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Heterobeltiosis in Indian Tropical Tasar Silkworm, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae) in Association with Crop Rearing Seasons

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Abstract: The semi-domesticated and wild ecoraces of tropical tasar silkworm, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae) contributes for vanya raw silk production in India. The commercial tasarculture currently depends on two semi-domesticated (Daba & Sukinda) ecoraces and the imperative need is hybridization for heterobeltiosis to make the activity more feasible. The viability of various (general & specific) F_1 hybrid combinations made among Daba (semi-domesticated), Jata and Raily (wild) ecoraces were evaluated during seed (July-August) and commercial (September-December) crop rearing seasons to assess the impact of rearing environment on heterobeltiosis in commercial traits. The Jata x Daba general hybrid combinations have shown relatively better performance among all the hybrids during both crop rearing seasons indicating their compatibility to varied environment over Raily x Daba general as well as specific hybrid combinations, which could record better only in shell weight and silk ratios. The heterobeltiosis was better and positive in all the hybrid combinations for larval span, shell weight and silk ratio than larval, cocoon and pupal weights, irrespective of the crop seasons. The higher positive heterobeltiosis in the larval span and silk related traits apart little improvement in cocoon weight was recorded in Jata x Daba general hybrid combination in commercial crop rearing season followed by the same hybrid combination of seed crop season. The study infers that, there is scope to exploit the hybridization for heterobeltiosis in relation to the crop rearing seasons in tasar silkworm hybrid genotypes to augment silk yield through superior phenotypes for making tropical tasarculture commercially more sustainable.

Key words: Crop seasons · Ecoraces · F_1 Hybrid Combinations · Tropical tasarculture · Vanya silk

INTRODUCTION

The nature grown cocoons of wild ecoraces Raily (bivoltine) and Jata (univoltine) of tropical tasar silkworm *Antheraea mylitta* Drury are collected from their host plants by tribes of Bastar (Chhattisgarh) and Thakurmunda (Orissa) respectively. This indicates the better quality and higher salable value of wild cocoons over the cocoons produced through commercial rearings by the semi-domesticated ecoraces like Daba (bi & trivoltine) and Sukinda (trivoltine). The commercial tasarculture currently depends on only Daba and Sukinda, the semi-domesticated ecoraces and the need is hybridization for yield optimization and to make the activity commercially viable. The least cost of production and better sustenance of sericulture industry basically depend on the quantity and quality of cocoon yields and in tasar silkworm, *A. mylitta* it is with the combining impact of fecundity, hatching, effective rate of rearing (ERR), cocoon weight and silk content in addition to the rearing environment of crop seasons [1]. The extent of heterosis (increased or decreased hybrid vigour in one or many traits over any of the parent) and heterobeltiosis (increased hybrid vigour in one or many traits over the better parent) expression in commercial traits depends on the interaction among the genetic variability of parental ecoraces along with the environment in which the hybrid grows [2,3]. The heritability of quantitative parameters found most useful in silkworm breeding [4,5] and however, the genotype environment interaction

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influences the tasar insect life cycle and its absolute silk yield [6,7]. The use of phenotypic variability in parents can build up a hybrid, exploiting heterosis to augment productivity and quality [8] and crossing of high x low, high x medium and medium x low yielding parents show positive heterosis [7,9,10]. The deviation among the tasar ecoraces is specific and large due to genetic variability and even after several generations, the Raily and Modal ecoraces found differing from Daba in many parameters [11]. The potential phenotypic expression of genotype needs suitable climate due to its interaction with environment [12,13] and the gene being the endogenic factor play major role and environment being the exogenic factor influences the genes expressivity to produce different phenotypes in different environments [14]. The expression of hybrid vigor varies with varying temperatures and the level of heterosis present in hybrids can be influenced by the environmental factors [15]. The role of environment selection of parent and production environment of the hybrid is equally important as the goal of breeding is for matching of performance with environment [16]. The property of systematic development of different phenotypes in different environments is called phenotypic plasticity [17] and its higher importance in the tropics has proven [18]. Maximum heterosis observed for fecundity, hatching and yield contributing traits in Daba x Modal and Raily x Laria combinations [9,19-21]. Presently, only two ecoraces are contributing for the major production of tropical tasar cocoons in India and the utilization of hybrids with season associated heterobeltiosis is essential in place of present ecoraces, Daba and Sukinda, to enhance silk yield in tasarculture. Hence, the present study has been aimed to raise F_1 hybrid combinations among wild ecoraces Jata (Orissa), Raily (Chhattisgarh) and cultivated Daba (Jharkhand) and also to evaluate their performances in respect of commercial traits under seed crop and commercial crop rearing seasons.

MATERIALS AND METHODS

Three parental ecoraces of Daba, Jata and Raily of *A. mylitta* were initially reared in a randomized block design with three replications each during the seed crop rearing season (July-August) and commercial crop seasons (September-November) for three successive years to raise the non hibernating and hibernating seed cocoon stocks. The said stocks of seed cocoons were kept in the tasar grainage house following integrated package of seed cocoons preservation and conducted grainage for silkworm seed production [22]. The fresh parental moths emerged from the said stocks of parental seed cocoons during the months of June and September of the respective year were used to produce disease free layings (Dfls) of F_1 hybrids viz; Jata x Daba, Raily x Daba and their specific combinations like high pupal weight female x high pupal weight male [PxP], high pupal weight female x high shell weight male [PxS], high shell weight female x high shell weight male [SxS], in addition to pure layings of parents through selfing. Three parental ecoraces along with eight F_1 hybrid combinations in total eleven (11) were reared simultaneously in a randomized block design with three replications each during seed (July-August) and commercial crop seasons (September-November) of three years on the economic plantation of *Terminalia tomentosa* (W&A) at field laboratory of Central Tasar Research and Training Institute, Ranchi, Jharkhand, India following integrated package of tasar silkworm rearing [23]. The larvae of one disease free laying (Dfl) of parents as well as F_1 hybrid combinations were considered as one replication during rearing for recording observations. The average larval weight, larval span, single cocoon, pupal and shell weights and silk ratios were calculated based on the equal number of random samples. The data recorded on different parameters in the study were subjected to statistical analysis.

RESULTS

The analysis of variance (ANOVA) revealed significant variance in respect of larval weight, larval span, single cocoon, pupal and shell weights and silk ratios among parents of seed crop, parents of commercial crop and F_1 hybrid combinations of seed and commercial crop rearing seasons (Table 1). However, the larval weight and span among the parents, pupal weight among the F_1 hybrid combinations and larval, cocoon and shell weights among parents versus F_1 hybrids are found non-significant. The silk ratio among the parents and hybrids and pupal weight in parents versus hybrids are significant at 5% level, while others are significant at 1% level indicates the performance variation and impact of heterobeltiosis among parents, hybrids over rearing seasons.

The performance levels of larval weight, larval span, single cocoon, pupal and shell weights and silk ratios in respect of F_1 hybrid combinations of seed crop season of rearing studied during the months of July and August (Table 2) indicates the positive and negative levels of

Table 1: ANOVA for seed, larval and cocoon characters of parents and F_1 hybrids of seed (Jul-Aug) & commercial crop rearing seasons (Oct-Nov)

Particulars	DF	Larval wt. (g)	Larval span (days)	Cocoon wt. (g)	Pupal wt. (g)	Shell wt. (g)	Silk ratio (%)
Replicates	02	11.4	5.6	0.19	0.39	0.07	8.4
Parents	02	5.2 NS	7.6 NS	8.6 **	6.0 **	0.32 **	7.1 *
F_1 Hybrids	07	44.6 **	37.8 **	1.8 **	0.42 NS	0.91 **	42.6 *
Parents x F_1 Hybrids	01	1.5 NS	79.9 **	1.9 NS	3.1 *	0.14 NS	26.4 **
Error	20	3.1	2.3	1.0	0.73	0.05	1.7

*: Significant at 5% level, **: Significant at 1% level, NS: Non-significant

Source: Mean sum of squares

Table 2: Heterobeltiosis percentage of F_1 hybrids of wild and semi-domesticated ecoraces during seed crop rearing season (Jul-Aug)

F_1 Hybrid combination	Larval wt. (g)	Larval span (days)	Cocoon wt. (g)	Pupal wt. (g)	Shell wt. (g)	Silk ratio (%)
J x D	+01.26	+17.38	+01.42	-0.580	+39.21	+30.80
R x D	+13.67	-03.22	+04.52	+0.320	+32.85	+24.53
J x D [PxS]	+03.96	+09.84	+02.84	+01.59	+34.31	+24.79
R x D [PxS]	-06.14	+12.10	-08.58	-09.40	-02.92	+04.19
J x D [PxP]	+03.49	+08.20	-0.920	+0.930	+03.92	+0.280
R x D [PxP]	-08.51	+14.52	-11.53	-10.98	-15.33	-06.13
J x D [SxS]	+07.69	+04.92	+07.80	+04.74	+55.88	+38.20
R x D [SxS]	+01.42	+03.22	-04.61	-08.45	+21.90	+19.49

J x D = Jata x Daba; R x D = Raily x Daba;

[PxP] = High Pupal weight female x High Pupal weight male;

[PxS] = High Pupal weight female x High Shell weight male;

[SxS] = High Shell weight female x High Shell weight male;

Table 3: Heterobeltiosis percentage of F_1 hybrids of wild and semi-domesticated ecoraces during commercial crop rearing season (Oct-Nov)

F_1 Hybrid combination	Larval wt. (g)	Larval span(days)	Cocoon wt. (g)	Pupal wt. (g)	Shell wt. (g)	Silk ratio (%)
J x D	-01.60	+04.12	+02.91	-01.51	+14.83	+12.58
R x D	+13.60	-0.790	-19.29	-19.26	+17.06	+35.55
J x D [PxS]	-0.300	+08.02	+07.28	+07.98	-02.20	-08.71
R x D [PxS]	-07.32	+15.41	-19.29	-21.32	-08.06	+13.92
J x D [PxP]	-12.69	+19.75	-06.10	-0.43	-40.11	-36.12
R x D [PxP]	-16.31	+23.81	-27.12	-24.83	-39.81	-17.45
J x D [SxS]	-03.13	+10.49	+04.18	-0.110	+20.33	+15.67
R x D [SxS]	+03.32	+04.08	-10.01	-16.87	+27.96	+42.16

J x D = Jata x Daba; R x D = Raily x Daba;

[PxP] = High Pupal weight female x High Pupal weight male;

[PxS] = High Pupal weight female x High Shell weight male;

[SxS] = High Shell weight female x High Shell weight male;

deviation in heterobeltiosis. The better performance was recorded in the general hybrid Raily x Daba in all the parameters except for larval span, which is again a positive trend of completing the crop in shorter span with gain in all other commercial characters of better pupal weight required for better fecundity required in seed crop, while the other silk related parameters can contribute for the higher silk yield indicating the hybrid suitable for silk production even in the seed crop season. However the other general hybrid, the Jata x Daba combination has recorded positive in all the parameters except for pupal weight indicates its suitability for silk production than seed even during the seed crop rearing season. Among the other specific hybrids, the Jata x Daba combination has performed better in all the parameters, while the Raily x Daba high shell hybrid was better in shell weight and silk ratios.

The performance levels in respect of larval weight, larval span, single cocoon, pupal and shell weights and silk ratios of F_1 hybrid combinations of commercial crop season of rearing conducted during October and November months (Table 3) indicates the deviation of heterobeltiosis among different F_1 hybrid combinations, in spite the rearing season remains same. In terms of suitability to seed production with better cocoon and pupal weights, the Jata x Daba high pupal and high shell combination has recorded better cocoon and pupal weights, while the shell weight and silk ratios were negative among all the hybrids reared in that rearing season. Among the hybrid combinations, the general and high shell have shown positive shell weights and silk ratios, while the high pupal and high shell and high pupal and high pupal hybrid combinations were almost negative in heterobeltiosis in all the parameters except for larval span.

DISCUSSION

The F_1 hybrid combinations prepared by crossing parental ecoraces with large genetic diversity can enhance the heterosis with genetic complementation, even on commercial prospective as heterobeltiosis [2,3]. The phenotypic diversity though occurs due to genetic structure, the genotype environment (GxE) interactions at times manifest considerable phenotypic variations in the selected and economically important traits [12-14]. Hence, the parental ecoraces from divergent eco-geographic areas (Jharkhand, Orissa & Chhattisgarh states of India) with higher phenotypic diversity have been chosen for the study. The ANOVA (Table-1) for the larval and cocoon characters of both seed and commercial crops showed that mean sum of squares of parents, hybrids and parents versus F_1 hybrids were highly significant indicating the existence of genetic diversity among the parents. The parental genetic diversity might be the reason for resulting to such significant deviation in the performance levels as heterobeltiosis among the F_1 hybrids and also in parents versus F_1 hybrids. Though, the general attention in tasarculture was for silkworm seed in seed crop reared cocoons and silk in commercial crop reared cocoons; the possible commercial exploitation is needed in Indian tropical tasarculture for silk production even during seed crop rearing season. The suitable application of pure or F_1 hybrid genotypes irrespective of the crop rearing season can exploit the advantage of shorter crop span of seed crop rearing season than commercial crop season. Also, the availability of quality leaf and lesser prevalence of predators during seed crop rearing season will become added advantages for crop success and better yields. Further, the generation of higher number of tasar cocoons during seed crop season will have the choice of selection for better seed cocoon material and any way, the excess can be utilized for reeling; which also generates raw silk besides creating employment round the year. The other promising indication from the study is that all the F_1 hybrids of the seed crop rearing season except for Raily x Daba high pupal combination have shown positive heterobeltiosis in shell weight and silk ratios, which clearly indicates the scope for their exploitation for silk production even during seed crop rearing season.

The breeding goal must be to combine good characters of parents by setting up specific breeding environment as the environmental conditions have a great influence on the effectiveness of selection, so do the selections that take advantage of crop rearing seasons [3,14]. In most of conventional heterosis breeding programmes, the geographical and phenotypic diversity is considered for available genetic distance among secluded populations [6,11]. 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 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. 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 shell weight and silk yield, as these three traits are commercially important. The performance of F1 hybrids during commercial crop rearing season with expanded larval span might not contributed for larval, cocoon and pupal weights and however, they could contribute for the enhanced shell weight and silk ratios in general hybrids and high shell weight specific hybrids. Keeping in view of prolonged larval span of commercial crop season, the proportionate growth of shell weight and silk ratios was found lesser than the improved heterobeltiosis during the seed crop season in the same F_1 hybrid combinations. In spite of increase in the larval span during commercial crop season, the balanced pupal weight gain was not noticed and this might be due to allocation of larval assimilation majorly to shell content than pupa weight. This is an indication of tasar silkworm larva fore-casting of forth coming prolonged winter and its predestined hibernation. Among the specific hybrid combinations, only high shell

combinations have performed better over general hybrids. This further indicates the rearing season impact on the heterobeltiosis in silk related traits and however, the extended larval span might correlate the rearing season for longer larval span and higher silk content in association with favourable environment [12-14] prevailed during commercial crop rearing season in comparison to seed crop rearing season.

CONCLUSION

Irrespective of crop seasons, the extent of heterobeltiosis for larval span, shell weight and silk ratio than larval, cocoon and pupal weights was better and positive in all hybrid combinations. However, the higher positive heterobeltiosis in the larval span and silk related traits with improved cocoon weight recorded in Jata x Daba general hybrid combination in commercial crop rearing season followed by same hybrid combination of seed crop rearing season indicates the scope of hybridization in relation to crop rearing seasons. Hence, the heterobeltiosis in tasar silkworm F_1 hybrid genotypes as superior phenotypes can augment the silk yield and can make Indian tropical tasarculture commercially more sustainable.

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