.91	-0.93	4.55	-4.69
N 5 X Pam 117	-4.11	-10.18	-5.88	4.07	7.92	1.09	-1.18
N 5 X S 8	0.72	-1.22	-3.03	-4.04	-1.51	5.62	-0.58
Pam 117 X DUN 22	-2.68	-5.39	-14.71	-10.58	-5.85	-2.17	-6.90
Pam 117 X DUN 6	3.24	-8.28	-5.88	0.65	4.80	1.09	-0.73
CSR 27 X DUN 22	-4.30	-7.36	-6.06	1.43	14.73	5.68	0.69
CSR 27 X DUN 6	-0.85	-6.51	-9.09	-7.82	5.28	-4.49	-3.91
DUN 22 X Pam 117	-3.22	-7.19	-14.71	-8.74	-4.09	0.00	-6.33
DUN 22 X CSR 27	-3.36	3.68	3.03	-1.88	1.37	0.00	0.47
DUN 22 X DUN 6	-9.80	-3.55	-3.03	-2.52	2.50	-4.49	-3.48
DUN 22 X S 8	-4.16	3.09	3.13	-3.99	-2.33	1.12	-0.52
DUN 22 X N 5	-8.72	-0.61	-3.03	-3.64	-3.73	2.33	-2.90
DUN 6 X Pam 117	0.71	-0.59	-2.94	-3.72	-7.60	-7.61	-3.63
DUN 6 X CSR 27	-2.40	-3.55	-8.82	-1.20	-0.26	-2.25	-3.08
DUN 6 X DUN 22	-15.70	-7.69	-9.09	-1.46	-5.62	-1.12	-6.78
DUN 6 X S 8	-6.21	-11.83	-9.09	-2.90	5.00	5.62	-3.24

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DUN 6 X N 5	3.39	-4.14	-3.03	-2.64	-6.52	2.25	-1.78
S 8 X DUN 22	-1.48	-3.70	-9.38	-8.27	-6.63	4.49	-4.16
S 8 X DUN 6	3.67	-8.28	-3.03	-0.25	-6.86	5.62	-1.52
N 5 X DUN 22	0.00	-1.22	0.00	0.00	-4.66	4.65	-0.21
N 5 X DUN 6	0.14	-8.88	-9.09	-4.83	-7.10	2.25	-4.59
SH6XNB4D2	4.93	-8.82	-6.45	2.57	5.41	3.26	0.15
CSR6XCSR26	-11.34	-4.91	-6.06	-0.35	1.62	1.15	-3.32
CSR2XCSR27	-6.60	-4.24	-5.88	-1.04	5.15	1.14	-1.91
MEAN	-0.92	-4.15	-5.29	-2.57	-0.42	0.95	-2.07
MAXIMUM	10.89	3.68	3.13	4.07	14.73	5.68	3.08
MINIMUM	-15.70	-11.83	-14.71	-10.58	-7.60	-7.61	-6.90
SD	5.81	3.69	5.03	4.21	5.40	3.70	2.62

Table7: Evaluation Index on Heterobeltiosis values of the hybrids during summer, 2019

Hybrids	Cocoon Yield by wt.	Single Cocoon Weight	Single Shell Weight	Shell Ratio	Filament Length	Pupation rate	Avg. Heterob-eltiosis
CSR 27 X Pam 117	70.33	54.74	60.52	60.33	53.81	47.43	65.48
CSR 27 X S 8	59.38	51.27	42.45	41.38	40.65	35.30	42.38
CSR 27 X N 5	63.30	54.63	36.42	32.14	47.54	59.73	48.33
Pam 117 X CSR 27	58.66	49.89	60.52	65.04	51.65	56.24	62.61
Pam 117 X S 8	51.20	57.99	48.83	45.70	39.80	29.81	42.55
Pam 117 X N 5	59.40	61.25	66.36	65.30	60.48	44.49	67.76
S 8 X CSR 27	63.80	54.61	60.52	60.67	62.41	62.62	69.65
S 8 X Pam 117	60.64	64.50	66.36	60.07	46.26	41.57	62.01
S 8 X N 5	51.34	48.02	42.45	39.14	46.91	53.51	44.48
N 5 X CSR 27	42.60	46.37	36.42	34.94	49.06	59.73	40.01
N 5 X Pam 117	44.51	33.66	48.83	65.77	65.44	50.38	53.39
N 5 X S 8	52.82	57.94	54.49	46.51	47.98	62.62	55.70
Pam 117 X DUN 22	46.97	46.64	31.27	30.97	39.94	41.57	31.58
Pam 117 X DUN 6	57.16	38.81	48.83	57.65	59.67	50.38	55.11
CSR 27 X DUN 22	44.18	41.30	48.47	59.50	78.06	62.78	60.52
CSR 27 X DUN 6	50.12	43.60	42.45	37.53	60.56	35.30	42.96
DUN 22 X Pam 117	46.04	41.76	31.27	35.34	43.20	47.43	33.76
DUN 22 X CSR 27	45.80	71.22	66.54	51.64	53.31	47.43	59.71
DUN 22 X DUN 6	34.72	51.63	54.49	50.12	55.41	35.30	44.61
DUN 22 X S 8	44.42	69.62	66.74	46.63	46.46	50.46	55.90
DUN 22 X N 5	36.57	59.59	54.49	47.46	43.87	53.73	46.83
DUN 6 X Pam 117	52.81	59.65	54.67	47.27	36.70	26.86	44.06
DUN 6 X CSR 27	47.45	51.63	42.98	53.25	50.30	41.35	46.15
DUN 6 X DUN 22	24.56	40.41	42.45	52.64	40.37	44.41	32.02
DUN 6 X S 8	40.90	29.19	42.45	49.22	60.04	62.62	45.55
DUN 6 X N 5	57.42	50.03	54.49	49.83	38.70	53.51	51.10
S 8 X DUN 22	49.04	51.22	41.87	36.46	38.50	59.57	42.02
S 8 X DUN 6	57.90	38.81	54.49	55.51	38.07	62.62	52.09
N 5 X DUN 22	51.58	57.94	60.52	56.10	42.15	60.00	57.12
N 5 X DUN 6	51.82	37.18	42.45	44.63	37.63	53.51	40.40

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SH6XNB4D2	60.07	37.34	47.69	62.21	60.80	56.24	58.47
CSR6XCSR26	32.07	47.94	48.47	55.27	53.78	50.54	45.25
CSR2XCSR27	40.22	49.76	48.83	53.63	60.31	50.51	50.60

DISCUSSION

The phenomenon of heterosis has been commercially exploited in agriculture, horticulture, animal husbandry, piggery, poultry and sericulture. Heterosis is the phenotypic result of gene interaction in heterozygotes and the degree of heterosis increases as the genetic similarities between two parent's decreases. By exploiting the heterosis, various silkworm-breeding efforts have significantly transformed the sericulture scenario by increased qualitative and quantitative production. Silkworm is the only animal, where hybrids are used compulsorily on the commercial scale. Systematic breeding approaches adapted by various silkworm breeders in different sericulture advanced countries [9-13] have contributed to synthesize silkworm (*B. mori* L) genotypes of desirable constitution and improvement of several quantitative and qualitative traits of economic value.

In the present study, among the 30 hybrids, only 13 hybrids showed a variable amount of relative heterosis. Hybrids having CSR 27, Pam 117, S8 and N5 as one of the parents have shown higher heterosis. The superiority of these parents has also been confirmed in a study on the identification of suitable silkworm foundation crosses [14]. Evaluation of the genetic potential of some genotypes of silkworm has also confirmed the superiority of PAM117 when studied under temperate climatic conditions [15].

The hybrids CSR 27 X Pam 117 and its reciprocal Pam 117 X CSR27 have shown the average heterosis values as 4.22 and 3.44 respectively. The top-ranking six hybrids are S8 X CSR27; CSR27 X Pam 117; Pam 117 X N5; Pam 117 X CSR27; S8 X Pam 117 and CSR27 X DUN22. These hybrids have scored >50 index value in most of the parameters studied. Among the 30 hybrids, only 8 hybrids showed a variable amount of heterobeltiosis. Hybrids having CSR 27, Pam 117, S8, N5 and DUN22 as one of the parents have shown higher heterobeltiosis. The hybrids CSR 27 X Pam 117 and its reciprocal Pam 117 X CSR27 have shown the average heterobeltiosis values as 1.99 and 1.24 respectively. Similar studies based on heterosis and heterobeltiosis has also been carried out for identification of silkworm foundation crosses [16].

The top-ranking six hybrids are S8 X CSR27; Pam 117 X N5; CSR27 X Pam 117; Pam 117 X CSR27; S8 X Pam 117 and CSR27 X DUN22. These hybrids have scored >50 index value in most of the parameters studied. The results obtained on heterosis, heterobeltiosis and Evaluation index conform to the observations of earlier workers [17-31].

CONCLUSIONS

Hybrids having CSR 27, Pam 117, S8 and N5 as one of the parents have shown higher heterosis and heterobeltiosis. Among the hybrids S 8 X CSR27 and CSR27 X Pam117 have shown higher relative heterosis and heterobeltiosis. The results have also been confirmed through evaluation index values calculated on relative heterosis and heterobeltiosis.

These hybrids can be exploited commercially during summer season under Kashmir climatic conditions.

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