Full Research Article

Expression of Heterosis in Bivoltine Hybrids of *Bombyx mori* L. for Silk Yield Contributing Traits under Sub-tropical Conditions

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Abstract

Synthesis of new-gene combinations by genetic manipulation is one of the powerful tools in exploiting the commercial qualities of plants and animals. The fundamental aim of silkworm breeding is to get robust and sturdy silkworm larvae for easy rearing and production of quality cocoon crop. Bivoltine breeds and hybrids excel in quality and productivity but do not display the crop stability. The main reason attributed to such instability is that the bivoltine breeds/hybrids suffer badly in adverse conditions. In the present study, an attempt was made to evaluate twenty-eight bivoltine hybrids raised by involving half (8×8) diallel set of bivoltine breeds including four hypersericigenous (PO_1, PO_3, ND_2 and ND_5) and four thermotolerents (Udhey-1, Udhey-3, Udhey-4 and Udhey-6) along with ruling bivoltine hybrid, $SH_6 \times NB_4 D_2$ in order to identify the thermotolerent, adaptable bi×bivoltine silkworm hybrids suited for sub-tropical climate. Observations were made on eight economically important traits namely, larval weight, crop weight, single cocoon weight, single shell weight, shell ratio, average filament length, non-breakable filament length and denier. The data was analyzed using Evaluation index (E.I.) method. Ten hybrid combinations recorded mean evaluation index (E.I.) values of >50 ranging from 51.13 to 63.35, whereas, control scored E.I. value of 49.22 only. Two hybrid combinations, $ND_5 \times PO_1$ (63.35) and $ND_2 \times$Udhey-6 (60.12) recorded Average E.I. value >60 for all the characters under sub-tropical conditions.

1. Introduction

Silk-the queen of textiles is adorned by rich and poor alike. Sericulture is an important component of the diversified agriculture which plays a vital role in generating employment opportunities for the masses of the farming community including women and the farmers with small land holdings to land less in the rural areas for livelihood (Trivedi and Sarkar, 2015). It denotes not only the industry concerned with the mulberry cultivation, silkworm rearing or reeling sector but also the science providing technical basis for the industry (Nowlakhe and Nawalakhe, 2000). The trend of sericulture development in India has shown a quantum jump in mulberry silk production with an annual production of 20,000 t during the last three decades (Lakshmanan and Kumar, 2012) and it enjoys the comfortable second position for the production of silk in the world next only to China, in which silkworm breeding and development of bivoltine hybrids have played a vital role. India being predominantly a tropical country

with marginal sub-tropical and temperate sericulture zones, mostly multi×bivoltine hybrids is reared in tropical areas of the country which do not meet the international standards. The silk produced by multivoltine breeds or multi×bivoltine hybrids is not so superior and cannot be sold in the international market. Thus, there is great need and scope for improving the bivoltine sericulture of the country (Datta et al., 2001). As a result, more emphasis needs to be given to bivoltine sericulture, if India has to produce international grade silk. Realizing the importance of bivoltine sericulture, efforts are being made by silkworm breeders (Babu et al., 2005; Guruswami, 2006 and Moorthy et al., 2007) of the country to evolve high yielding bivoltine silkworm breeds/hybrids for commercial purpose over years through conventional breeding approach and genetic improvement of multiple traits. Most of the silkworm breeding programmes now-a-days are oriented towards boosting the bivoltine silk yield and fiber quality.

The northern states of India, such as Jammu & Kashmir,

Himachal Pradesh, Uttrakhand and some pockets of Punjab assumes special significance due to its salubrious climate congenial for rearing of bivoltine silkworms and these states have observed an increasing trend in cocoon production and has a high potential for bivoltine sericulture activities (Shah, 1993). However, this production is limited to spring season (March/April) as only one commercial rearing is conducted throughout the year, though enough of mulberry leaf is available for second rearing (September/October). It is in recent years that an attempt for second commercial rearing during autumn season (September/October) has also been initiated, though the percentage of success in this period is imperatively less due to certain reasons such as poor leaf quality, high temperature, high relative humidity, and incidence of diseases besides lack of autumn specific productive silkworm breeds and hybrids (Ram, 2010; Arafat, 2014). These factors combinedly act as main constraints in boosting the silk production of the sub-tropical regions. To overcome this, the development of indigenous adaptable thermotolerent silkworm breeds/hybrids is imperative for introducing additional crop in autumn season for commercial exploitation in this region.

2. Materials and Methods

The present study was undertaken at Division of Sericulture, Sher-e-Kashmir University of Agricultural Sciences and Technology, Udheywalla, Jammu with an intention to develop, evaluate and identify new bi×bivoltine hybrids suitable for rearing during autumn season in sub-tropical conditions of northern India. For this purpose, four hypersericigenous (PO$_1$, PO$_3$, ND$_2$ and ND$_5$) and four thermotolerent (Udhey-1, Udhey-3, Udhey-4 and Udhey-6) breeds (Table 1) were crossed to get F1 hybrids by employing half diallel method (Table 2) and studied along with ruling bivoltine hybrid, SH$_6$×NB$_4$D$_2$. All the F1 hybrids along with the control were reared in the completely randomized block design with three replications each during autumn 2014 and autumn 2015 (i.e. September to October). Standard rearing techniques as suggested by Krishnaswamy (1988) were followed. Data was recorded replication- wise for all the treatments viz*.*, larval weight, crop weight, single cocoon weight, single shell weight, shell ratio, average filament length, non-breakable filament length and denier for both the seasons and the data was further pooled for both the seasons and was then analyzed using multiple trait index (Evaluation index) method.

The Evaluation Index method developed by Mano et al. (1993) was found to be very useful in selecting potential hybrids. Data on the economically important traits was collected, pooled and analyzed. The Evaluation Index (E.I.) was calculated as per the procedure:

$$\text{Evaluation index} = \frac{A-B}{C} \times 10 + 50$$

Where, A=Value obtained for a particular trait of a particular hybrid combination.
B=Mean values of a particular trait of all the hybrid combinations.
C=Stand deviation of a particular trait of all the hybrid combinations.
10=Standard Unit.
50=Fixed Value.
The E.I. value fixed for the selection of hybrid is 50 or >50 for the traits. The hybrid, which scored above the limit, is considered to possess greater economic value.

3. Results and Discussion

Silkworm breed is the most influential factor in the development of sericulture. In the long history of sericulture, many silkworm races have been recognized as valuable for practical use and the same has been preserved. In the present study, an attempt was being made to identify the superior crossbreed through conventional breeding approach by assessment on multiple traits of the developed silkworm hybrids.

Silkworms are voracious eaters of mulberry during its larval stages and around 80% leaf is consumed in last two instars (Fukuda, 1960). Highlighting the importance of food intake,

Table 1: Salient features of parental breeds developed by Division of Sericulture, SKUAST-J

Parent breeds	Larval marking	Cocoon shape	Cocoon colour	Average E.I.		
				Single cocoon weight (g)	Single shell weight (g)	Shell ratio (%)
U*-1	Marked	Constricted	White	53.33	46.00	47.16
U-3	Marked	Constricted	White	50.00	42.00	45.63
U-4	Plain	Elongated	White	43.33	44.00	50.43
U-6	Plain	Elongated	White	45.83	52.00	27.64
PO$_1$	Plain	Oval	White	47.50	50.00	55.10
PO$_3$	Plain	Oval	White	52.50	54.00	55.10
ND$_2$	Marked	Constricted	White	50.83	62.00	63.44
ND$_5$	Marked	Constricted	White	75.83	74.00	61.09

Table 2: Half diallel crosses of eight parental breeds

	Udhey-1	Udhey-3	Udhey-4	Udhey-6	PO_1	PO_3	ND_2	ND_5
Udhey-1	$U^*-1 \times U-1$							
Udhey-3	$U-3 \times U-1$	$U-3 \times U-3$						
Udhey-4	$U-4 \times U-1$	$U-4 \times U-3$	$U-4 \times U-4$					
Udhey-6	$U-6 \times U-1$	$U-6 \times U-3$	$U-6 \times U-4$	$U-6 \times U-6$				
PO_1	$PO_1 \times U-1$	$PO_1 \times U-3$	$PO_1 \times U-4$	$PO_1 \times U-6$	$PO_1 \times PO_1$			
PO_3	$PO_3 \times U-1$	$PO_3 \times U-3$	$PO_3 \times U-4$	$PO_3 \times U-6$	$PO_3 \times PO_1$	$PO_3 \times PO_3$		
ND_2	$ND_2 \times U-1$	$ND_2 \times U-3$	$ND_2 \times U-4$	$ND_2 \times U-6$	$ND_2 \times PO_1$	$ND_2 \times PO_3$	$ND_2 \times ND_2$	
ND5	$ND_2 \times U-1$	$ND_2 \times U-3$	$ND_2 \times U-4$	$ND_2 \times U-6$	$ND_2 \times PO_1$	$ND_2 \times PO_3$	$ND_5 \times ND_2$	$ND_5 \times ND_5$

(*Udhey)

Horie et al. (1978) reported that for the production of 1 g larval dry weight, requirement of ingestion and digestion of food is 4.2 mg and 1.8 mg respectively. The intake of food during total larval life was also reflected by weight of 10 mature larvae. The perusal of data (Table 3) revealed that three hybrids scored E.I. value >60 for larval weight. Similar findings were also reported by Rao et al. (1998). Minagawa and Otsuka (1975) have reported inter relationship between multiple characters in silkworm. It therefore, becomes essential to evaluate the breeds and their hybrids to understand the magnitude of heterosis towards improvement in cocoon and silk productivity (Bandopadyay, 1990). Economic characters like cocoon yield, cocoon weight, cocoon shell weight and cocoon shell percentage are inter-related and moreover they influence the productivity. In the present study, a great deal of variability was observed in the expression of crop weight. Four hybrid combinations scored E.I.>60 (Table 3) for this trait. Malik et al. (1998) suggested that cocoon yield/10,000 larvae by weight, single cocoon weight, shell weight and shell ratio percentage are important parameters for a quality cocoon crop.

The cocoon weight, shell weight and shell ratio are the important commercial parameters for cocoon stage and reeling performance. The cocoon weight has a negative correlation with shell ratio but positive correlation with shell weight whereas shell weight has a positive correlation with shell ratio. Cocoon characters are commercially important and in the present study two hybrids scored E.I.>60 for single cocoon weight. Saratchandra et al. (1992) has reported superior mulberry variety particularly triploids responsible for higher cocooning characters. Shell weight has a positive co-relation with cocoon shell ratio. Four hybrids scored E.I. value of >60; whereas, control remained at 31.90 for single shell weight character. Higher shell ratio percentage is an important character for silk filament. In hybrids, three combinations

were found scoring E.I. value >60 for shell ratio parameter. However, control hybrid, $SH_6 \times NB_4D_2$ remained at E.I. value of 31.90 only (Table 3). Cocoon yield, pupation rate, single cocoon weight, single shell weight and shell ratio combined constitute the major qualitative and quantitative traits of the silk industry.

Among post cocoon parameters, filament length and denier are considered as important characters from economic point of view and have direct bearing on the merit of a breed or hybrid. Increase or decrease in filament length is dependent on increase or decrease in the thickness of silk filament and cocoon shell weight of breeds and hybrids (Kobari and Fujimato, 1966; Nagaraju and Kumar, 1995). Results of the present study revealed fluctuations in filament length in different hybrids. Seven and six hybrids respectively, crossed the E.I. bench mark of >60 for both filament length and non-breakable filament trait (Table 3). The results are in agreement with the findings of Rao et al. (2004) who observed variations in F1 hybrids. Rajalakshmi et al. (1998) opines that the quality of the good hybrid is to have minimum or no breaks during reeling. Five hybrid combinations including control crossed E.I. >60 for filament size. The control hybrid $SH_6 \times NB_4D_2$ could not qualify for total filament length and non-breakable filament length character.

Malik et al. (2002); Ram et al. (2003) suggested that the superiority and potential of a hybrid mainly depends on the ranking and considering all the major larval, cocoon yield and silk contributing parameters. Based on these facts, ten hybrid combinations $ND_5 \times PO_1$, $ND_2 \times U-6$, $ND_5 \times U-3$, $ND_5 \times U-6$, $ND_2 \times PO_3$, $ND_2 \times U-1$, $ND_5 \times U-4$, $PO_1 \times U-6$, $ND_2 \times U-4$ and $ND_2 \times PO_1$ were found to be heterotic scoring E.I. value >50, whereas, control hybrid scored E.I. of 49.21 only. Based on this, two hybrids identified viz., $ND_5 \times PO_1$ and $ND_2 \times U-6$ scored E.I. value>60 for eight commercially important characters and may be utilized for commercial exploitation.

Table 3: Estimation of Evaluation Index (E.I.) values of bivoltine hybrids for commercial traits during autumn (Pooled data)

Hybrids	Traits								
	Larval weight (g)	Crop weight (kg)	Single cocoon weight (g)	Single shell weight (g)	Shell ratio (%)	Average filament length (m)	Non-break-able filament length (m)	Denier (d)	Aver-age E.I.
$SH_6 \times NB_4D_2$ (control)	50.83	45.11	64.82	49.66	31.90	45.62	44.87	60.89	49.21
$ND_5 \times PO_1$	59.26	64.66	66.92	68.00	56.26	67.22	66.17	58.27	63.35
$ND_2 \times$U-6	64.46	57.79	60.00	62.33	56.37	66.72	57.07	56.17	60.11
$ND_5 \times$U-3	50.05	56.89	55.08	58.66	57.00	62.20	69.88	64.03	59.22
$ND_5 \times$U-6	55.40	57.49	56.92	61.33	58.75	64.88	55.48	61.93	59.02
$ND_2 \times$PO3	63.44	39.53	44.12	59.33	73.39	62.95	61.49	60.36	58.07
$ND_2 \times$U-1	48.63	52.13	65.17	62.00	49.60	64.38	55.04	59.31	57.03
$ND_5 \times$U-4	50.12	57.41	52.10	59.00	61.46	54.75	53.53	62.98	56.42
$PO_1 \times$U-6	47.84	65.56	59.82	59.00	51.55	53.07	51.94	53.03	55.23
$ND_2 \times$U-4	68.64	50.09	55.61	59.00	56.84	51.06	43.28	55.65	55.02
$ND_2 \times$PO1	54.77	48.06	56.75	59.00	55.38	44.78	45.14	45.18	51.13
$PO_3 \times$U-6	27.99	44.28	39.21	42.00	50.97	62.62	70.33	61.93	49.91
$PO_3 \times$U-3	55.25	49.56	55.08	47.66	39.85	46.37	53.18	51.98	49.87
$ND_5 \times$ND2	52.72	42.98	48.15	54.66	59.86	38.34	44.70	55.13	49.56
$PO_1 \times$U-4	57.06	54.85	49.82	51.00	51.69	41.10	47.61	42.56	49.46
$PO_1 \times$U-1	56.27	58.92	51.14	43.00	37.19	52.91	60.78	35.23	49.34
U-6×U-1	53.35	62.02	50.78	45.33	41.35	40.85	47.35	47.80	48.60
$ND_5 \times$PO3	57.69	38.17	43.42	53.33	64.34	44.53	32.32	45.18	47.37
$PO_3 \times$PO1	36.26	46.32	46.31	40.00	38.20	54.50	61.75	55.13	47.31
$ND_5 \times$U-1	48.94	56.13	51.84	52.33	51.21	47.04	34.35	36.28	47.27
$PO_3 \times$U-1	50.44	63.90	58.59	53.66	44.92	37.75	37.27	29.47	47.00
$PO_3 \times$U-4	44.77	39.60	35.08	43.66	59.89	54.25	40.19	56.70	46.77
$PO_1 \times$U-3	52.36	55.00	46.22	40.00	38.31	45.62	44.87	37.32	44.96
U-4×U-1	55.99	51.45	51.49	42.33	35.70	40.01	46.67	34.71	44.77
$ND_2 \times$U-3	43.82	30.62	44.03	46.00	51.16	49.81	43.37	36.28	43.13
U-6×U-3	37.52	37.41	38.85	37.33	43.07	45.20	51.94	50.41	42.72
U-4×U-3	40.12	54.09	39.03	36.33	41.37	35.66	41.87	44.65	41.64
U-3×U-1	40.24	42.92	42.80	37.33	38.73	32.89	38.95	43.09	39.62
U-6×U-4	25.63	26.92	20.87	28.33	53.20	42.77	49.38	48.84	36.99

4. Conclusion

Two hybrids namely $ND_5 \times PO_1$ (Av.E.I. 63.35) and $ND_2 \times$U-6 (Av. E.I. 60.11) can be exploited for autumn rearings in the field at farmer's level for better prospects of bivoltine sericulture in sub-tropical areas.

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