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Heterosis Pattern and Commercial Prospective of Assorted F_1 Hybrids of Indian Tropical Tasar Silkworm, *Antheraea mylitta* Drury

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Abstract: Assorted F_1 hybrids and reciprocals of divergent tasar ecoraces of *Antheraea mylitta* viz., Daba, Jata and Raily were evaluated for relative heterosis. The Daba×Jata [R] (random female and male) and its reciprocal hybrids have recorded high positive heterosis for fecundity (+17.45 and +1.70%), egg fertility (+11.58 and +7.20%), shell weight (+34.76 and +27.44%), silk ratio (+30.49 and +24.15%) and silk yields (+94.33 and +82.51%), respectively. Daba× Jata [P×S] (high pupal female and high shell male) hybrid, although recorded positive heterosis for all traits, but was next to random parental hybrids. The Daba×Jata [P×P] (high pupal female and high pupal male) combination and its reciprocal have shown positive heterosis only for fecundity (+22.13 and +35.89%), while Daba×Jata [S×S] (high shell female and high shell male) hybrid and its reciprocal are positive in shell weight (+45.12 and +33.54%) and silk ratios (+26.95 and 27.95%). All hybrids of Daba×Raily including reciprocals have shown negative heterosis for fecundity and silk yields. However, Daba×Raily [R], [S×S], [P×S] hybrids and their reciprocals have shown uneven positive heterosis for egg fertility (+1.65 to +20.74%), shell weight (+7.56 to +56.98%) and silk ratios (+1.02 to +54%). In general, all reciprocal F_1 hybrids of Daba, Jata and Raily ecoraces have shown lesser heterosis. The dissimilar performance of assorted F_1 hybrids and reciprocals of Daba, Jata and Raily ecoraces reveal their varied potential on relative heterosis. However, the study infers commercial prospective and optimal seed cocoon expediency in Daba and Jata ecoraces as F_1 hybrids [R] and reciprocals. While, the trait specific positive heterosis in high pupal and high shell hybrids (assorted F_1 hybrids) have application in segregating lines with desired traits and aggregating them in to needy one(s).

Key words: *Antheraea mylitta*, Daba, F_1 hybrids, heterosis, Jata, Raily, reciprocals

INTRODUCTION

The biological selection of parents on specific trait will lead to explicit individuals by their progeny in later generations, an advantage to have specific genotype of breeding application (Aruga, 1994; Singh *et al*., 2002; Moorthy *et al*., 2007). The strong heterosis and large variation among assorted hybrids supports further improvement of breed as per requirement (Li *et al*., 1998; Reddy *et al*., 2008). The crossbreeding is a simple method to

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increase health and efficiency of many animals causing heterosis by introducing and maintaining gene interactions (Siddiqui and Sengupta, 1993; Nagaraju *et al*., 1996; Puttaraju and Rajanna, 1997; Moghaddam *et al*., 2005). To develop productive hybrids and high yielding segregants in *Antheraea mylitta*, the pre requisites are selection of genetically diverged parental ecoraces, identification of commercial traits with heterotic potential (Sengupta *et al*., 1987; Siddiqui, 1997). The Daba ecorace reported as good combiner for silk yield and its F_1 hybrids have shown better heterosis through dominance of gene action (Suryanarayana *et al*., 1987; Siddiqui *et al*., 1988), while silkworm crosses of congenic and syngenic lines provide better heterosis over conventional hybrids (Verma *et al*., 2005). The Daba×Modal and Raily x Laria hybrid combinations recorded high heterosis in absolute silk yield with collective effect of fecundity, egg hatching, Effective Rate of Rearing (ERR) and shell weight (Siddiqui, 1997; Sinha *et al*., 2001; Singh *et al*., 2002). The variation in temperature, nutritional status, feeding duration and larval density influence body plasticity, thus the performance of breed and its voltinism (He and Wang, 2006; Hansda *et al*., 2008) and environment regulates the genotypic expression to produce different phenotypes (Zhao *et al*., 2007; Kumar *et al*., 2008). However, the information on parental selection with desired traits for hybridization and their trait related heterotic pattern in tropical tasar silkworm is very scanty. Hence, the hybridization conducted with parents of specific pupal and shell values using divergent (semi domesticated and wild) geographic ecoraces i.e., Daba (Jharkhand), Jata (Orissa) and Raily (Chhattisgarh) to cram the potential of heterosis on egg and silk related traits for commercial application.

MATERIALS AND METHODS

The study including the generation of parental seed cocoons, preparation of assorted F_1 hybrids and their field evaluation have been carried out on economic plantation, *Terminalia tomentosa* (Wand A) at field laboratory of Central Tasar Research and Training Institute (CTR and TI), Ranchi, India successively for two years during 2007 and 2008.

Generation of Parental Seed Cocoons

The parental stocks of ecoraces viz., Daba, Jata and Raily of tasar silkworm, *Antheraea mylitta* were raised during the seed crop rearing season (July-August) of two successive years following integrated package of tasar silkworm rearing in a Randomized Complete Block Design (RCBD) with three replications on economic plantation, *Terminalia tomentosa* at field laboratory of Central Tasar Research and Training Institute, Ranchi, to minimize the problems of erratic emergence and non synchronization in moth coupling (experienced with wild stocks collected from nature), while preparing the Disease free layings (Dfls) of varied F_1 hybrid combinations and reciprocals. The stocks of three parents were maintained for further experimentation for two years over seed and commercial crop seasons.

Preparation of Assorted F_1 Hybrids

The ecorace wise male and female cocoons are segregated based on pupal and shell weights and preserved in separate cocoon cages at the grainage house of the research institute. The male and female moths emerged out of said non-diapausing cocoon batches of three divergent ecoraces were used for preparation of Dfls following integrated package of tasar silkworm seed production. The ecorace wise selfing, general and selective F_1 hybrid combinations were prepared along with their reciprocals based on high pupal [P×P], high shell [S×S] and high pupal and high shell [P×S] weights along with control i.e., random parents [R] at grainage house of CTR and TI, Ranchi during September for two successive years for their evaluation in commercial crop (October-December) season.

Evaluation of F_1 Hybrids and Reciprocals

The four general and twelve selective F_1 hybrid and reciprocal combinations along with three parents, nineteen in totals, were reared in a Randomized Complete Block Design (RCBD) with three replications for each treatment on economic plantation, *Terminalia tomentosa* at field laboratory of CSR and TI, Ranchi, India in commercial crop rearing season (October-December) for two successive years. The total number of eggs, fertilized eggs of one Dfl and silk yield based on average shell weight and number of cocoons harvested per Dfl in respect of parents as well as hybrids were considered as one replication and single shell weight, silk ratios were calculated with equal number (twenty) of random cocoon samples. The observations recorded on fecundity, egg fertility, shell weight, silk ratio and silk yield were subjected for statistical analysis.

RESULTS

Comparative Performance (*in situ*) of Parental Ecoraces

The performance levels of parental ecoraces viz., Daba, Jata and Raily under *in situ* habitats (Table 1) show variations in respect of their place of origin, food plants and voltinism in addition to commercial traits like fecundity, egg fertility, shell weight, silk ratio and silk yield. This indicates substantial phenotypic variability and genetic diversity besides their nativity in chosen parental material for hybridization. The semi domesticated Daba parent show superiority in egg fertility (190 No.) and silk yield (108 g) in spite of lesser fecundity (220 No.), shell weight (1.80 g) and silk ratios (15.00%). While, the other two wild ecoraces Jata and Raily could not compete with Daba in respect of silk yield (main commercial

Table 1: Performance levels of parental ecoraces (Daba, Jata and Raily) under *in situ* habitation

	Daba ecorace				
Parameters	Range	Average	Place of origin	Food plant(s)	Voltinism
Fecundity (No.)	180-250	220.00	Singhbhum (Jharkhand)	*Terminalia* species	Bi and Trivoltine
Fertile egg (No.)	160-230	190.00			
Shell weight (g)	1.25-2.36	1.80			
Silk ratio (%)	16.28-14.13	15.00			
Silk yield (g)	62.5-177.0	108.00			
	Jata ecorace				
Parameters	Range	Average	Place of origin	Food plant(s)	Voltinism
Fecundity (No.)	250-350	315.00	Simlipal (Orissa)	*Terminalia* species	Univoltine
Fertile egg (No.)	110-180	130.00			
Shell weight (g)	1.60-2.34	2.05			
Silk ratio (%)	15.94-18.95	17.45			
Silk yield (g)	24.0-44.5	34.85			
	Raily ecorace				
Parameters	Range	Average	Place of origin	Food plant(s)	Voltinism
Fecundity (No.)	240-290	255.00	Bastar (Chhattisgarh)	*Shorea* species	Bivoltine
Fertile egg (No.)	100-160	110.00			
Shell weight (g)	1.97-2.82	2.23			
Silk ratio (%)	15.67-19.67	18.66			
Silk yield (g)	35.5-70.5	46.83			

Table 2: ANOVA for egg and cocoon commercial traits of Daba ecorace and its F_1 hybrids

		Mean sum of squares				
Source of variance	df	Fecundity (No.)	Fertile egg (No.)	Shell weight (g)	Silk ratio (%)	Silk yield (g)
Replicates	02	230.5	107.2	0.01	1.10	574.6
Hybrids	15	8898.3***	144.8**	0.84**	42.89***	6542.9***
Parent vs hybrids	01	7683.8**	469.5**	0.54**	27.07**	2562.5**
Error	32	646.1	49.6	0.06	2.75	284.2

**Significant at 1% level, ***Significant at 0.1% level

Table 3: Relative heterosis (%) in F_1 hybrids and reciprocals of Daba and Jata ecoraces

F_1 hybrid combination	Fecundity (No.)	Fertile egg (No.)	Shell weight (g)	Silk ratio (%)	Silk yield (g)
Daba×Jata [R]	+17.45	+11.58	+34.76	+30.49	+94.33
Daba×Jata [P×P]	+22.13	-08.95	-30.48	-30.22	-17.20
Daba×Jata [S×S]	-03.83	-04.13	+45.12	+26.95	+40.43
Daba×Jata [P×S]	+00.43	+05.21	+13.41	+02.07	+47.32
Jata×Daba [R]	+01.70	+07.20	+27.44	+24.15	+82.51
Jata×Daba [P×P]	+35.89	-17.68	-32.93	-25.42	-58.69
Jata×Daba [S×S]	-15.74	-04.09	+33.54	+27.95	-54.80
Jata×Daba [P×S]	+11.06	-17.80	+09.15	+01.67	-12.95

[R] = Random female and male, [P×P] = High pupal weight female and high pupal weight male, [S×S] = High shell weight female and high shell weight male, [P×S] = High pupal weight female and high shell weight male

parameter), though they posses better fecundity (315 and 255 No.), shell weight (2.05 and 2.23 g) and silk ratios (17.45 and 18.66%) because of their low egg fertility (130 and 110 No.) and silk yield (34.85 and 46.83 g), respectively.

The ANOVA among the common parent of hybrids, i.e., Daba with F_1 hybrids and reciprocals (Table 2), indicates significant variability for all characters viz., fecundity, egg fertility, shell weight, silk ratio and silk yield. This indicates remarkable relative heterosis potential in varied F_1 hybrids along with reciprocals over semi-domesticated and commercially exploited Daba parental ecorace. While, the mean sum of squares in respect of parents versus hybrids, which is the measure of heterosis potential, found significant in egg and silk commercial traits, emphasizing the imminent of parental specificity and varied crossings (assorted F_1 hybrids and reciprocals) on heterotic expression for commercial traits.

Performance F_1 Hybrids of Daba and Jata Ecoraces

The pattern of heterosis among the parents Daba and Jata along with their reciprocals (Table 3) indicate superior performance in Daba×Jata [R] and its reciprocal followed by high pupal and high shell combination of Daba×Jata [P×S] and high shell combination of Daba×Jata [S×S]. The relative heterosis recorded positive in five traits studied viz., fecundity (+17.45 and +1.70%), egg fertility (+11.58 and +7.20%), shell weight (+34.76 and +27.44%), silk ratio (+30.49 and +24.15%) and silk yields (+94.33 and +82.51%), respectively in Daba×Jata [R] and its reciprocal hybrid combinations. The high pupal and high shell combination, Jata×Daba [P×S] has shown lesser positive heterosis in fecundity (+0.43%), egg fertility (+5.21%), shell weight (+13.41%), silk ratio (+2.07%) and silk yield (+47.32%). The Daba×Jata [P×P] combination and its reciprocal have recorded positive heterosis in fecundity (+22.13% and +35.89%). The Daba×Jata [S×S] combination recorded positive heterosis in shell weight (+45.12%), silk ratio (+26.95%) and silk yield (+40.43%) while its reciprocal, Jata×Daba [S×S] is positive in shell weight (+33.54%) and silk ratio (+27.95%). The reciprocal F_1 hybrid Jata×Daba [P×S] has shown positive heterosis in fecundity (+11.06%), shell weight (+9.15%) and silk ratio (+1.67%) and negative in egg hatching and silk yield (-17.80 and -12.95%).

Performance F_1 Hybrids of Daba and Raily Ecoraces

The pattern of heterosis among the parents Daba and Raily along with their reciprocals (Table 4) indicate positive performance only in egg hatching, shell weight and silk ratios

Table 4: Relative heterosis (%) in F_1 hybrids and reciprocals of Daba and Raily ecoraces

F_1 hybrid combination	Fecundity (No.)	Fertile egg (No.)	Shell weight (g)	Silk ratio (%)	Silk yield (g)
Daba×Raily [R]	-33.76	+05.79	+42.44	+42.60	-26.03
Daba×Raily [P×P]	-26.34	+06.13	-38.37	-23.71	-67.69
Daba×Raily [S×S]	-34.98	+01.65	+25.58	+31.92	-07.04
Daba×Raily [P×S]	-33.74	+05.05	+07.56	+01.02	-25.40
Raily×Daba [R]	-28.81	+02.92	+43.60	+46.78	-42.26
Raily×Daba [P×P]	-41.97	-02.86	-26.16	-10.19	-65.59
Raily×Daba [S×S]	-32.51	+20.74	+56.98	+54.00	-35.53
Raily×Daba [P×S]	-31.27	+06.94	+12.79	+23.50	-53.74

[R] = Random female and male, [P×P] = High pupal weight female and high pupal weight male, [S×S] = High shell weight female and high shell weight male, [P×S] = High pupal weight female and high shell weight male

while they recorded negative in fecundity and silk yields. The Daba×Raily [R], Daba×Raily [S×S], Daba×Raily [P×S] and their reciprocals are positive in heterosis for egg hatching (+1.65 to +20.74%), shell weight (+7.56 to 56.98%) and silk ratios (+1.02 to 54.00%). The high pupal hybrid, Daba×Raily [P×P] shown marginal positive heterosis only in egg hatching (+6.13%), while it's reciprocal Raily×Daba [P×P] was negative in all traits. The best performance among the Daba×Raily hybrids was exhibited by reciprocal hybrid combination, Raily×Daba [S×S] with positive heterosis in egg hatching (+20.74%), shell weight (+56.98%) and silk ratio (+54.00%) followed by reciprocal of Raily×Daba [R] and Daba×Raily [R] F_1 hybrids.

DISCUSSION

The use of phenotypic variability in parents can build up a hybrid, exploiting heterosis to augment productivity and quality (Singh *et al*., 2002) and crossing of high x low, high x medium and medium x low yielding parents show positive heterosis (Siddiqui and Sengupta, 1993). In most of conventional heterosis breeding programmes, the geographical and phenotypic diversity is considered for available genetic distance among secluded populations. The other way of assessing the genetic diversity is with expression of heterosis in a particular hybrid as it demonstrates the existing degree of genetic diversity in parents. The phenotypic diversity though occurs due to genetic structure, the genotype environment (GxE) interactions at times manifest phenotypic variations. The reason for selecting Daba, Jata and Raily ecoraces was their varied yielding pattern in commercial trait(s) and their origin from semi domesticated and wild habitats. The parental ecoraces from divergent eco-geographic areas (Jharkhand, Orissa and Chhattisgarh states of India) with higher phenotypic diversity can magnify the inherent expression of heterosis at F_1 level is the other reason for choosing these three parental ecoraces for the study. While, the selection of individual parents based on high pupal and high shell weights (for making varied F_1 hybrids) was due to close association of bigger pupae with egg fecundity and higher cocoon shell with shell weight and silk yield, as these three traits are commercially important.

The higher positive relative heterosis in egg and cocoon commercial traits of Daba×Jata [R] and its reciprocal indicates that Daba and Jata are best combiners and these findings are in conformity with earlier reports on Daba ecorace as best combiner (Suryanarayana *et al*., 1987; Siddiqui *et al*., 1988). This has commercial applicability in tasarculture as both parents can be utilized reciprocally for maximum egg output with minimum quantity of seed cocoons, which helps in-time supply of commercial seed with least cost of production. The positive heterotic gain among randomly coupled parents, Daba and Jata in F_1 hybrids and reciprocals might be due to epistasis effect (Falconer, 1985; Aruga, 1994), while the positive heterosis in egg fecundity and shell weight might be due to dominant and over dominant gene(s) expression for a character (Verma *et al*., 2005; Reddy *et al*., 2008). Though, the F_1 hybrid combination, Daba×Jata [P×S] could show heterosis in egg and cocoon commercial traits, it could not achieve the production status of random parental hybrids in silk yield due to lesser levels of heterosis in fecundity, egg fertility, shell weight and silk ratio traits.

The expression of highly varied and in consistent heterosis by Daba×Raily and its reciprocal F_1 hybrids might be due to hybrid weakness with non-allelic interaction which also can decrease heterosis. The negative heterosis for fecundity and silk yield of these hybrids coincides with inferior performance of one of its parental ecorace i.e., Raily under *ex situ* conditions with its non amenability and non acclimatization to changed environment and food plant; as it survives better under natural (*in situ*) habitat and prefers to feed on *Shorea robusta*. The major share of country's tasar raw silk production from natural grown Raily cocoons, although indicate its production potential, but they are only under its natural habitat. Though, Daba parent emerged as best general combiner for most characters, the Daba×Raily hybrid is best reported for shell weight and silk ratios (Suryanarayana *et al*., 1987) and in present study, the Raily×Daba [S×S] and [P×S] combinations (reciprocals) have also shown same trend. In spite of positive heterosis for egg fertility, shell weight and silk ratio, the Daba×Raily and its reciprocal hybrid combinations could not enhance the economically important total silk yield due to higher negative heterosis in fecundity. This low fecundity has nullified the marginal positive heterosis of egg fertility and made these F_1 hybrid combinations economically non-viable.

The low fecundity and egg fertility with better cocoon commercial traits and poor cocoon commercial characters with better fecundity and egg fertility prevailing in several ecoraces is one of the major constraints of commercial tasarculture. The potential of selection response in chosen character of parental herd was found improved in offspring generation; however, it basically depends on genetic variation existing among parents, selection intensity and accuracy induced while choosing the parents (Siddiqui and Sengupta, 1993; Reddy *et al*., 2008). The better relative heterosis recorded for fecundity in F_1 hybrid combinations of Jata×Daba [P×P], high pupal parents and its reciprocal indicate the selection response in chosen trait. Constructive modification of a breed for enhanced production needs the parental races of desired commercial traits (Falconer, 1985) and higher breeding magnitude of silk moth from heavier pupae laying more eggs (Singh *et al*., 1994; Reddy *et al*., 2009) might be the reasons for enhanced fecundity. This approach of improving/evolving a line of higher fecundity has applicability against persistent problem of low fecundity in many ecoraces of tropical tasar silkworm, which were otherwise good in remaining cocoon commercial traits. Also, the positive relative heterosis shown by selective hybrid combinations and reciprocals of Daba×Jata [S×S] and Daba×Raily [S×S] in respect of shell weight and shell ratio indicates the positive heterotic response of parents with high shell weights. The better positive heterosis for shell weight and silk ratio also might be due to positive heterotic effect and better combinability of parents for yield contributing traits (Suryanarayana *et al*., 1987; Naqvi *et al*., 2004) significant correlation of a genotypic with phenotypic expression in respect of shell weight (Siddiqui and Sengupta, 1993), besides the dominance and over dominance in gene(s) expression for a chosen commercial trait (Verma *et al*., 2005).

Evolving a breed of high egg and silk yield traits depends on parental selection, effective utilization and adoption of apt breeding procedure (Moorthy *et al*., 2007). The objective of improving either fecundity or shell weight or both is to attain overall gain in silk yield of ecorace for its commercial sustenance. But, such selection of one or few economic character(s) results negatively with correlated changes on other commercially important character(s) or performance of breed (Moghaddam *et al*., 2005) and this might be the reason for decrease either in fecundity or in shell weight among selective (high pupal and high shell combinations) F_1 hybrids. However, these combinations can be improved again to some extent by subsequent crossings with another strain of higher fecundity or better shell weight (Aruga, 1994). The productivity enhancement in all commercial or economically important traits is not achievable as productivity and survivability of a breed are negatively correlated (Moorthy *et al*., 2007) hence, a line moderately balancing both and better over existing on hand races should be designed. However, the segregated lines (assorted F_1 hybrids) with special characters have certain application for a specific season, breeding purpose, to infuse and balance a line with needy commercial trait(s).

CONCLUSION

In general, all reciprocal F_1 hybrids of Daba, Jata and Raily ecoraces have shown lesser heterosis. The dissimilar performance of assorted F_1 hybrids and reciprocals of Daba, Jata and Raily ecoraces reveal their varied potential on relative heterosis. However, the study infers commercial prospective and optimal seed cocoon expediency in Daba and Jata ecoraces as F_1 hybrids [R] and reciprocals. While, the trait specific positive heterosis in high pupal and high shell hybrids (assorted F_1 hybrids) have application in segregating lines with desired traits and aggregating them in to needy one(s).

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