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Application of Parental Selection for Productivity Improvement in Tropical Tasar Silkworm *Antheraea mylitta* Drury-A Review

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Abstract: In spite of huge availability of nature grown tropical tasar silkworm food plants and rural tribal man power, the tasarculture and raw silk production is yet to attain the potential. The reason being the inadequacy of prospective commercial silkworm seed and breed options, and the urgent need is a coherent application of existing parental races by effective selection. The global demand for vanya silks in general and tasar silk in particular, call-for sustainable utilization of country's seri-biodiversity potential. Viability and productivity proportion of tasarculture in terms of seeds, cocoons and essentially raw silk, need attention for its vital role in reforming the livelihood and economic condition of rural, backward and tribal farmers. The conventional approaches on basic stock maintenance, commercial seed production, selective use of parental races or parents for heterosis and heterobeltiosis, method of backcrossing to exploit the traits of commercial importance and applying the advantage of Genotype×Environment (G×E) interactions are indispensable. In spite of current knowledge on sophisticated transgenic silkworm, appropriate application of on-hand parental resource material and methodologies can expedite tasar silk productivity improvement in addition to up-keep the agro based cottage industry's cost-effectiveness and biodiversity conservation. The review deals with the current situation and probable strategies for enhancing the productivity and quality of tasar raw silk.

Key words: Tasar silk, *Antheraea mylitta*, parental selection, productivity, tribal farmers

INTRODUCTION

Tropical tasarculture is the rearing of wild silkworms of *Antheraea mylitta* Drury for production of tasar silk known for aesthetic look and distinctive feel. Over generations, wild sericigenous insect species have adapted to different environments and 44 ecoraces with phenotypic variations are reported in tropical India (Suryanarayana and Srivastava, 2005). They feed mainly on primary food plants viz., *Shorea robusta* (Sal), *Terminalia arjuna* (Arjun) and *Terminalia tomentosa* (Asan) besides other secondary and tertiary food plants (Suryanarayana *et al*., 2005). Among the ecoraces, only Daba and Sukinda along with a little of Jata are semi domesticated and commercially applied in India (Hansda *et al*., 2008;

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Ojha *et al*., 2009). The intensification of activity needs *in situ* conservation, *ex situ* acclimatization and appropriate application of ecorace resources as it got ample prospects in up-liftment of rural tribals, by generating employment along with upkeep of seri-biodiversity. The selection of parental races should be precise as per commercial requirement and productivity (Nagaraju *et al*., 1996; Raju, 1999; Nagaraju, 2002; Munoz *et al*., 2004; Mulder and Bijma, 2005; Reddy *et al*., 2008; Manohar *et al*., 2009c). The diverse mating systems can balance the traits in selected line for high cocoon, silk yield (Yamaguchi, 2001; Manohar *et al*., 2009a) and the selection of bigger female cocoon/pupa improves fecundity in *Bombyx mori* L. (Singh *et al*., 1994), in *Antheraea proylei* (Ghosh *et al*., 1996) and in other lepidopterans (Badhera, 1992; Miller, 2005; Manohar *et al*., 2009b). The parental selection with specific traits lead to explicit individuals in their progeny (Darlington and Mather, 1952) and when the silkworm strain of low fecundity crossed with better strain, it regains fecundity levels (Aruga, 1994). The fecundity, cocoon and shell weights have higher correlations and co-heritability with silk yield (Siddiqui *et al*., 1989; Naqvi *et al*., 2004). The males of different breeds influence the grainage performance of *B. mori* L. (Rajanna *et al*., 1999; Krishnaprasad *et al*., 2002) and the age of mother moths in *A. mylitta* D (Rath *et al*., 2007). Superior silkworm varieties can be evolved using repeated backcrossing with choice of donor and recipient parents (Raju and Krishnamurthy, 1993; Das, 2001; Moghaddam *et al*., 2005: Reddy *et al*., 2009). The introgressive hybridization with parents of genetic diversity offer heterosis with dominance of genes (Verma *et al*., 2005). Silkworm hybrids have shown improved reeling performances over pure races (Takabayashi *et al*., 1994) and the silk filament length is positively correlated with cocoon weight and negatively with silk filament denier (Sekharappa *et al*., 1999). Although, the semi-domestication of ecoraces, inadequate seed production, unpredictable outdoor environment and erratic cocoon yields affects consistency in silk production, the suitable application of on-hand parental materials and proven methodologies can substantiate the tasar silkworm productivity and quality.

PARENTAL SELECTION APPROACH FOR PRODUCTIVITY IMPROVEMENT

Selection is the process of deciding superior quality animals to become parents of next generation and is a basic tool for improving the genetic structure and productivity status of any stock in the direction desired. Though the simplest form of selection is choosing parents based on preferred phenotypic traits, the degree of improvement depends on variability among parents, extent of selection pressure induction, heritability of trait; as the induced artificial selection acts only as additional force to enhance the natural processes of selection. The role of environment on genotype found apparent, the productive potential of progeny needs to be attained with matching seasons and specifically for the trait of commercial importance. Further, the selection of more traits reduces the expressiveness of phenotype on trait of economic importance. Unlike fully domesticated mulberry silkworm, *B. mori*, the wild/semi-domesticated tropical tasar silkworm, *A. mylitta*, with pupal diapause, needs coherent application of parental variation available among ecoraces or within the ecorace, to optimize the productivity. The *ex situ* stabilization, correct combining of male, female components, application of suitable varieties for heterosis and operation of backcrossing to elevate viable traits, importantly the exploitation of genotype x environment interactions are the vital areas to be tapped in attaining productivity potential.

RESULTS AND DISCUSSION

Basic Seed Stock Maintenance and Multiplication

The maintenance and multiplication of basic seed, periodical replenishment with breeder's stock are essential for utilizing optimal vigor of ecorace in meeting the quality needs of commercial tasar seed. The performance of Daba ecorace of *A. mylitta* is comparatively inferior under *ex situ* (commercial rearings) than its *in situ* (natural rearings) habitat and on orderly maintenance of ecorace for five successive generations, revealed positive improvement (Table 1). The improved performance in fecundity from 257 to 309 eggs in T_2 indicates the role of specific parents in improving trait of commercial importance (Singh *et al*., 1994; Ghosh *et al*., 1996; Raju, 1999). Also, different types of parental mating can balance desired traits leading to high egg recovery, cocoon and silk yield (Yamaguchi, 2001; Manohar *et al*., 2009b, c) and same way, T_3 and T_4 could clearly augment shell weight and fecundity cum shell weights, respectively. The improvement in commercial traits among treatments, though all lines originate from same stock, clearly indicates the role of parental selection in improving breed with desirable traits. The higher fecundity along with better hatching found advantageous, as they together can contribute more number of brushed larvae (which was all along a persistent problem in tasarculture), which can assure improved cocoon yield, in spite of larval loss under fluctuating outdoor rearing environment. The improvement of total silk yield (main commercial parameter) at G_5 although, generation was seed crop season, could compete with commercial crop season at G_4. This is one of the salient impacts of selected parents and could occur with contribution of associated traits like fecundity, egg hatching and shell weights (Siddiqui *et al*., 1989; Manohar *et al*., 2009a). The least variation in control (T_1) compared to other treatments (T_2, T_3 and T_4) specify the role of parents selected over generations in modifying breed for productivity improvement. The enhancement in shell weight was minimum in T_2, reflecting same trend in total silk yield and was vice versa in T_3, where the total silk yield (78.4 g), improved over T_2 in spite of un-changed fecundity (261). But in T_4, where the parents are mixture of high pupal and high

Table 1: Impact of parental selection on commercial traits of Daba ecorace during basic seed stock maintenance over five generations

	Factors				
Treatment vs. Generations	Fecundity (No.)	Hatching (%)	Shell weight (g)	Silk ratio (%)	Total silk yield (g)
$T_1\times G_1$ to $T_4\times G_1$(C)	255±4.1	58.3±1.7	1.0±0.0	10.8±0.1	50.0±3.0
$T_1\times G_2$	250±7.4	68.6±1.1	1.5±0.0	13.5±0.3	73.5±5.2
$T_1\times G_3$	253±12.0	68.4±0.9	1.2±0.03	11.7±0.3	65.9±6.1
$T_1\times G_4$	260±2.0	71.2±1.2	1.5±0.03	13.7±0.4	81.9±4.8
$T_1\times G_5$	257±4.0	73.4±1.3	1.1±0.03	11.2±0.5	68.2±3.5
$T_1\times G_2$	286±5.0	54.3±2.4	1.2±0.03	12.1±0.4	23.0±0.6
$T_2\times G_3$	309±10.0	50.6±1.7	1.1±0.06	10.0±0.2	32.8±1.1
$T_2\times G_4$	295±6.4	54.5±1.1	1.1±0.1	10.8±0.8	34.6±0.9
$T_2\times G_5$	287±8.2	55.7±2.0	1.1±0.1	10.6±0.7	45.3±0.2
$T_3\times G_2$	257±5.5	59.8±1.2	1.6±0.0	14.7±0.2	37.7±4.9
$T_3\times G_3$	262±9.4	61.7±3.9	1.4±0.03	13.1±0.3	55.8±4.9
$T_3\times G_4$	256±5.9	65.1±0.7	1.6±0.07	14.8±0.4	57.2±3.8
$T_3\times G_5$	261±3.7	68.8±0.9	1.5±0.06	13.8±0.3	78.4±4.5
$T_4\times G_2$	278±5.8	65.6±2.3	1.9±0.06	17.2±0.5	67.8±10.0
$T_4\times G_3$	273±4.3	64.2±1.1	1.5±0.06	13.4±0.3	60.6±2.0
$T_4\times G_4$	283±4.0	70.4±1.2	1.9±0.09	17.7±0.7	110.0±5.1
$T_4\times G_5$	294±4.0	73.7±2.6	1.4±0.07	14.0±0.8	91.8±7.2

Values are Mean±SE. T_1: Control: Parents randomly mated, T_2: High pupal female×high pupal male, T_3: High shell female×high shell male, T_4: High pupal female×high shell male, G_1: July/August' 06, G_2: Sept/Nov' 06, G_3: July/August' 07, G_4: Sept/Nov' 07, G_5: July/August' 08 shell weights, fecundity, hatching and shell weights improved and contributed highest for total silk yield (91.8 g). The highest silk ratio (17.7%) recorded in T_4 at G_4 was due to significant improvement of shell weight (1.9 g) and highest total silk yield in T_4 at G_4 (110 g) and G_5 (91.8 g) levels was due to overall influence of fecundity, hatching and shell weights. This infers the importance of parental selection in basic seed stock maintenance of Daba ecorace for genetic recombination and gain in desired traits of productivity.

Optimization of Commercial Seed Production

The performance of silk insect reproduction varies with extraneous climatic factors in addition to physiological status of the parents involved. The correlation between the sizes of parental cocoons, pupae, moths, etc. and reproduction of economic insects is of vital importance to make their cultures commercially viable. The significant variations among different groups of males versus mid pupal group of females and vice versa in both Daba and Jata ecoraces (Table 2, 3) indicate the importance and impact of parental selection. The quantity and quality are fundamentally important even for economics of commercial seed production and use of right parents and combinations can optimize productivity improvement. In spite of better female component, the optimal reproductive success can be attained with availability of appropriate male counterpart. The fertility, vital character of egg hatching, depends on potency of male in transferring sperms along with secretions of

Table 2: Reproductive performance of different pupal weight group of females against standard pupal weight group of males

Ecorace	Pupal group	Female pupal weight (g)	Fecundity (No.)	Egg hatching (%)	Egg fertility (%)
Daba	Random (C)	No selection	244±12.9	69.4±1.8	92.93±0.8
Daba	Lower weight	7.50-8.80	141±7.8	60.7±1.7	79.54±2.1
			(-42.2)	(-12.5)	(-14.4)
Daba	Middle weight	9.00-10.00	281±7.5	86.6±2.9	95.80±1.1
			(+15.2)	(+24.8)	(+03.1)
Daba	Higher weight	10.50-11.40	220±4.0	69.2±1.9	87.68 ±1.5
			(-09.8)	(-0.30)	(-05.6)
Jata	Random (C)	No selection	200±6.1	68.8±1.5	92.00±0.7
Jata	Lower weight	8.60-9.30	128±6.6	64.4±3.5	81.69±1.5
			(-36.0)	(-06.4)	(-11.2)
Jata	Middle weight	9.50-11.30	244±7.4	78.2±2.1	92.97±1.3
			(+22.0)	(+13.7)	(+01.1)
Jata	Higher weight	11.50-12.35	202±10.4	66.0±2.8	86.03±0.7
			(+01.0)	(-04.1)	(-06.5)

Values are Mean±SD and % change over control

Table 3: Reproductive performance of different pupal weight group of males against standard pupal weight group of females

Ecorace	Pupal group	Male pupal weight (g)	Fecundity (No.)	Egg hatching (%)	Egg fertility (%)
Daba	Random (C)	No selection	244±12.9	69.4±1.8	92.93±0.8
Daba	Lower weight	5.70-6.45	243±7.4	68.6±3.0	90.93±1.2
			(-0.40)	(-01.2)	(-02.1)
Daba	Middle weight	6.50-7.50	256±7.8	85.9±2.6	96.22±0.5
			(+04.9)	(+23.8)	(+03.5)
Daba	Higher weight	7.75-8.45	208±9.7	64.6±4.2	81.42±2.1
			(-14.7)	(-06.9)	(-12.4)
Jata	Random (C)	No selection	200±6.1	68.8±1.5	92.01±0.8
Jata	Lower weight	5.65-6.50	195±7.7	66.1±2.0	87.37±1.5
			(-02.5)	(-03.9)	(-05.0)
Jata	Middle weight	6.75-7.70	219±5.7	86.1±2.4	95.79±0.8
			(+09.5)	(+25.1)	(+04.1)
Jata	Higher weight	7.85-8.65	166±15.1	63.1±3.5	80.51±2.5
			(-17.0)	(-08.3)	(-12.5)

Values are Mean±SE and % change over control

Table 4: Impact of different male components on the grainage parameters

Season	Combination	Coupling (%)	Fecundity (No.)	Hatching (%)	Fertility (%)
June/July	C = Daba×Daba	80.0	206	71.2	90.6
	T_1 =Daba×Jata	83.3	271	77.5	94.1
	T_2 =Daba×Raily	56.7	151	64.9	90.9
	T_3 =Daba×[Jata×Daba]	73.3	237	70.8	91.1
	T_4 =Daba×[Raily×Daba]	46.7	182	47.3	70.9
Sept/Oct.	C = Daba×Daba	75.8	213	74.2	87.2
	T_1 =Daba×Jata	87.5	264	83.6	94.0
	T_2 =Daba×Raily	62.5	163	63.4	91.4
	T_3 =Daba×[Jata×Daba]	75.0	251	73.1	89.5
	T_4 =Daba×[Raily×Daba]	45.8	194	51.0	69.9

Table 5: Performance levels of parents and hybrids during commercial crop season

Race/hybrid combination	Fertilized eggs (No.)	Shell weight (g)	Silk yield (g)	Filament length (m)
Daba	243±5.9	1.70±0.02	95.6±6.5	880±19
Jata	155±13.4	1.82±0.12	85.6±5.3	1249±89
Raily	139±12.3	2.11±0.09	36.7±3.5	1257±56
Daba×Jata	245±7.6	2.21±0.18	162.2±10.4	1790±129
	(+23.1)	(+25.6)	(+79.0)	(+68.1)
Daba×Raily	137±3.5	2.45±0.20	44.9±2.8	1109±19
	(-28.3)	(+28.3)	(-32.1)	(+3.8)

Values are Mean±SE, % of mid parent heterosis

accessory glands (Ravikumar *et al*., 1995; Krishnaprasad *et al*., 2002). Likewise, in spite of better male component, the optimal reproductive success depends on the healthiness and size of female counterpart in laying more of fertile eggs (Singh *et al*., 1994; Ghosh *et al*., 1996; He and Wang, 2006; Reddy *et al*., 2008; Manohar *et al*., 2009c). The optimal fecundity and fertility is possible only with proper mating combination of parents from middle to low pupal weight groups in males and middle to high in females (Singh *et al*., 1994; Calvo and Molina, 2005) in attaining productivity and sustainability of commercial tasar seed. The pattern of reproductive performance with varied male components (Table 4) indicates higher moth coupling in Daba×Jata combination specify higher mating propensity of Jata race and role of a male breed (Krishnaprasad *et al*., 2002). The poor coupling in Daba×Raily, performance at par with control in Daba×(Jata×Daba) and least in Daba×(Raily×Daba) indicates the role of male parent in moth coupling. The higher fecundity and better hatching in Daba×Jata indicates the potency of Jata male in transferring adequate sperms, spermatic fluid along with Fecundity Enhancing Substances (FES) (Kishorekumar and Paul, 1993; Singh *et al*., 1994; Ravikumar *et al*., 1995; Rajanna *et al*., 1999), in addition to heterotic effect on egg hatching at F_1 level (Naqvi *et al*., 2004). The results reveal that there is an ample scope of applying different parents in improving the tasar seed productivity and quality.

Conservation and Utilization of Parent Ecoraces

The performance of parental ecoraces and their hybrids (Table 5) clearly indicate the role of their origin and genetic diversity (Moghaddam *et al*., 2005; Tuteja *et al*., 2006; Ojha *et al*., 2009) on commercial out-put. The higher number of fertilized eggs, highest silk yield in Daba race proves its commercial superiority and economic viability in spite of lower shell weight. In contrary, the other two wild ecoraces, Jata and Raily in spite of having better shell weight and longer filament length, their low egg fertility and lesser silk yield made them un-suitable for commercial rearings. However, the in-depth study on ecoraces under various zones and their *in situ* conservation and *ex situ* stabilization can wider the parental base to use under various tasar practicing locations for productivity improvement. The mixing of advantage characters of both domesticated and wild ecoraces through hybridization (Aruga, 1994;

Table 6: Levels of heterobeltiosis (better parent heterosis in %) in general and specific F_1 hybrids

Hybrid combinations	Fecundity (No.)	Hatching (%)	Shell weight (g)	Shell ratio (%)
(J×D) Jata × Daba	-14.40	-14.01	+39.21	+30.80
(R×D) Raily × Daba	-36.62	-00.17	+32.85	+24.53
Jata×Daba (P×P) (high pupal weight female and high pupal weight male)	+23.87	-37.79	+03.92	+00.28
Raily×Daba (P×P) (high pupal weight female and high pupal weight male)	-39.09	+25.80	-15.33	-06.13
Jata×Daba (S×S) (high shell weight female and high shell weight male)	-14.40	+00.66	+55.88	+38.20
Raily×Daba (S×S) (high shell weight female and high shell weight male)	-44.44	+44.18	+21.90	+19.49
Jata×Daba (P×S) (high pupal weight female and high shell weight male)	+13.17	-38.63	+34.31	+24.79
Raily×Daba (P×S) (high pupal weight female and high shell weight male)	-30.86	+11.36	-02.92	+04.19

Moorthy *et al*., 2007; Manohar *et al*., 2009a) contributes for enhancing productivity. The mid parent heterosis in Daba×Jata has shown strong hybridization force with elevated leap in silk yield and filament length (Siddiqui *et al*., 1989; Sekharappa *et al*., 1999; Verma *et al*., 2005) indicating its commercial prospective. The study infers the need of parental ecorace conservation and their effective utility in producing hybrid seed and in optimizing productivity improvement.

Exploitation of Heterobeltiosis through F_1 Hybrids

The commercial utilization of heterosis is based on the excess over middle parent i.e., relative heterosis and excess over better parent i.e., heterobeltiosis. The potential of selection response in chosen character was found improved in offspring generation; however, it depends on genetic variation, selection accuracy among parents (Darlington and Mather, 1952). Selection of parental commercial characters based on breeding value is very much essential for productivity improvement (Yamaguchi, 2001; Rao *et al.,* 2003; Reddy *et al*., 2008; Manohar *et al*., 2009a, b) and silk moth off heavier pupae lay more eggs is of great concern in breeding (Singh *et al*., 1994). The ecorace with better cocoon characters have low fecundity and egg fertility or ecorace with higher fecundity and egg fertility have poor cocoon commercial characters are the main constraints in tasarculture. The general and specific F_1 hybrids of wild and semi-domesticated parents have shown heterosis and heterobeltiosis in egg and cocoon characters (Table 6). Parental nativity, phenotypic variability and genetic diversity found to be imperative reasons for better heterobeltiosis in fecundity, hatching, shell weight and silk ratios (Sengupta *et al*., 1987: Siddiqui, 1997; Hansda *et al*., 2008; Reddy *et al*., 2008). The better positive heterobeltiosis for fecundity in Jata×Daba [P×P] and Jata×Daba [P×S] combinations and positive heterobeltiosis for shell weight, silk ratio in combinations of Jata×Daba [S×S] and Raily×Daba [S×S] indicate specific combining ability for fecundity and shell weight cum silk ratios, respectively (Siddiqui, 1997; Naqvi *et al*., 2004). The involvement of specific parents is the reason seen expressing character wise heterobeltiosis among different hybrid combinations with prospect of productivity improvement through fecundity and shell weights.

Utilization of Heterosis through Reciprocal F_1 Hybrids

The heterosis in commercial characters of reciprocal hybrids (Table 7) denotes scope of total usage of parental cocoon material in commercial seed production and to cut-off seed production cost. The high heterosis potential recorded for fecundity in selective reciprocal hybrid, Daba×Jata [P×P] indicates the selection response between the chosen traits of divergent geographic ecoraces. This is of large applicability against persistent problem of low fecundity in many ecoraces, or otherwise they are good in all cocoon commercial characters. Also, the positive relative heterosis showed by Daba×Jata [S×S] and Daba×Raily [S×S] in respect of shell weight and shell ratio indicates the selection response of parents. The most important objective of improving shell weight is to attain overall gain in silk yield and improvement in shell weight and silk ratio indicate positive heterotic effect and combinability of parents for yield contributing traits (Siddiqui *et al.*, 1989; Naqvi *et al.*, 2004) while, the positive heterotic gain among random coupling of parents Daba, Jata show epistasis effect (Sengupta *et al.*, 1987: Siddiqui, 1997; Reddy *et al.*, 2008; Manohar *et al.*, 2009a). The positive heterosis for egg fertility, shell weight and silk ratio in Daba×Raily indicates its contribution for better silk yield as egg fertility and shell weights are main factors responsible for productivity improvement. The selective parents as reciprocal hybrids have heterosis potential to augment productivity improvement through fecundity and shell weights.

Backcrossing to Improve Egg Hatching, Silk Yield and Quality

Silkworm breed with better fecundity and egg hatching can achieve viable cocoon production on commercial scale. Jata ecorace with high fecundity (315 eggs) and low egg hatching (45%) as recipient and Daba which is vice versa, with low fecundity (200 eggs) and high egg hatching (80%) as donor parent were chosen to introgress egg hatchability trait through repeated backcrossing. The subsequent selection with better fecundity, egg hatching, at every stage of breeding and high pupal weight for specific hybrids, the backcrossing resulted (Table 8) to introgress the desired character of egg hatching (Singh *et al.*, 1994; Ghosh *et al.*, 1996; Raju and Krishnamurthy, 1993; Das, 2001;

Table 7: Levels of heterosis (mid parent heterosis in %) in general and specific reciprocal hybrids

Hybrid combinations	Fecundity (No.)	Egg fertility (%)	Shell weight (g)	Silk ratio (%)
Daba×Jata [R] (Random coupling)	+17.45	+11.58	+34.76	+30.49
Daba×Jata [P×P] (high pupal weight female and high pupal weight male)	+22.13	+07.20	-30.48	-30.22
Daba×Jata [P×S] (high pupal weight female and high shell weight male)	+00.43	+05.21	+13.41	+02.07
Daba×Jata [S×S] (high shell weight female and high shell weight male)	-03.83	-04.13	+45.12	+26.95
Daba×Raily [R] (Random coupling)	-33.76	+05.79	+42.44	+42.60
Daba×Raily [P×P] (high pupal weight female and high pupal weight male)	-26.34	+06.13	-38.37	-23.71
Daba×Raily [P×S] (high pupal weight female and high shell weight male)	-33.74	+05.05	-07.56	00.00
Daba×Raily [S×S] (high shell weight female and high shell weight male)	-34.98	+01.65	+25.58	+31.92

Table 8: Performance levels of backcross hybrids (F1, BC1 and BC2)

Parent/hybrid status	Crop seasons	Fecundity (No.)	Hatching (%)	Larval weight (g)	Cocoon weight (g)
DABA (D) Donor	Jun/Jul '06	241±10.5	73.82±2.1	31.84±0.17	10.48±0.24
JATA (R) Recipient	Jun/Jul '06	266±7.9	65.24±2.8	31.15±0.42	11.18±0.32
Jata×Daba F1 (G)	Sep/Nov '06	239±7.9	61.09±1.5	38.05±0.61	11.22±0.32
General hybrid		(-0.90) (-10.1)	(-17.2) (-06.4)	(+19.5) (+22.2)	(+07.1) (+0.40)
Jata×Daba F1 (P×P)	Sep/Nov '06	267±16.0	62.38±1.4	39.95±0.56	10.83±0.24
high pupal hybrid		(+10.8) (+0.40)	(-15.8) (-04.4)	(+25.5) (+28.2)	(+03.3) (-03.1)
Jata×Daba BC1 (G)	Jun/Jul '07	245±8.9	65.15±2.0	30.55±0.29	10.86±0.43
General hybrid		(+01.7) (-07.9)	(-12.7) (-0.14)	(-04.1) (-01.9)	(+03.6) (-02.9)
Jata×Daba BC1 (P×P)	Jun/Jul '07	258±9.8	69.85±0.45	31.95±0.83	10.81±0.26
high pupal hybrid		(+07.1) (-03.0)	(-05.4) (+07.1)	(-0.40) (-03.3)	(+03.1) (+06.7)
Jata×Daba BC2 (G)	Sep/Nov '07	254±7.8	64.45±0.84	40.24±0.77	11.36±0.30
General hybrid		(+05.4) (-04.5)	(-12.6) (+0.32)	(+26.4) (+01.6)	(+08.4) (+05.6)
Jata×Daba BC2 (P×P)	Sep/Nov '07	289±13.2	78.25±0.66	42.65±1.36	11.19±0.64
high pupal hybrid		(+19.9) (+08.6)	(+06.0) (+19.9)	(+33.9) (+0.10)	(+06.8) (+10.0)

Values are Mean±SE and % change over donor and recipient parents

Table 9: Performance levels of backcross hybrids (F1, BC1 and BC2)

Parent/hybrid status	Crop seasons	Shell weight (g)	Total silk yield (g)	Filament length (m)	Filament denier (d)
Daba (D) Donor	Jul/Aug '06	1.56±0.15	96.23±9.33	798.7±86.24	10.61±0.17
Jata (R) Recipient	Jul/Aug '06	1.72±0.09	70.70±2.95	1016.0±79.0	12.59±0.36
Raily (R) Recipient	Jul/Aug '6	2.11±0.09	39.33±3.16	1157.0±83.17	13.65±0.39
Jata×Daba (F1)	Sep/Nov '06	2.09±0. 14	152.3±9.90	1744.0±48.8	12.32±0.17
		(+34.0) (+21.5)	(+58.3) (+115.4)	(+118.4) (+71.7)	(+16.1) (-2.1)
Raily×Daba (F1)	Sep/Nov '06	2.47±0.12	35.01±3.02	1546.0±39.7	10.86±0.40
		(+58.3) (+17.1)	(-63.6) (-11.0)	(+93.6) (+33.6)	(+2.4) (-20.4)
Jata×Daba (BC1)	Jul/Aug '07	1.93±0.06	130.1±5.27	1234.7±39.0	11.55±0.27
		(+23.7) (+12.2)	(+35.2) (+84.0)	(+54.6) (+21.5)	(+8.9) (-8.3)
Raily×Daba (BC1)	Jul/Aug '07	1.95±0.04	34.35±4.93	1177.7±46.8	11.73±0.18
		(+25.0) (-7.6)	(-64.3) (-12.7)	(+47.5) (+1.8)	(+10.6) (-14.1)
Jata×Daba (BC2)	Sep/Nov '07	2.16±0.07	166.3±12.8	1554.0±51.4	11.76±0.31
		(+38.5) (+25.6)	(+72.8) (+135.2)	(+94.6) (+53.0)	(+10.8) (-6.6)
Raily×Daba (BC2)	Sep/Nov '07	2.36±0.15	35.87±3.28	1394.3±98.1	13.65±0.12
		(+51.3) (+11.8)	(-62.7) (-8.8)	(+74.6) (+20.5)	(+28.7) (0.00)

Values are Mean±SE and % change over donor and recipient parents

Moghaddam *et al*., 2005) (with an improvement of +19.9% over *ex situ* stabilized) into Jata ecorace at BC_2 level. The high pupal parents selected because of their correlation with fecundity and to retain same while improving the egg hatching. The intensity of introgression was additional in selective high pupal hybrids indicate the role of parental selection in target oriented breeding (Aruga, 1994; Chattopadhyay *et al*., 2001; Moghaddam *et al*., 2005; Moorthy *et al*., 2007; Manohar *et al*., 2009c). The egg hatching and fecundity improvement was marginal in general hybrids while the high pupal hybrid could surpass even recipient parent, authenticates the role of selected parents in productivity improvement through improved egg hatching and regained fecundity. The selection of breeding method is to develop a breed with stability and productivity in terms of quantity and quality of silk and for such aspire the apt method is repeated backcrossing (Tazima, 1984). The parental selection is always crucial and hence, the variation in total silk yield and filament denier apart from varied shell weight, silk ratio and filament length (Table 9) are the main reasons for selection of divergent races as parents. To introgress the silk associated commercial characters, total silk yield and finer filament denier in to Jata and Raily races, the backcrossing has been repeated with males of Daba race and the approach found momentous as parental selection was based on their quantitative and qualitative traits. While domestication and *ex situ* acclimatization, the performances of ecoraces will come down and superior traits found in natural habitat will recede and hence, are not effective as donor to introgress desired economic trait(s). In view of this, selection of nature grown ecorace as recipient parent for its superior characters and to infuse additional compatible trait(s) from domesticated Daba race with continued selection for desired trait(s) in the following generations found logical. The induced selection on parents at every stage of breeding for desired trait(s) and the repeated backcrossing with Daba resulted to better viability in terms of total silk yield (Raju and Krishnamurthy, 1993; Moghaddam *et al*., 2005; Tuteja *et al*., 2006) into Jata race. The opposite trends in respect of total silk yield, filament length by the same hybrid at F_1 and BC_2 levels indicate the correlation between quantity and quality of silk (Siddiqui *et al*., 1989; Sekharappa *et al*., 1999; Verma *et al*., 2003; Reddy *et al*., 2009). But, the non improvement of silk yield in Raily race, coincides with its *ex situ* performances of non amenability and acclimatization to the changed environment and food plant, as against its superior survival under natural habitat on *S. robusta*. However, the improvement in shell weight and silk ratios of Jata and Raily races at F_1 and BC_2 levels signifies the interaction of high heterogenousity and introgressive hybridization (Verma *et al*., 2003; Reddy *et al*., 2008; Manohar *et al*., 2009a). This also infers better silk trait expressiveness of phenotype under commercial crop season, which have optimal genotype×environment relations with longer larval feeding period, better leaf quality and congenial climate. The introgression of finer filament denier with improved silk yield indicates the prospects of Jata and Daba ecoraces as parental resource for improving productivity.

EXPLOITATION OF GENOTYPE×ENVIRONMENT INTERACTION

Phenotype is the combined produce of genotype and environment (Kumar *et al*., 1999; Jong and Bijma, 2002; Munoz *et al*., 2004; Srivastava *et al*., 2004; Mulder and Bijma, 2005; Zhao *et al*., 2007) and the tasarculture being an outdoor practice and providing the suitable environment is not under control, it will be more logical to choose an ecorace which performs better in foreseen seasons. Environmental conditions have a great influence on effectiveness of parental selection, so do the selections that take an advantage of season's different characteristics (Kumar *et al*., 1999, 2008; Munoz *et al*., 2004; Mulder and Bijma, 2005). In commercial crop season (Sep-Nov), selection of silk yield and filament length, the traits of quantitative nature should be stressed because of congenial weather and quality of feed in addition to longer larval feeding period (Jong and Bijma, 2002). While during seed crop season (Jul-Aug), the fluctuating weather and quality of feed with intermittent rainfall, the priority should be on higher fecundity and better egg hatching to provide extra population to compensate the larval loss (Zhao *et al*., 2007). The superior performance of parental lines, general and specific hybrids under commercial crop (favourable seasons) indicate the attachment and interactions of genotype with environment. However, the tasarculture need separate breed options for different crop seasons due to varied behavior of non-diapause and diapause destined silkworms with varied climatic conditions. The cocoons of seed crop with thin shell and low silk; commercial crop cocoons with thick shell and high silk denotes their specific contribution towards seed and silk along with genotype x environment interactions in tasar productivity improvement.

EPILOGUE

Adoption of well-proven genetic principles, use of resourceful material by selection, testing and multiplication procedures, genetic correlations certainly augment silk insect productivity. The need based application of parents and combinations by selection; suits combating irregular reproductive behavior, inadequate basic and commercial seed, semi domestication and low race option for rearings and unstable silk productivity and quality. The yield exploitation through heterosis, quality advancement through backcrossing and yield stability through integration of physiological, nutritional and ecological (G×E) essentials, no doubt requires choice of parents. In the years to come, these traditional methods will continue with adoption of advanced biotechnological tools to make the selection of parents more effective in achieving higher productivity with effective cost benefit ratio. This success generates confidence and involvement among rural, backward and tribal rearers in sustainable expansion of tasarculture and conserving endangered wild seri-biodiversity for future generations.

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