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Heterosis phenomenon in mulberry silkworm

Rubia Bukhari, Kritika Sharma, Rayees Ahmad Bhat, Vinod Singh

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Authors:
R. Bukhari ✉
PG Department of Sericulture, Poonch Campus, University of Jammu, India. Pin Code-185101

K. Sharma
Division of Sericulture, SKUAST-JAMMU, Main Campus Chatha, Jammu and Kashmir India. Pin Code-180009

R. A. Bhat
Department of Zoology, Kurukshetra University, Kurukshetra, India. Pin Code-136119

V. Singh
Regional Sericultural Research Station, Central Silk Board, [Ministry of Textiles - Govt of India], Miran Sahib, Jammu, 181101, Jammu and Kashmir, India

✉ rubiabukhari@gmail.com

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Abstract

Bivoltine Silkworm double hybrids are anticipated to have added genetic plasticity to buffer against damaging effects of extremely changeable ambient conditions dominant in countries like India. The occurrence of heterosis and its usefulness in silkworm breeding studies are extensively popular and the assessments of heterosis over mid parent and better parent values are hugely valuable in determining the genetic potential of any silkworm arrangement. Studies on heterotic effect on economic traits results in over dominance and linked favorable dominant gene contributes towards higher productivity. The level of genetic diversity between the two parents used for crossing is a feasible predictor of hybrid performance. Hybrids of bivoltine silkworms are essentially preferred to overcome deleterious environmental effects expected in widely varying agro-climatic conditions during different seasons in a year, and sericultural farmers often require a silkworm hybrid which can possess inherent buffer potential to mitigate such challenges.

Keywords bivoltine breeds, *Bombyx mori*, heterosis, hybrid vigour, temperature

Introduction

Double hybrids of bivoltine silkworm are essentially preferred to overcome deleterious environmental effects expected in widely varying agro-climatic conditions. India, being a tropical country poses such challenges to any agricultural occupation in abundance, having extensive variations in ambient environmental conditions during different seasons in a year and sericultural farmers often needs a silkworm genotype or hybrid, which can hold natural buffer potential to alleviate such challenges. Heterosis, articulated as the upgrading in a trait shown by a hybrid over their mid or better parental value, is a crucial extent of genetic progress made in plant and animal selection [1]. It is widely exploited for the development of hybrid varieties in many crops and animal species [2-5]. Heterosis breeding has been recognized as the most suitable breeding methodology for augmenting yield in silkworms. The obligatory goals of growing productivity in the fastest likely time can be attained only through heterosis breeding, which is a consistent practice in this crop. The magnitude of heterosis in different cross combinations is a basic requisite for identifying crosses that exhibit a high amount of exploitable heterosis [6-7]. Therefore, a concise review study has been taken up to measure the extent of heterosis expected in double hybrids of bivoltine silkworm and thereby to assess their utility to encounter such challenges in raising commercial cocoon crops. The exploitation of heterosis through hybridization proved revolutionary in silkworm for economic traits and triggered changes in quantitative and qualitative silk output to maximize the cocoon yield, decrease in larval mortality, increase in filament length, and lowering of renditta. In this article, we have discussed a brief account of available literature that has direct/indirect bearing on the study topic.

Heterosis phenomenon in bivoltine races/breeds

Jolly et. al., [8] reported that the bivoltine race CPP_1 could withstand high temperature and low management levels and gave steady yield even with poor leaf quality. It recorded higher fecundity (610), cocoon weight (1.576 g), shell weight (0.285 g), and shell ratio (18.17%). The relative performance of pure lines viz., NB_7, NB_{18}, and Wai-1 indicated that larval survival was higher in Wai-1 (88.03 %) as against NB_7 (65.69 %) and NB_{18} (61.50 %). NB_{18} and NB_7 had a shorter larval period of 26 and 25 days, respectively, while Wai-1 had 26.70 days. Pillai et al., [9] reported that the bivoltine hybrids (KA × NB_4D_2, NB_4D_2 × KA, KA × NB_{18}, NB_4D_2 × NB_7, NB_{18} × NB_7, and NB_{18} × KA) reared on rainfed Mysore local mulberry, recorded an average cocoon yield of 45 to 50 kg/100 dfls (disease free layings) during July to February as compared to 30 to 40 kg/100 dfls during March to June. Rayar [10] observed superior performance of bivoltine races compared to the local multivoltine, Pure Mysore. Among the bivoltine races, KA was superior in cocoon weight (2.084 g), cocoon shell weight (0.410 g), and cocoon shell ratio (19.60 %), but cocoon filament was longer in NB_7 (1035.93 m) and denier was more in Saniish-18 (3.45). Trag et al., [11] evolved ten high-yielding bivoltine silkworm genotypes from Japanese F1 hybrids (5 marked and 5 plain) designated as SKUAST lines. The evolved lines significantly surpassed the conventional race (J_{122}) in mature larval weight, single cocoon, and shell weights, shell ratio, filament length, and yield. Kamili et al., [12] evolved eight bivoltine silkworm breeds (SKUAST-27 to SKUAST-34) with improved commercial characters. All the eight lines at the F15 level showed stable expression of various economic traits. Six breeds out of eight studied surpassed the checks viz. SKUAST-1, SKUAST-6, NB_4D_2, and KA in characters like cocoon yield, cocoon weight, shell weight, and shell percentage. Qadir et al., [13] crossed six promising bivoltine genotypes, JP_1A, KY_1, SM_1, JP_1B, CP_1B and J-Plain with adequate phenotypic diversity for different economic traits. The partial diallel fifteen hybrids along with control SH_6 × NB_4D_2 and parents were reared in three seasons. The data was pooled season-wise and evaluated by using the Evaluation Index (E.I.) method. Based on E.I., high ranking, season-specific hybrids for spring (CP_1B × JP_1B), summer (CP_1B × J-Plain), and autumn (CP_1B × JP_1B) seasons were identified. Rajalakshmi et al., [14] prepared twenty-three bivoltine hybrids from thirteen newly evolved bivoltine silkworm breeds. The genotypes were tested along with popular bivoltine hybrids (KA × NB_4D_2 and NB_4D_2 × NB_7) as a control to identify the promising hybrids under the hill conditions. Observations were made on eight economically important cocoon yield as well as silk yielding characters. The EI values recorded eleven hybrids ranging from 54 to 60.90 and MST Asst. selection index values of 19 to 25. Three hybrids, *viz*., CNR_{14} × D, CNR_{12} × D and CNR_{14} × O recorded E.I. values of 60.90, 59.93, and 56.70 and MST index values of 22, 19, and 20 respectively.

Hybrid vigour in different crossing systems

Rayar et al., [15] utilized five popular traditional multivoltine races *viz*., C. Nichi, Sarupat, Nistari (Normal), Nistari (Marked), and Tamil Nadu White to identify a superior multi × bivoltine hybrid in place of existing Pure Mysore × NB_{18}. Among the hybrids studied, Sarupat × NB_{18} scored superiority in full-grown larval weight (47.68 g), ten cocoon weight (22.68 g), shell weight (3.913 g), cocoon yield/25dfls (21.59 Kg), and the number of cocoons/Kg (461.50) as compared to Pure Mysore × NB_{18}. Hybrid Nistari-(Marked) x NB_{18} was significantly good in filament length (1355.25m), ERR (90.75%), and at par with Sarupat × NB_{18} in cocoon and shell weight. The larval duration was significantly short in C. Nichi × NB_{18} (647.00 hr) and ranked third in overall performance among the hybrids studied. Krishnakumar [16] observed better performance of CSR, KSO_1, and NP_2 breeds over KA and NB_4D_2 for most of the traits. CSR_5 performed better in total moulting duration (5 Days: 23 Hr), shell weight (0.380 g), silk productivity (4.09 cg/day), shell content (23.00 %), filament length (980 m), filament weight (0.31 g) and denier (2.87). CSR-2 was better in larval weight (4.30 g), larval volume (5.00 ml), cocoon yield (0.70 kg/500 larvae), fecundity (500), filament weight (0.31 g) and denier (2.87). CSR-4 recorded 25 days and 12 h of larval duration, cocoon weight (1.66 g), and denier (2.87). While, NP-2 and KSO-1 performed better in effective rate of rearing, pupation rate, and hatching percentage. Siddiqui et al., [17] initiated the bivoltine breeding program to evolve thermo-tolerant bivoltine breed with high pupation rate and moderate silk recovery at RSRS, Dehradun. Three Chinese type races *viz*., ATR-6, ATR-16, and ATR-28 and three Japanese type races viz., ATR-11, ATR-13 and ATR-29 were evolved. The pupation rate achieved was over 80 percent and the shell ratio around 20 percent. Kumar et al., [18] evolved the thermo-tolerant bivoltine breeds CSR_{18} and CSR_{19}. The rearing performance. CSR_{18} and CSR_{19} recorded 92.30 and 92.00 percent pupation; 16.80 and 16.70 kg cocoon yield/10000 larvae; 1.82 g cocoon weight; 0.399 and 0.392 g shell weight; 21.90 and 21.60 percent shell ratio; 17.20 and 17.00 percent raw silk; 1112 and 964 m filament; 2.68 and 2.91 denier and 82.00 and 83.00 percent reelability. While as KA and NB_4D_2 recorded 76.60 and 88.20 percent pupation; 15.10 and 16.40 kg cocoon yield/10000 larvae; 1.96 and 1.86 g cocoon weight; 0.334 and 0.386 g shell weight; 19.40 and 20.70 percent shell ratio; 15.10 and 16.20 percent raw silk; 878 and 857 m filament; 2.98 and 3.12 denier and 78.0 and 79.00 percent reelability.

Malik et al., [19] tested eighteen bivoltine silkworm genotypes along with two newly authorized breeds (SKAU-R-1 and SKAU-R-6). Ranking of the genotype was done by evaluation index method giving weightage to seven economically important metric traits. Five genotypes viz. SKAU-R-8, SKAU-R-23, SKAU-R-25, SKAU-R-13 and SKAU-R-7 performed better than check parent (SKAU-R-6). Maribashetty and Ahamed [20] developed a hardy bivoltine line KSO_2 with Japanese racial features. The breed was found to be superior in viability traits like cocoon yield by number, pupation rate, and fiber technological characters with a slight decrease in cocoon weight, shell weight, and shell percentage over CSR_2 and SP_2.

Heterosis and environment

Ravinder [21] studied the rearing performance of CSR18 and CSR19 breeds during summer and pre rainy seasons under Dharwad conditions. Both the breeds performed better than NB_4D_2 for most of the economic traits except for the fifth instar larval duration. Venkatesh [22] identified $CSR_4 \times CSR_2$, $CSR_2 \times CSR_4$, and $CSR_{18} \times CSR_{19}$ as potential hybrids over KSO-1 × NP-2 and NP-2 × KSO-1 for all economic traits studied under the transitional zone of northern Karnataka. Babu et al., [23] studied the combining ability effects of eight bivoltine breeds and their fifty-six hybrid combinations including reciprocals in 8 x 8 diallel crosses for six characters *viz*., cocoon yield/ 10000 larvae by weight, pupation rate, cocoon weight, cocoon shell weight, shell ratio, and filament length. All the characters were controlled by additive but predominantly by non-additive gene action as evidenced from high estimates of specific combining ability (SCA) variance compared to general combining ability (GCA) variance. The comparison of parents based on general combining ability effects indicated the superiority of APS-11 and APS-5 breeds as good combiners. The hybrid combination viz., $APS_{13} \times APS_6$, APS-5 × APS-2, and APS-5 × APS-8 were considered as most promising hybrids as they recorded highly significant specific combining ability effects for five out of six traits studied. The reciprocal combination APS-6 × APS-1 showed a positive reciprocal effect for five out of six traits. Chakravorty et al., [24] evaluated four bivoltine hybrids; $CSR_2 \times CSR_5$, $APS_5 \times APS_4$, $APS_9 \times APS_8$, and KA × NB_4D_2 for their suitability to the agro-climatic conditions of Assam during spring and autumn seasons. Among hybrids, $APS_5 \times APS_4$ was found superior to the effective rate of rearing by weight, single cocoon weight, and yield per 100 dfls in the spring season. During the autumn season, KA × NB_4D_2 was superior. Jaiswal and Goel [25] evaluated bivoltine hybrids., $SH_6 \times NB_4D_2$, $CSR_{18} \times CSR_{19}$, SH_6 × KA, and $P_5 \times NB_{18}$ in monsoon and spring season of Uttar Pradesh. SH_6 x NB_4D_2 was found to be superior in respect of major cocoon parameters in both seasons. Krishnaprasad et al., [26] studied the rearing and grainage performance of bivoltine breeds viz., CSR_2, CSR_4, CSR_5, and NB_4D_2. CSR_4 recorded significantly higher effective rate of rearing (91.96 %), cocoon weight (1.80 g), shell weight (0.380 g), shell ratio (21.24 %), pupal weight (1.40 g), moth emergence (98.00 %), fecundity (608 eggs/ laying) and hatching (98.50 %) over other breeds. Ram et al., [27] observed twelve cross combinations of single, double, three ways, and backcrosses of locally isolated silkworm lines. Evaluation Index of nine commercially important characters was worked out and ten combinations in spring and eight in autumn season recorded 50 to 59.24 E.I. values. DC_4, TC_1, and TC_2 scored EI > 55 in spring and DC_2, DC_3, DC_4 & TC_1 scored E.I between 56 to 59 during the autumn season. The authors recommended these combinations for season-specific exploitation for the Jammu division. Rao et al., [28] studied the field performance of CSR_2 × CSR_4 and CSR_2 × CSR_5 hybrids in the Kolar district of Karnataka and the hybrids recorded an average yield of 46.0 kg/100dfls with a wide range of 7.00 to 91.00 kg yield. Only 32.24 percent of the farmers recorded an average yield of more than 50.00 kg/100 dfls. December rearing season was found to be more favorable (49.03 kg/100 dfls) followed by October (47.48 kg/100 dfls). Veeraiah et al., [29] evaluated the field performance of bivoltine hybrids *viz*., CSR_2 × CSR_4, CSR_2 × CSR_5, and Gen hybrids. The field data recorded was in Gen hybrids (65.62 kg) followed by CSR hybrids (62.54 kg). A higher shell ratio (22.64 %) was also observed in Gen hybrids. During February rearing, Gen hybrids recorded a higher yield per 100 dfls (84.96 kg) followed by September and October (72.89 kg). CSR hybrids recorded higher yield per 100 dfls during June (86.24 kg), July (72.86 kg), and March (69.39 kg) season rearings.

Heterosis and silkworm breeding

Vijaykumari et al., [30] studied the performance of CSR_3 × CSR_6, CSR_{12} × CSR_6, and CSR_{16} × CSR_{17} hybrids. CSR_{12} × CSR_6 and CSR_3 × CSR_6 hybrids performed well in cocoon yield and quality when provided with 10 percent more feed and 20 percent excess bed spacing (2460 kg by shoot and 700 sq. ft. bed space), while, CSR-16 x CSR-17 performed better with 23 percent less feed and 10 percent more spacing (1728 kg by shoot and 650 sq. ft. bed space). The shoot cocoon ratio was better in hybrid CSR_{16} × CSR_{17}. Chandrashekharaiah et al., [31] developed a new productive bivoltine silkworm hybrid, APS_{77} × APS_{100}. The evolved hybrid showed better economic merit for the characters fecundity (500 to 535 eggs/laying), hatching (94.00 to 96.00 %), larval duration (22 to 23 days), survivability (92.0 to 94.00 %), cocoon yield per 10000 larvae (16.50 to 17.00 kg), cocoon weight (1.800 to 1.850 g), cocoon shell weight (38.00 to 39.00 cg), shell ratio (21.50 to 22.00 %), filament length (1050 to 1100 m), reelability (86.00 to 87.05), raw silk recovery (17.00 to 18.00 %) and neatness (91.00 to 93.00 %) over the control hybrid, APS-9 × APS-8. Mirhosieni et al., [32] studied six economical characteristics viz. the number of surviving larvae and pupae, percentage of pupal survival, single cocoon weight, single cocoon shell weight, and percentage of cocoon shell in seven lines of Chinese and Japanese origin along with their hybrids. The results showed that the general combining ability (GCA) of Japanese lines was significant for all the characteristics. The GCA of Chinese lines for resistance characters was insignificant and for productive characters was highly significant. Specific combining ability (SCA) for productive characteristics and number of surviving larvae was significant while the number of surviving pupae and its percentage was insignificant. SCA of the resistance character in the hybrid Xihang-1 × Koming-1 was higher than other crosses studied. Reddy et al., [33] developed productive bivoltine breeds, CSR_{16} and CSR_{17}. CSR_{16} (93.00 %) and CSR-17 (94.40 %) showed highest pupation over control breeds (NB_4D_2, CSR-4, KA and CSR-2). CSR-17 recorded the highest cocoon yield (19.00 kg/10000 larvae). The highest cocoon shell ratio of 22.50 and 24.80 percent was recorded in CSR-16 and CSR-17. The other characters such as filament length, filament size, reelability, and neatness did not vary much. Babu et al., [34] evaluated 47 bivoltine breeds (22 oval and 25 dumbbell) at APSSR&DI, Hindupur for three seasons over two years. The oval breeds comprise, APS_5, APS_9, APS_{11}, APS_{31}, and APS_{47} while dumbbell hybrids studied were APS_8, APS_{18}, APS_6, APS_{64}, APS_{22}, APS_{12}, and APS_{60} and were identified as potential breeding resource materials for developing promising hybrids for tropical conditions. Islam et al., [35] utilized the line × tester method for eight existing and four newly developed popular bivoltine races to estimate the combining ability to effective rate or rearing by number and by weight, single cocoon weight, shell weight, and shell ratio. Among the lines BSRTI-4, BSRTI-5 and BSRTI-7 were found to be the best general combiners. Hybrids BSRTI- 4 × CH-BV2, BSRTI-5 × CH-BV_2, and BSRTI-7 × CH-BV_2 exhibited a significant positive GCA effect for most of the economic character. Kalpana et al., [36] studied forty-two bivoltine hybrids for fine denier. Hybrids, CSR_{48} × CSR_5 was identified for their superiority over the existing bivoltine hybrids namely CSR_2 × CSR_4, CSR_2 × CSR_5, and CSR_{18} × CSR_{19} for the majority of the qualitative traits. Post cocoon testing of a large quantity of cocoons of CSR_{48} x CSR_5 resulted in the production of high quality "3A" grade silk, with filament size 2.4 d, standard size deviation 0.983 maximum size deviation 1.322, neatness 96 p, reelability 85 percent, tenacity 3.87 g/d, elongation 22.32 percent and cohesion 110 strokes. Rao et al., [37] evaluated general and specific combining abilities among popular and newly evolved thermo-tolerant bivoltine breeds and their hybrids through diallel crossing system under high temperature (36 ± 1°c) and low humidity (50 ± 5% RH) conditions. The evaluation results for 8 quantitative traits revealed that among 12 breeds, breed SR_1, SR_3, SR_4, SR_5, and SR_6 exhibited positive GCA effects for the majority of the traits studied. Among 66 hybrids studied, one hybrid SR_1 × SR_4 showed a positive SCA effect for seven traits, and three hybrids namely SR_3 x NB_4D_2, CSR_2 × SR_5, and SR_4 × CSR_4 exhibited highly significant (P<0.01) SCA effects. The most promising hybrid SR_1 × SR_4 was selected for laboratory evaluation. Kariappa et al., [38] studied general and specific combining abilities and hybrid vigor of five multivoltine and six bivoltine breeds for eight economic characters. Among the lines, BK_4 was found good general combiner, possessing significant general combining ability effects for five characters. Among the tester, KA and CSR_{18} were found good general combiners for three characters each. The hybrid BK_4 × CSR_{19} was found promising which showed significant specific combining ability effects for the five characters. Two hybrids *viz*. BK_1 × CSR_4 and PM × CSR_4 manifested significant hybrid vigor for six characters. Dandin et al., [39] evolved two bivoltine breeds *viz*., CSR_{50} and CSR_{51}. Breed CSR-5 exhibited higher productivity, while CSR_{51} was found comparatively tolerant to high temperature and disease. The breeds are currently being utilized for the bivoltine hybrid. Kumar et al., [40] evolved robust bivoltine breeds CSR_{46} and CSR_{47}. These breeds recorded higher pupation of 93.40 percent over CSR_{18} (92.30 %) and CSR_{19} (92.00 %). CSR_{46} and CSR_{47} registered 17.00 and 16.30 kg of cocoons/10000 larvae; 1.820 and 1.758 g cocoon weight; 0.424 and 0.401g shell weight; 23.30 and 22.90 percent shell percentage; 1200 and 1005 m filament, 2.72 and 2.71 denier and 85 and 83 percent reelability. Breed CSR_{18} and CSR_{19} recorded 16.80 and 16.70 kg cocoon yield; 1.82 and 1.82 g cocoon weight; 0.399 and 0.392 g shell weight; 21.90 and 21.60 shell percentage; 1112 and 964 m filament, 2.68 and 2.61 denier and 82.0 and 83.0 percent reelability. Ram et al., [41] evaluated six newly evolved bivoltine silkworm breeds and their hybrids through the Evaluation Index method of Mano. Two breeds (P_1 and P_2) and two hybrids (H_3 and H_6) were shortlisted for the spring season whereas breeding P2 and two hybrids H8 and H9for the autumn season were found suitable when compared with the popular hybrid NB_4D_2 × SH_6 under Jammu conditions. Rao et al., [42] evaluated general and specific combining abilities among popular and newly evolved thermotolerant bivoltine breeds and their hybrids through a diallel crossing system under high temperatures (36 ± 1°C) and low humidity (50 ± 5%) conditions. The evaluation result for eight quantitative traits revealed that among 12 breeds, hybrid SR_1 × SR_4 showed a positive SCA (specific combining ability) effect for seven traits. Three hybrids, SR_3 × NB_4D_2, CSR_2 × SR_5, and SR_4 × CSR_4 exhibited high significance (P<0.01) SCA effects. Promising hybrid SR_1 × SR_4 was selected for field evaluation.

Manifestation of hybrid vigour

Moorthy et al., [43] developed D6 (P) N bivoltine breed suitable for variable climatic conditions of tropics. The breed showed significantly higher survival as compared to receptor D6 (P) parent and control bivoltine breed (NB_4D_2). Rao et al., [44] evolved bivoltine breeds SR_2 and SR_5 for rearing throughout the year. Breed SR_2 recorded a pupation rate of 88.5 percent with 22.80 percent shell, while, SR_5 recorded 87.10 percent pupation and 22.2 percent shell ratio. Lakshmi and Chandrashekharaiah [45] maintained forty-seven bivoltine breeds under summer (high temperature (30-36°C) and low humidity (50-55%) conditions. Nine economic characters *viz*., fecundity, cocoon yield per 10000 larvae by weight (kg), pupation rate (%), cocoon weight (g), cocoon shell weight (g), cocoon shell ratio (%), filament length (m), reelability (%) and neatness (%) were observed. The results showed that twenty bivoltine breeds comprising of ten oval breeds scored lower values *viz*. , APS_5 (2.5764), APS_7 (3.3050), APS_{19} (3.6508), APS_{11} (4.0610), APS_9 (4.1034), APS_{31} (4.2272), APS_{27} (4.2939), APS_{45} (4.2956), APS_{39} (4.5588) and APS_{17} (4.7332) and ten peanut breedsAPS_4 (3.1863), APS_8 (3.2886), APS_{32} (3.4138), APS_{24} (3.5794), APS_{12} (3.8078), APS_{16} (3.9715) APS_{18} (4.1263), APS_{62} (4.2164), APS_6 (4.2656) and APS_{10} (4.3777) were adjudicated as potential breeding resource material for initiation of the breeding program for the development of bivoltine silkworm hybrids for tropical conditions. Reddy et al., [46] evolved a series of productive bivoltine breeds with higher survival and cocoon shell percentage. By systematic evaluation of a large number of crosses, productive hybrids namely $CSR_2 \times CSR_4$, $CSR_2 \times CSRS$, and $CSR_{16} \times CSR_{17}$ with cocoon shell percentage of 23-24; raw silk recovery of 18-19 percent and 2A-3A grade silk were developed. Significant improvements were noticed in raw silk recovery, filament length, and renditta in all hybrids and were authorized for rearing in favorable months on V1 mulberry variety with assured irrigation adopting recommended rearing technology package. Buhroo et al., [47] evaluated eleven popular bivoltine silkworm breeds *viz*., CSR_2, NB_4D_2, SK_1, CSR_4, DUN_6, SH_6, SK_6, CSR_{19}, SK_{28}, DUN_{22}, and SK_{31} for their performance during the spring season. The data generated in respect of different traits during two years was verified replication-wise and pooled. Six breeds *viz*., NB_4D_2, SK_1, SH_6, SK_6, SK_{28}, and SK_{31} were short-listed on higher EI values (>50) and suggested that these breeds can be used for the preparation of season-specific hybrids to push up bivoltine silk productivity under specified environmental conditions in the Kashmir valley. Gowda et al., [48] evaluated 113 bivoltine silkworm breeds for their performance during the winter season based on 12 important quantitative traits. After preliminary screening, and on per se performance, top-performing breeds were identified after evaluating many economic parameters. The selected bivoltine breeds were analyzed for their consistency in the expression of the quantitative traits by adopting the multiple trait evaluation index method. Among the identified bivoltine breeds, BBE_{0272} expressed better performance in 8 parameters whereas the remaining 5 accessions (BBE_{0197}, BBE_{0222}, BBE_{0187}, BBE_{0186}, and BBI_{0235}) were found performing better in 7 economic parameters only.

Conclusion

One of the chief objectives of the breeders is to suggest silkworm breeds/hybrids to farmers that are stable under diverse environmental conditions and diminish the possibility of dropping below a particular yield level. Silkworm breeds that are nurtured over a sequence of environments showing less differences are considered stable. Therefore, it becomes indispensable to develop bivoltine breeds/hybrids which can deal with high-temperature growth environments. To introduce bivoltine races in a tropical country like India, it is essential to have steadiness in cocoon crops under high-temperature environment. Due to the bad performance of fruitful bivoltine hybrids during the summer season, importance should be given to develop bivoltine silkworm breeds which are appropriate to tropical conditions to attain the main objective of developing bivoltine sericulture with quality raw silk.

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