Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 2219-2223
Received: 19-05-2018
Accepted: 23-06-2018

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Expression of heterosis in silkworm hybrids with popular commercial hybrid CSR2×CSR4as control

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Abstract
The study was carried out to evaluate 9 silkworm hybrids along with check hybrid CSR2×CSR4 in order to identify high yielding hybrid. All the observations obtained for various parameters were tabulated and subjected to statistical analysis, following Analysis of Variance techniques. The results were tested for the treatments mean by applying F- test of significance (ANOVA) on the basis of null hypothesis as mentioned by Cochran and Cox (1957).Observation was made on the basis of 13 economically important characters viz; fecundity, hatching, brushing, wt. of 10 mature larvae, ERR by no\by weight, pupation, single cocoon weight, single shell weight, shell ratio percentage, filament length, non breakable filament length and filament size. Out of 9 hybrids 2 hybrids U6×ND3 and CSR4×PO1 shows good result when compared with control.

Keywords: bivoltine, silkworm, hybrids, hypothesis

Introduction
In India, agriculture is practised by nearly 70 percent of the rural population, yet the GDP in agriculture continues to fall due to number of factors like decline in productivity, non-involvement of women and marginal land holdings etc. In order to minimise the receding income of the farmers, adoption of multidisciplinary ventures is of prime importance to increase the earnings and socio economic status of the poor and marginal farmers. One such venture which fetches quick returns to the farmers is sericulture. Sericulture is a farm based commercially attractive activity which falls under cottage industry and suits the poor landless and marginal farmers of the country as it requires no electric energy and very low investment but fetches higher returns. Being an insect of economic importance mulberry silkworm (*Bombyx mori* L.) spins valuable silk fibre, making it one of the most beneficial insect to mankind. The trend of sericulture development in India has shown a quantum jump in mulberry silk production with an annual production of 20,000 MT during the last three decades (Lakshmanan and Kumar, 2012) [15]. India is the second largest producer of silk after China with 14.5 per cent share in global raw silk production and is the biggest consumer of raw silk in the world. Inspite of India's second position on world map, bulk of silk comes from multivoltine, a breed which produces inferior quality. Among various sericultural zones of India, the state of J&K is the only traditional uni/bivoltine area producing quality mulberry silk. In order to meet the large requirements of the silk industry, different silkworm hybrids, which can sustain in high temperature and humidity, needs to be developed so that they get well adapted under local climatic conditions for stable cocoon production. Thus, there is a need to make new hybrids and to evaluate them for high productivity suitable for this region. Considering the economic importance of silkworm rearing as an employment and income generating activity, therefore, the present investigation was aimed to develop and evaluate indigenous silkworm hybrids for spring season that can results in better yield and quality for successful commercial exploitation of bivoltine crop.

Materials and Methods
The present investigation was conducted during spring 2015-16 at Division of Sericulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu with an intention to develop, evaluate and identify new bivoltine hybrid combinations suitable for rearing during spring season in northern India. The experimental research material for the proposed study comprised of nine bivoltine silkworm hybrids CSR2×PO3, CSR4×PO1, CSR5×SPO, KA×ND5, CC1×U1, NSP×U1, JD6×U6, U1×NSP, U6×ND3(evolved at Division of Sericulture, SKUAST-J, Udheywalla) and the popular commercial hybrid CSR2×CSR4 was also included in the study as check.

These hybrids along with the control were reared in the completely randomized block design (CRBD) with three replications each. Standard rearing techniques as suggested by Dandin *et al*. (2003) [6] were followed. Data was recorded replication- wise for all the treatments. viz; fecundity, hatching brushing, wt. of 10 mature larvae, ERR by no\by weight, pupation, single cocoon weight, single shell weight, shell ratio percentage, filament length, non breakable filament length and filament size.All the observations obtained for various parameters were tabulated and subjected to statistical analysis, following Analysis of Variance techniques. The results were tested for the treatments mean by applying F- test of significance (ANOVA) on the basis of null hypothesis as mentioned by Cochran and Cox (1957) [5].

Results and Discussion

Mulberry silkworm *Bombyx mori* L. undoubtedly is an important economic insect and also a tool to convert leaf protein into silk protein. Silkworm being monophagus responds positively towards its food i.e. mulberry leaves which improve quality and quantity of silk spun by them. During the last few decades, a number of silkworm breeds/hybrids have been developed (Chandrashekharaiah and Babu 2003) [3] and selected for exploitation at the field level. These productive hybrids are not only nutritionally efficient but are also originated from indigenous breeds. India being majorly a tropical country under limited area of mulberry production, estimation of phenotypic stability for high nutritional efficiency conversion is considered one of the most important aspects for sustainable progress in silkworm breeding. Earlier studies have demonstrated fundamental interaction of nutrition/physiology on gene expression (Giacobino *et al*. 2003 and Phillips *et al*. 2008) [9, 22]. The perusal of data revealed that the bivoltine hybrids varied significantly in terms of fecundity, hatching and brushing. Fecundity is an important trait for viability of a commercial grainage. Variation in fecundity was found in different hybrids, which resulted in fluctuation of egg number per brood. In the present study, maximum value for fecundity was recorded in hybrid U1 × NSP (626.33) followed by control CSR_2 ×CSR_4 (582.00) and U6×ND3 (557.33) and least for JD6×U6 (417).. (Table1). Higher fecundity registered in F1 hybrids can be attributed to heterotic effect prevailing in hybrids. However, Ullal (1964) [28] observed that the silkworm seed produced from autumn cocoon crop resulted in better fecundity than seed produced from spring reared cocoons. According to Tazima (1957) [27], fecundity mainly depends upon genotype of mother moth and environmental conditions at the time of oviposition. Muthukrishnan and Pandian (1987) [20] revealed that species which grow larger but feed at lower rates and pass through extended adult life span display very low egg production efficiency. Hosseini *et al.*, 2005 [10] analyzed that the adequate quantity of offered mulberry leaves is important in silkworm rearing, which affects the fecundity of females, weight of mature larvae and growth rate. The results are supported by Yokoyama (1957). Hatching and brushing being two important commercial characters and high percentage of hatching and brushing generally results into more cocoon production. In present study hatching and brushing percentage was significantly high in hybrid U6×ND3 closely followed by CC1×U1, CSR2×CSR4 and KA×ND5 (Table 1). It may be due to physiological status of embryonic development and environmental factors like temperature, light and humidity during incubation of eggs (Tazima, 1957) [27]. The higher value for hatching and brushing percentage observed in hybrids studied indicate genetic superiority of said combinations due to the heterotic effect of intercrossing as reported by Nacheva (1980) [7]. This observation is in concordance with the findings of Narayanaswamy *et al*. (2001) [21]. Successful commercial silkworm rearing is determined by number of factors and one amongst them is silkworm breed/hybrid. Silkworm breed/hybrid are known to differ in their genetic superiority with respect to their efficiency to convert ingested food to silk. Minagava and Otsuka (1975) [17] 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 cocoon and silk productivity (Bandopaday, 1990) [1]. Economic characters like cocoon yield, cocoon weight, cocoon shell weight and cocoon shell percentage being inter-related influence silk productivity for quality cocoon crop as well as potential hybrid (Malik *et al*., 1998) [16]. The observations made important parameters at cocoon stage revealed significant variations among hybrids on the basis of performance values. In the present study, significant difference observed in the expression of cocoon yield (by wt. and by no.).The cocoon yield / 10,000 larvae by wt. was significantly higher in hybridU6×ND3 (17.43) followed by CSR4× PO1 (17.23), JD6 × U6 (16.36) and lowest for NSP× U1 (13.43). Cocoon yield by no. being important parameter contributing viability was significantly higher in hybridCSR2 ×PO3 (9821.66) followed by CSR4 × PO1 (9583.66), JD6×U6 (9532.33) and least for NSP × U1 (8929.00)(Table2). This is due to the superiority of these heterotic hybrids and due to the fact that larval survival percentage was higher in these hybrids. Positive correlation of cocoon yield, single cocoon weight with fecundity, hatching and brushing percentage has been reported by Jayaswal *et al*. (1990) [12]. Pupation rate is one of the important economic characters to determine the variability of a breed/hybrid and is a positive sign for seed production. These are generally influenced by rearing environment and other abiotic factor. The genetic and environment interaction gets more reflected in this character. In the present study, hybrid CSR2 ×PO3 (96.66) followed by CSR4 × PO1 (93.66), U1 ×NSP and U6×ND3 (91.66) and least for NSP × U1 (85.00) (Table3). Variations observed in pupation rate can be attributed to the influence of environment on silkworm hybrids. Pupation rate is a low heritable character and is prone to large variations in different environments and management (Gamo and Hirabayashi, 1983) [8]. The observations are in accordance with findings of Gowda *et al*. (2017) [11]. The cocoon weight, shell weight and shell ratio are important commercial parameters. Cocoon weight has a negative correlation with shell ratio but positive correlation with shell weight where as shell weight has a ppositive correlation with shell ratio. In the present study, significantly higher value for cocoon weight was achieved in hybrid CSR5 × SPO (1.836) followed by KA× ND5 (1.804), U-6× ND3 (1.798) and least for NSP × U1 (1.521)(Table3). Saratchandra *et al*. (1992) [26] has reported superior mulberry variety particularly triploids responsible for higher cocooning characters. Shell weight has a positive co-relation with cocoon shell ratio. The current findings indicate significant variability in the expression of single shell weight among different hybrids studied. Highest significant value was recorded inU6 × ND3 (0.386) followed by control CSR2 × CSR4 (0.375), JD6 × U6 (0.369) and least for NSP × U1 (0.333).by for the said trait (Table3). Similar were the finding of Mukherjee *et al*. (2013) [18]. Higher shell

ratio percentage is important for silk filament and different hybrids behaved differently in respect of shell ratio. The shell ratio was significant among the hybrids studied. Maximum shell ratio with respect to per se performance was observed for NSP × U1 (21.89) closely followed by control CSR2×CSR4 (21.63), CSR2×PO3 (21.58) and lowest for hybrid CC1×U1 (18.96). (Table3). This indicates the superiority of hybrids and is in support of the view that phenomenon of heterosis could be either due to additive gene action or due to dominance hypothesis as reported by Petkov (1989) or it might be due to higher ingestion, digestion and conversion factors. High fecundity may be the reason for low value of shell ratio as fecundity and shell ratio are negatively correlated as reported by Ram (1994) [25]. Similar findings were reported by Choudhary and Singh (2006) [4]. 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 breed/hybrids. 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 (Basavaraja, 1996) [2]. Results of the present study revealed significant difference for total filament length, non-breakable filament length and denier among different hybrids studied. Total filament length was significantly higher forU6× ND3 (909) closely followed by CSR4 × PO1 (877.66) and NSP× U1 (834.33) and least for CC1×U1 (778.66). (Table4). This may be due to higher mature larval weight (Satenahalli *et al.*, 1990) [23]. High fecundity results in lower filament length because these two characters are negatively correlated (Ram, 1994) [25]. Rajalakshmi *et al.* (1998) [24] opines that the quality of a good hybrid is to have minimum or no breaks during the process of reeling. Hybrid U1 × NSP (806.33) scored significantly higher value for non-breakable filament length followed by CSR4 × PO1 (797) and U6 × ND3 (758). Leastnon breakable filament length was recorded for CSR2 × CSR4 (651.66) (Table 4). This finding can be attributed to longer V instar duration and higher larval weight (Satenahalli *et al.*, 1990) [23]. Similar were the findings of Khan *et al*. (2007) [13] and Kumar *et al*. (2013). Filament size being genetically controlled character may not have significant co-relation with other parameters. Hybrid JD6×U6 (2.85) followed by CSR5×SPO (2.76) and KA×ND5 (2.65) and least for CSR2×PO3 (2.07) Scored significantly higher values for filament size (Table 4). This may be due to the fact that shorter filament length generally results into comparatably thick denier. Similar were the findings of Murthy *et al*. (2013) [19].

Table 1: Performance of different bi × bi silkworm hybrids for egg characters for spring (2015-16)

Hybrid	Fecundity	Hatching	Brushing
CSR2 x PO3	541.66	98.02	97.47
CSR4 x PO1	505.66	97.48	97.02
CSR5 x SPO	463.33	96.76	93.74
KA xND5	426.66	97.80	97.64
CC1 x U1	519.00	98.13	98.07
NSP x U1	506.33	97.57	96.84
JD6 x U6	417.00	95.21	94.64
U1 x NSP	626.33	97.32	96.19
U6 x ND3	557.33	98.43	98.14
CSR2 x CSR4	582.00	98.39	95.47
CD5%	33.46	1.36	1.23

Table 2: Performance of different bi × bi silkworm hybrids for cocoon characters for spring (2015-16)

Hybrid	ERR By wt.	ERR By No.	Flimsy Cocoon (%)	Dead Cocoon (%)	Double Cocoon (%)
CSR2 x PO3	16.13	9821.66	1.66	0.33	0.66
CSR4 x PO1	17.23	9583.66	.000	0.00	0.66
CSR5 x SPO	16.26	9009.33	1.00	1.33	1.33
KA x ND5	16.03	9051.33	0.33	1.00	0.66
CC1 x U1	15.96	8945.00	0.33	1.00	0.66
NSP x U1	13.43	8929.00	2.33	1.33	0.66
JD6 xU6	16.36	9532.33	0.33	0.33	2.66
U1 x NSP	15.56	9456.66	1.00	0.33	1.33
U6 x ND3	17.43	9427.66	1.00	0.66	0.33
CSR2 x CSR4	16.16	9392.00	0.00	0.00	1.33
CD5%	0.510	184.11	NS	NS	NS

Table 3: Performance of different bi × bi silkworm hybrids for cocoon characters for spring (2015-16)

Hybrid	Pupation (%)	Single Cocoon weight(g)	Single shell Weight(g)	SR%
CSR2 x PO3	96.66	1.631	0.352	21.58
CSR4 x Po1	93.66	1.787	0.363	20.31
CSR5 x SPO	87.66	1.836	0.363	19.77
KA xND5	87.66	1.804	0.364	20.17
CC1 x U1	87.33	1.782	0.338	18.96
NSP x U1	85.00	1.521	0.333	21.89
JD6 x U6	91.33	1.733	0.369	21.29
U1 x NSP	91.66	1.659	0.340	20.49
U6 x ND3	91.66	1.798	0.386	21.46
CSR2 x CSR4	89.33	1.733	0.375	21.63
CD5%	2.42	0.09	0.02	0.636

Table 4: Performance of different bi × bi silkworm hybrids for post cocoon characters for spring (2015-16).

Hybrid	Total filament length(m)	NBFL(m)	Filament Size(d)
CSR2 x PO3	822.66	685	2.07
CSR4 x Po1	877.66	797	2.60
CSR5 x SPO	824.00	749	2.76
KA x ND5	824.33	749.33	2.65
CC1 x U1	778.66	707.00	2.42
NSP xU1	834.33	695.33	2.31
JD6 x U6	833.33	757.00	2.85
U1 xNSP	806.33	806.33	2.27
U6 xND3	909.00	758.00	2.65
CSR2 x CSR4	814.33	651.66	2.64
CD5%	22.74	22.43	0.139

Conclusion

On the basis of present study, ANOVA for qualitative and quantitative traits two hybrid combinations viz; U6×ND3 and CSR4×PO1were found to be heterotic and can be exploited at commercial level after multi location trials.

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