Evaluation ofreproductiveand developmental traitsin new breeds and hybrids of bivoltine silkworm (*Bombyx mori* L.)

ABSTRACT

This study aimed to evaluate the potential of new bivoltine silkworm parental breeds and their hybrids inexpressing reproductive and developmental traits critical for optimizing silk production and ensuring sericulture sustainability. Five thermotolerant pure breeds (B1, B2, B4, B6 and B8) and four popular CSR breeds (CSR2, CSR27, CSR6, and CSR26) were utilized to develop six foundation crosses and eight double hybrids. These parental breeds and hybrids were assessed for ten traits. Results demonstrated that among the parental breeds, B1 exhibited superior performance across six out of the ten evaluated traits, including fecundity (524.00), hatching percentage (98.67%), dead eggs (1.33%), pupal weight (1.31 g), pupation rate (96.84%) and cumulative survival index (CSI) (93.84%). Among the foundation crosses, B1× B2 excelled in fecundity (553.67), larval mortality (2.67%), pupal weight (1.53 g), ERR (97.33%) and CSI (93.27%).FC2 exhibited better performance in hatching percentage (97.60%), dead eggs percentage (2.40%), fifth instar larval duration (157.21 h), larval weight (35.64 g)and pupation rate (96.33%). Within the double hybrids, (B1 × B2) × (FC1) demonstrated superior performance in fecundity (614.33), larval mortality (1.41%), pupal weight (2.06 g), ERR (98.59%)and CSI (97.24%). FC2 × FC1 excelled in larval duration (141.11 h), fifth instar larval weight (51.96 g) and pupation rate (98.94%). Overall, the results indicated significant improvements in all traits of double hybrids compared to their parental breeds and foundation crosses. These enhancements may be attributed to inherent advancements, suggesting potential for field testing and further development. The newly identified breeds and foundation crosses offer promise for use in silkworm breeding, particularly in developing new double hybrids as alternatives to established CSR breeds and hybrids.

Keywords: *Bombyx mori*,double hybrids, developmental traits,foundation crosses, parental breeds, reproductive traits.

Introduction:

Silkworm rearing has been a cornerstone of sericulture, contributing significantly to the global textile industry. Mulberry silkworm(*Bombyx mori* L.) is an important economic insect in the commercial production of silk, a natural fiber prized for its luster, strength and breathability. India, being a tropical country, predominantly relies on multivoltine × bivoltine hybrids, the resulting raw silk often falls short of international quality standards compared to bivoltine x bivoltine hybrids (Datta and Pershad, 2002).Emphasizing bivoltine sericulture is crucial to meet these benchmarks and enhance silk production. In recent years, efforts have intensified to enhance silk production and ensure the sustainability of sericulture through the development of new bivoltine silkworm breeds and hybrids. Bivoltine silkworm breeds offer an efficient means to increase silk yield. Nevertheless, with climate change presenting challenges such as fluctuating temperatures, there is a growing need for silkworm breeds and hybrids capable of thriving under these conditions while maintaining high cocoon quality to sustain the sericulture industry's growth.

Traditional breeding methods have successfully produced productive silkworm breeds in India. However, pure silkworm races often exhibit a negative correlation between high cocoon shell ratio and low pupation rate, necessitating careful management. While hybrids offer the potential for high yields, obtaining a sufficient number of eggs from parent cocoons remains a challenge. To address this, double hybrid production through foundation crosses (dumbbell × dumbbell or oval × oval) has emerged as a solution for increased egg numbers and recovery. These foundation crosses are not only easier for farmers to manage but also result in healthier pupae compared to single-parent lines (Nirmal Kumar et al., 1998). However, continuous inbreeding leads to the deterioration of parental stock performance, necessitating the timely evolution of new, productive breeds and hybrids to replace weaker counterpart (Shabir et al., 2017). The introduction of the new season and region-specific silkworm hybrids ensures higher gain for both the primary producers and reelers alike.

The evaluation of reproductive and developmental traits in the new bivoltine breeds is crucial for selecting high-performing breeds and hybrids that can contribute to improved silk production efficiency and ultimately, a more sustainable sericulture industry. Understanding the genetic diversity and performance of different silkworm strains is essential for breeders seeking to develop superior varieties with desirable traits. This study focuses on ten key traits*viz.*,fecundity, hatching& dead egg percentage, larval mortality, fifth instar larval duration& larval weight, pupal weight, pupation rate, ERR and cumulative survival index (CSI). Assessing the performance of both parental breeds and their hybrid progeny is crucial for identifying promising individuals with superior traits, thus facilitating their selection for further advancement in breeding programs.

Materials and Methods:

The present study was conductedat the Department of Sericulture, University of Agricultural Sciences, GKVK, Bengaluru during 2022-2023. Five thermotolerant bivoltine silkworm breeds *viz.*, B1, B2, B4 (oval cocoon spinning breeds) B6 and B8 (pea nut cocoon spinning breeds)and four productiveCSR parental races (CSR2, CSR27, CSR6 and CSR26) wereutilized for the preparation of hybrids. Accordingly, F_1's of four oval cocoon spinning foundation crosses (FCs)*viz*., B1× B2, B1× B4, B2× B4 &FC2 (CSR2 × CSR27) and two peanut cocoon spinningFCs*viz*., B6 × B8& FC1(CSR6 × CSR26) were developed.Oval and dumb-bell FCs were used(Oval × Oval) × (dumb-bell × dumb-bell) in double hybrids preparation. By using six foundation crosses, eight double hybrids were developed *viz.*,(B1 × B2) × (B6 × B8), (B1 × B4) × (B6 × B8), (B2 × B4) × (B6 × B8), (FC2) × (B6 × B8), (B1× B2) × (FC1), (B1 × B4) × (FC1), (B2 × B4) × (FC1) and FC2 × FC1.

Silkworm rearing of parental breeds and development of foundation crosses and double hybridswere done by following the suitable rearing method and standard hybridization procedures (Dandin and Giridhar, 2014). Fresh V-1 mulberry leaves were fed to all the silkworm breeds and hybrids until spinning. After third moult, 200 larvae with three replications each for all the breeds and hybrids were maintained.Reproductive parameters such as fecundity, hatching rate, percentage of dead eggsand pupation rate, along with developmental traits including larval mortality, fifth instar larval weight, larval duration, pupal weight, effective rate of rearing (ERR)and cumulative survival indexwere assessed for all parental breeds and hybrids.Using a completely randomized design, the mean data gathered from two rearing was analysed using OP STAT software. Duncan's Multiple Range Test (DMRT) was used to compare the mean values of the study (Duncan, 1955). To assess the overall survivability of silkworms, cumulative survival index (CSI) (Sahana et al., 2021) was calculated using the formula,

CSI=[(ERR%/100) × (per cent pupation/100)] ×100

where, CSI- Cumulative Survival Index; ERR- Effective Rate of Rearing

Results and Discussion:

The rearing performance of all the parental breeds, foundation crosses and double hybrids with itsstatistical analysis is presented in tables1, 2 and 3 respectively.

Fecundity:

Significant variation ($P < 0.05$) in fecundity was observed in parents and their hybrids.Fecundity is a hereditary character and its expression is in direct correlation with severalphysiological and ecological factors. From breeding point of view,it plays vital role because it denotes the efficacy of any silkworm hybrid to be selected as a parental breed for grainage purpose.Among the parental breeds, B1 recorded significantly highest fecundity of 524.00 followed by CSR2 (512.00). In foundation crosses, B1× B2 recordedsignificantly highest fecundity (553.67)followed by FC2 (541.67). In double hybrids, (B1 × B2) × FC1 exhibited significantly highest fecundity of 614.33 surpassing the control FC2 × FC1 (597.33).

According to Tazima (1957), fecundity mainly depends upon genotype of mother moth and environmental conditions at the time of oviposition. Variation in fecundity was found in different breeds and hybrids, which resulted in fluctuation of egg number per brood. Present results are consistent with earlier studies. Bindroo *et al*. (2014) recorded a fecundity of 540.00 in CSR2 × CSR4 and Jayachamaraja recorded highest fecundity (625.00), surpassing Krishnaraja (620.00).

Hatching percentage:

Significant variation in hatching percentage was observed in parents and their hybrids.Hatching percentage serves as a key commercial trait for hybrid validation, reflecting egg viability.Insect survival and development are subject to ecological conditions and genetic factors, influencing their biological activities (Srivastava and Upadhyay, 2013). Among parental breeds, B1 recorded significantly highesthatching percentage of98.67 per cent followed byB4 (97.44%).In foundation crosses, FC2 recorded significantly highest hatching percentage (97.60%) followed by FC1(96.30%).In double hybrids, (B1 × B4) × FC1 exhibited significantly highest hatching percentage of 97.42 per cent followed by (B1 × B2) × FC1 (97.23%).

These results are in conformity with earlier studies by Bharath Kumar et al. (2019) who recorded highest hatching percentage in CSR50 × APS5 (97.25%) compared to FC2 (96.27%).Higher hatching percentages of some breeds and hybrids could be attributed to their genetic traits favouring better egg viability, embryonic development and the physiological condition of the female moth(Buhroo et al., 2017). 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.

Dead eggs percentage:

Significant variation (P < 0.05) in dead eggs was observed in parents and their hybrids.Dead eggs percentage indicated the proportion of nonviable eggs, reflecting egg quality and potential issues with female moth health, mating or rearing conditions. Among nine parental breeds, B1 recorded significantly least dead egg percentage of1.33 per cent compared to control followed by B4 (2.16%).In foundation crosses, FC2 recorded significantlyleast dead egg percentage (2.40%)followed by FC1 (3.70%). In double hybrids, (B1 × B4) × FC1 exhibited significantly least dead egg percentage of 2.52 per cent followed by (B1 × B2) × FC1 (2.77%).

The current findings corroborate with prior research. Kumar and Singh(2012) reported least dead egg percentage in foundation crosses in HL1 × HL7 (1.32%) compared to the control CSR2 × CSR4 (2.78%).Considerable amount of reduction in dead eggs percentage was noticed in double hybrids compared to the pure races and foundation crosses (Narayana swamy et al., 1991).

Larval mortality:

Significant variation (P < 0.05) in larval mortality was observed in parents and their hybrids.Among parental breeds, CSR2 recorded significantly least larval mortality of 3.01per cent followed by B1 (3.09%). In foundation crosses, B1 × B2 recorded significantly least larval mortality (2.67%) compared to CSR breeds, followed by B1 × B4 (2.79%). In double hybrids, (B1 × B4) × FC1 exhibited significantly least larval mortality of 1.41 per cent followed by (B1 × B2) × FC1 (1.59%) both surpassing FC2 × FC1.

Comparable findings have been reported in earlier studies. Usama *et al*. (2017) reported least mortality in O323 × H155 (0.70%), followed by J325 × O323 (1.05%). Further, Sajgotra *et al*. (2018) reported least mortality rate in CSR26 × CSR27 (3.67%).The present findings pertaining to larval mortality underline the influence of environmental conditions and genetic traits on silkworm survival rates. Hybrids with lower mortality are considered better performers because they are less affected by the external factors.

Fifth instar Larval duration:

Fifth instar larval duration was calculated from the first day of the fifth instar until 50 per cent spinning.Significant variation (P < 0.05) in fifth instar larval mortality was observed in parents and their hybrids.Larval duration is considered as an important attribute of economic value in sericulture as the reduction in larval duration would not only help in minimizing the quantum of the food consumption by the insect but also in completion of larval period in desirable time period besides minimizing the labour requirement (Rahmathulla et al., 2012). Among parental breeds, CSR2 recorded significantly least fifth instar larval duration of 160.21 h followed by B4 (164.28 h). In foundation crosses, FC2 recordedsignificantly least fifth instar larval duration (157.21h), followed by B1 × B2 (159.21 h). In double hybrids, (B2 × B4) × (B6 × B8) exhibited significantly least fifth instar larval duration of 134.92 h, followed by (B1 × B4) × FC1 (140.26 h).

In a recent study, Monika *et al*. (2022) reported highest fifth instar larval duration in FC1 × FC2 (149.52 h), followed by PO3 × ND5 (149.28 h) which are shorter compared to the present findings.In *B. mori*, the larval duration, while genetically determined, is also influenced by various factors, including macro and micro-environmental conditions, as well as the rearing skills (Rajalakshmi et al., 1998). This diversity can be attributed to the hybrids responsiveness to rearing practices and *in-vitro* conditions maintained during the rearing period.

Fifth instar Larval weight:

Significant variation in fifth instar larval weight was observed in parents and their hybrids.Fifth instar arval weight is one of the important parameter that determines not only the health of the larvae, but also the quality of the cocoons spun [Nguku et al., 2007)].Among parental breeds, CSR2 recorded significantly highest fifth instar larval weight of 31.47 g followed by B1 (31.27 g). In foundation crosses, FC2 recorded significantlyhighest fifth instar larval weight (35.64 g), followed by B1 × B4 (35.39 g). In double hybrids, FC2 × FC1 exhibited significantly highest fifth instar larval weight of 51.96 g, followed by (B1 × B2) × FC1 (48.33 g).

The observed variation in larval weight among hybrids aligns with earlier studies. Munemanik *et al*. (2018) reported highest fifth instar larval weight in FC2 × FC1 (44.04 g/ 10 larvae) followed by CSR16 × CSR17 (43.91 g/ 10 larvae). The differences in grownup larval weight among the breeds and hybrids studied could be attributed to the racial character, differences in degree of assimilation and the quality and quantity of feed consumed by the larvae which has a direct bearing on the growth and development of larvae. This superiority can be attributed to their good genetic variability, potentially favourable combinations of parental traits and responsive growth patterns, which collectively contribute to enhanced larval growth and weight gain(Buhroo *et al.* 2017).

Pupal weight:

Significant variation in pupal weight was observed in parents and their hybrids.The difference between cocoon and shell weight is the weight of the pupa and are considered important with respect to commercial traits evaluated for productivity in sericulture [Gaviria et al., 2006].Among parental breeds, B1 recorded significantly highest pupal weight of 1.31 g followed by B4 (1.28 g). In foundation crosses,B1 × B2 recordedsignificantlyhighest pupal weight (1.53 g), followed by FC2 (1.41 g). In double hybrids, FC2 × FC1 exhibited significantly highest pupal weight of 2.06 g, followed by (B1 × B2) × FC1 (2.03 g).

Jayashree et al. (2020) noted the maximum pupal weight in F_1's of the same breeds used in the present study *viz.*, B1 × B4 (1.46 g) followed by B1 × B8 and B4 × B1 (1.44 g each). Chandrakala *et al*. (2022) documented highest pupal weight in the hybrid B1 × CSR4 (1.54 g), followed by B4 × CSR4 (1.52 g). The pupal weight of *B. mori* has been noticed to be influenced by the variation in the level of secreted hormones and genotype variation. Higher pupal weight attained by some breeds and hybrids indicates their better feed consumption and good larval growth during the larval periods which could also be attributed to better larval growth period and reduced meltage during pupal development (Pardeshi et al., 2014)

ERR:

No significant difference ($P < 0.05$) was observed for this trait among parents, foundation crosses and double hybrids.A higher value of ERR is indicative of higher survival and thereby silk productivity. It is important to study the survival probability of silkworm breeds and hybrids. Among parental breeds, CSR2 recordedhighest ERR of 96.99 per centfollowed by B1 (96.91) and all other pure breeds which are on par statistically.In foundation crosses,B1 × B2 recorded highest ERR (97.33%), followed by FC2 (97.21%) and other FCs which are on par with each other. In double hybrids, (B1 × B4) × FC1 exhibited highest ERR of 98.59 per cent followed by (B1 × B2) × FC1 (98.41%) and other double hybrids which are on par statistically.

The present outcomes are supported by Sajgotra *et al.* (2018) who reported highest ERR (96.33%) in CSR26 × CSR27.In a thermotolerant double hybrid TT21 × TT56, highest ERR of 89.20 per cent was observed, surpassing FC1 × FC2 (82.24%) (Sivaprasad et al., 2018). Survival percentage is directly related with the cocoon yield and hence more weight age has to be given for survival while evaluating the FCs of the hybrids and identifying them for exploitation

(Rajalakshmi and saktivel, 2019). The insignificant variation for larval survival can be attributed to uniform rearing condition and non-occurrence of disease. In the preset study, equally superior performance of some hybrids concerning ERRcould be attributed to optimum rearing conditions, selection of parent lines with desirable traits, resulting in hybrids that inherit advantageous genetic characteristics, efficient growth patterns and potentially optimized metabolic processes.

Pupation rate:

No significant difference (P< 0.05) was observed for pupation among parents, foundation crosses and double hybrids.Pupation rate signifies the number of cocoons containing live pupae, holds paramount importance as it directly impacts cocoon yield and the quality of silk production(Bharat Kumar et al., 2019). It is particularly crucial for seed cocoon crops, as far as farmers are concerned because it fetches better price for their cocoons. To determine the variability of a breed/hybrid it is one of the important economic characters. Among parental breeds, B1 recordedhighest pupation rate of 96.84per centfollowed by CSR 2 (96.68%) and all other pure breeds which are on par statistically. In foundation crosses, FC2recorded highest pupation rate (96.33%), followed by B1 × B4 (95.29%) and all otherFCs which are on par statistically. In double hybrids, FC2 × FC1 exhibited highest pupation rateof 98.94 per cent, followed by (B1 × B2) × FC1 (98.78%) and all other double hybrids which are on par statistically.

The observations follow the findings of Bindroo *et al*. (2014) who observed highest pupation rate of 95.20 per cent in Jayachamaraja surpassing Krishnaraja (95.10%). There is significant improvement in the rate of pupation in foundation crosses and double hybrids over parental breeds due to positive heterosis.Good 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. The genetic and environmental interaction is more reflected in this character(Sharma and Bali., 2019).The insignificant variation in pupation ratecould be attributed to the controlled rearing environment provided, which optimized temperature and humidity conditions, fostering favourable pupal development and survival for each hybrid combination.

cumulative survival index:

No significant difference (P< 0.05) was observed for pupation among parents, foundation crosses and double hybrids.CSI is determined by combining effective rate of rearing and pupation rates, serves as a comprehensive measure of the overall survival ability of breeds and hybrids across their entire lifecycle, from the larval stage to moth emergence. ERR and pupation rate being of paramount importance in deciding the survivability of silkworm breeds and hybrids, the cumulative survival indices were calculated to know the overall survival abilityutilizing those values for all thebreeds and hybrids in the study.

Among nine parental breeds, B1 recorded significantly highest pupation rate of 93.84 % followed by CSR 2 (93.76). In foundation crosses,B1 × B4 recorded highest pupation rate (93.27%), followed by FC2 (92.63%). Among eight double hybrids, (B1 × B2) × FC1 exhibited significantly highest pupation rate of 97.24%, followed by (B1 × B4) × FC1 (97.21%). These findings align with the outcomes reported by Sahana *et al*. (2022), who observed a 100 per cent CSI in Pure Mysore, followed by CSR2 (91.11%) and B4 (90.67%).

Conclusion:

In summary, the parental breeds demonstrated their purity and consistency, maintaining the original breed characteristics. Both foundation crosses and double hybrids exhibited a higher level of hybrid vigor surpassing the parental breeds.Double crosses have shown greater variability, followed closely by foundation crosses.Parental breeds B1, CSR2 and B4 consistently perform well across all evaluated traits, suggesting their suitability as oval parents in hybrid preparation. Similarly, foundation crosses B1 × B2, FC2and B1 × B4 also demonstrate positive traits across all the traits. Double hybrids (B1 × B2) × (FC1) and (B1 × B4) × (FC1) performedon par with control (FC2 × FC1) and showed promising performance. Consequently, these new double hybrids can be further evaluated in field trials and considered as viable alternatives to the FC2 × FC1 hybrid.

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Table 1: Performance of oval and dumbbell parental breeds for reproductive and developmental traits

Breeds	Fecundity	Hatching	Dead eggs	Larval mortality	Larval duration	Larval weight	Pupal weight	ERR	Pupation rate	CSI
B1	524.00^{a}	98.67^{a}	1.33^{h}	3.09^{f}	165.48^{cd}	31.27^{a}	1.31^{a}	96.91^{a}	96.84^{a}	93.84^{a}
B2	477.00^{d}	95.47^{abcd}	4.53^{d}	3.87^{d}	178.54^{a}	29.87^{abc}	1.07^{cd}	96.13^{a}	96.06^{a}	92.34^{a}
B4	509.00^{ab}	97.84^{ab}	2.16^{g}	3.57^{e}	164.28^{cd}	30.11^{abc}	1.28^{a}	96.43^{a}	96.64^{a}	93.18^{a}
CSR2	512.00^{ab}	97.44^{ab}	2.56^{f}	3.01^{f}	160.21^{d}	31.47^{a}	1.26^{a}	96.99^{a}	96.68^{a}	93.76^{a}
CSR27	501.00^{abc}	95.97^{abc}	4.03^{e}	4.02^{cd}	176.87^{a}	30.67^{ab}	1.18^{b}	95.98^{a}	95.22^{a}	91.39^{a}
B6	471.00^{d}	92.19^{d}	7.81^{a}	6.03^{a}	177.57^{a}	27.65^{d}	1.02^{d}	93.97^{a}	92.33^{a}	86.76^{c}
B8	464.00^{d}	93.21^{cd}	6.79^{b}	5.98^{a}	180.67^{a}	28.67^{cd}	1.01^{d}	94.02^{a}	93.29^{a}	87.71^{bc}
CSR6	492.00^{bcd}	94.61^{bcd}	5.39^{c}	4.17^{c}	175.34^{ab}	29.34^{bcd}	1.05^{cd}	95.83^{a}	94.09^{a}	90.16^{abc}
CSR26	506.00^{ab}	96.01^{abc}	3.99^{e}	4.47^{b}	170.29^{bc}	29.47^{bc}	1.10^{c}	95.53^{a}	94.98^{a}	90.73^{ab}
F Test	*	*	*	*	*	*	*	NA	NA	*
S.Em ±	8.509	1.009	0.056	0.056	2.052	0.536	0.021	1.667	1.642	1.103
CD@5%	25.476	3.021	0.168	0.168	6.143	1.606	0.062	NA	NA	3.302
CV (%)	2.977	1.826	2.265	2.287	2.064	3.114	3.126	3.682	2.99	2.097

Table 2: Performance of oval and dumbbell foundation crosses for reproductive and developmental traits

Breeds	Fecundity	Hatching	Dead eggs	Larval mortality	Larval duration	Larval weight	Pupal weight	ERR	Pupation rate	CSI
B1 × B2	553.67^{a}	95.2^{ab}	4.8^{c}	2.67^{e}	159.21^{c}	34.71^{a}	1.53^{a}	97.33^{a}	94.98^{abc}	93.27^{a}
B1 × B4	537.33^{ab}	96.1^{ab}	3.9^{d}	2.79^{de}	165.18^{b}	35.39^{a}	1.4^{b}	97.21^{a}	95.29^{ab}	92.44^{ab}
B2 × B4	522.67^{b}	92.34^{b}	7.66^{a}	3.89^{b}	174.11^{a}	31.41^{b}	1.09^{d}	96.11^{a}	93.22^{bc}	89.59^{ab}
FC2	541.67^{ab}	97.6^{a}	2.4^{f}	3.17^{c}	157.21^{c}	35.64^{a}	1.41^{b}	96.83^{a}	96.33^{a}	92.63^{ab}
B6 × B8	497^{c}	93.98^{ab}	6.02^{b}	4.42^{a}	167.67^{b}	30.62^{b}	1.07^{d}	95.58^{a}	92.33^{c}	88.24^{b}
FC1	529.67^{b}	96.3^{ab}	3.07^{e}	2.86^{d}	165.56^{b}	31.96^{b}	1.28^{c}	97.14^{a}	94.29^{abc}	91.59^{ab}
F Test	*	*	*	*	*	*	*	NA	NA	NA
S.Em ±	6.523	1.324	0.068	0.044	1.267	0.59	0.014	1.684	0.83	1.398
CD@5%	20.32	0.056	0.211	0.139	3.948	1.839	0.043	NA	NA	NA
CV (%)	2.13	2.407	2.529	2.334	1.332	3.072	1.827	3.016	1.524	2.653

Table 3: Performance of double hybrids for reproductive and developmental traits

Double hybrids	Fecundity (No.)	Hatching (%)	Dead eggs (%)	Larval mortality (%)	Larval duration (h)	Fifth instar larval weight (g/10 larvae)	Pupal weight (g)	ERR (%)	Pupation rate (%)	CSI (%)
(B1 × B2) × (B6 × B8)	522^{cd}	94.81^{a}	2.77^{f}	3.32^{d}	148.81^{bc}	43.44^{de}	1.92^{b}	96.68^{a}	97.29a	94.05a
(B1 × B2) × (FC1) $	614.33^{a}	97.23^{a}	4.92^{d}	1.41^{g}	142.11^{cd}	48.33^{b}	2.06^{a}	98.59^{a}	98.78a	97.24a
(B1 × B4) × (B6 × B8)	501.33^{d}	95.08^{a}	2.52^{f}	4.09^{b}	140.81^{cd}	43.89^{de}	1.78^{c}	95.91^{a}	97.05a	93.08a
(B1 × B4) × (FC1) $	568^{b}	97.42^{a}	6.48^{a}	1.59^{g}	140.26^{cd}	47.1^{b}	2.03^{a}	98.41^{a}	98.64a	97.21a
(B2 × B4) × (B6 × B8)	498.67^{d}	93.52^{a}	5.52^{b}	4.73^{a}	134.92^{d}	42.55^{e}	1.85^{bc}	95.27^{a}	97.01a	92.42a
(B2 × B4) × (FC1) $	528.33^{c}	94.48^{a}	3.18^{e}	3.61^{c}	141.11^{cd}	46.44^{bc}	2.03^{a}	96.39^{a}	98.41a	94.85a
(FC2) $ × (B6 × B8)	541.33^{c}	96.65^{a}	3.35^{e}	3.13^{e}	156.11^{b}	44.65^{cd}	1.92^{b}	96.87^{a}	97.65a	95.59a
FC2 $ × FC1 $	597.33^{a}	96.82^{a}	5.19^{c}	1.91^{f}	166.81^{a}	51.96^{a}	2.02^{a}	98.09^{a}	98.94a	97.05a
F Test	*	*	*	*	*	*	*	NA	NA	NA
S.Em ±	7.712	1.551	0.086	0.055	2.624	0.601	0.03	1.205	1.128	1.635
CD@5%	23.319	0.087	0.261	0.166	7.934	1.819	0.091	NA	NA	NA
CV (%)	2.444	2.806	3.527	3.197	3.105	2.263	2.678	2.15	1.994	2.975