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Studies on evaluation and identification of suitable bivoltine hybrids (*Bombyx mori* L.) for better productivity in Odisha

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Abstract
Ten silkworm hybrids SK6 X SK7 & B.Con1 X B.Con4; CSR50 X CSR51, CSR16 X CSR17, GEN3 x GEN2, CSR2 X CSR4 & FC2 x FC1; Dun6 X Dun22; APS45 x APS12 & HTO5 x HTP5 were evaluated in three crops (Aug-Sept 2018; Oct-Nov 2018; Feb-Mar 2019). The rearing and reeling performance was documented for analysis and multiple trait evaluation index values were utilized to determine the best performing hybrid. FC1 x FC2, HTO5 x HTP5, GEN3 x GEN2 and CSR50 x CSR51 generally performed well in all the seasons in Odisha; while CSR16 x CSR17 also in October-November crop. FC1 x FC2 occupied the top position with an MEI of 61.66 followed by HTO5 x HTP5 (55.44), CSR50 x CSR51 (50.78) and CSR16 x CSR17 (50.71). The result of the present study indicated that FC1 x FC2 has scored average EI values >50 for the maximum of 9 individual traits viz., single cocoon weight, single shell weight, shell ratio, cocoon yield by weight and number, average filament length, non breakable filament length, reelability and average neatness particularly with respect to overall performance irrespective of seasons. BCon1 x BCon4 and SK6 x SK7, the ruling foundation crosses reared in Eastern & NE India recorded 16-17% shell ratio only with 85% survival and were placed right at the bottom for their overall performance. Average and non-breakable filament lengths were >1050 in HTO5 x HTP5 and FC1 x FC2. Non-significant differences between the hybrids were observed for reelability and neatness. FC1 x FC2, bivoltine double hybrid which is quite popular in South/North India stood first for its overall performance in Odisha conditions also.

Keywords: Bivoltine silkworm, economic traits, evaluation index, seasons

Introduction
Increasing demand for production of import substitute raw silk necessitated the importance of bivoltine silkworm breed or hybrids in sericulture. Unfortunately, bivoltine silk production in India could not reach to the most of the farmers despite best possible efforts made by sericultural functionaries of the country. The major constraints for production and popularization of bivoltine silkworm hybrids in India are their instability in cocoon yield and non suitability for varied climatic conditions. Presently much emphasis is being given for promotion of bivoltine sericulture to cater the need of quality silk matching international standards. Systematic research efforts on silkworm breeding programmes in different countries have resulted development of several robust and productive bivoltine hybrids (Mano *et al.*, 1991) [10] (Hong *et al.*, 1992) [7] Thiagarajan *et al.*, 1993) [24] (Datta *et al.*, 2001) [4] (Basavraja *et al.*, 2013) [3]. Unfortunately, many of the breeds continues to suffer badly under adverse environmental conditions coupled with poor rearing management practices of small and marginal farmers; causing wide gap between realized cocoon yield in laboratory and field. Therefore situation demands assessment, evaluation and identification of season/region specific silkworm breeds/hybrids to mitigate variation in adaptability and quantitative characters of the breeds under diverse environmental conditions.
Sericulture practicing areas of Odisha state experiences wide variation in temperature, humidity and rainfall. But continuous efforts are in place to promote bivoltine sericulture in the state, unfortunately none of the bivoltine breed or hybrid could become popular due to fluctuating climatic conditions and fear of crop loss. Silkworm breeding programme in India for last few decades have resulted in the development of many productive silkworm breeds which have contributed significantly in increasing the silk production of the country. Therefore knowing the importance of adaptability to the local environment for better productivity, silkworm breeds have been evaluated in many occasions to find out region and season specificities (Nguku *et al.*, 2009) [12]. Till date there is no such attempt to evaluate and identify superior and productive bivoltine hybrids particularly with reference to Odisha.

Hence, the present study was undertaken to evaluate the performance of 9 bivoltine single and a double hybrids in different seasons at RSRS, Koraput to screen out the best one for the local conditions.

Materials and methods

In the present study, nine bivoltine hybrids and a double hybrid *viz*., BCon1x BCon4, SK6 x SK7(procured from CSRTI, Berhampore) APS45 x APS12, HTO5 x HTP5 (procured from APSSRDI, Hindupur),Dun6 x Dun22, (Procured from RSRS, Sahaspur), CSR2 x CSR4, CSR16 x CSR17, CSR50 x CSR51, GEN3 x GEN2 and FC1 x FC2 (Procured from CSRTI,Mysuru), were evaluated during 2018-2019 in three different crop seasons namely February-March(Spring), August-September crop (Monsoon) and October – November (Autumn) crop. The rearing of all the hybrids were carried out in a completely randomized design (CRD) with three replications each consists of 300 larvae maintained after third instar by following the standard rearing techniques of (Krishnaswami 1978) [8]. During rearing, three feeding with mature mulberry leaves were provided to the worm till the onset of spinning. Plastic collapsible mountages were used as substrate for cocooning of the ripened worms. Cocoon harvesting was carried out on the $6^{th}/7^{th}$ day of spinning. The hybrids were evaluated for different cocoons and associated parameters viz; larval weight, cocoon yield by number and by weight, single cocoon weight, single shell weight, shell ratio% and post cocoon parameters like filament length, non breakable filament length, reelability% and neatness% etc. The data generated in respect of different traits was pooled separately, analyzed statistically and subjected further to multiple trait evaluation index using the following formula (Mano *et al*., 1993) [11].

$$\text{Evaluation Index (E. I.)} = \frac{(A - B)}{C} \times 10 + 50$$

Where,

A = Value of a particular breed for particular trait,

B = Mean value for a particular trait of all the breeds,

C = Standard Deviation of a particular trait for all the breeds,

10 = Standard unit,

50 = Fixed value.

Minimum / average E.I. value fixed for selection of a breed is >50.

Results and Discussions

9 (Nine) promising single hybrid and 1 (one) double were evaluated at RSRS, Koraput, their comparative performances, statistical analysis along with evaluation index for different pre cocoon and post cocoon parameters are presented in Table-1, 2, 3 and 4.

During Feb-Mar crop, performance of the hybrids revealed that among 10 hybrids HTO5 x HTP5 scored highest values for larval weight (40.51 g), filament length (1078 m) and non breakable filament length (1078 m) where as GEN3 x GEN2 for ERR by number (8156), ERR by weight (15.11 Kg) and single cocoon weight(1.684 g), FC1 x FC2 for highest single shell weight (0.345 g), SR%(22.60), reelability (75%) and neatness (81%). During Aug-Sep crop FC1 x FC2 registered maximum values for ERR by number (8758), ERR by weight (16.84 kg), single shell weight (0.395 g), SR% (21.24), filament length (875 m) non breakable filament length (715 m), and neatness (81%) while GEN3 x GEN2 recorded highest larval weight (42.48) and HTO5 x HTP5 for maximum reelability (76%) and single cocoon weight (1.934 g). Similarly in Oct-Nov crop FC1 x FC2 exhibited maximum values for the characters ERR by number and weight (9694, 17.44), single shell weight and SR% (0.385g, 22.67), CSR50 x CSR51 for larval weight (37.61 g), single cocoon weight (2.00 g) and neatness (75%), CSR16 x CSR17 for non breakable filament length (715 m), reelability (78%) and HTO5 x HTP5 for filament length (969 m). However with respect to the mean performance of the breeds irrespective of season FC1 x FC2 out performed most of the other breeds with highest values for the traits ERR by number and weight (8765, 15.92 kg), single cocoon weight (1.793 g), single shell weight (0.395 g) SR% (22.08) and neatness (81.33%) while HTO5 x HTP5 exhibited highest values for filament length (993 m) non breakable filament length (792 m) reelability (75.81%) and the hybrid CSR50 x CSR51 for larval weight (39.37 g).

The present research findings based on evaluation index (E.I) revealed that five hybrids *viz*., FC1 x FC2 (58.08), GEN3 x GEN2 (55.63), HTO5 x HTP5 (53.47), CSR16 x CSR17 (52.13), and CSR50 x CSR51 (50.08) were performed well during Feb-Mar crop. During Aug-Sep crop only three hybrids were found to be good performer namely FC1 x FC2 (60.15), HTO5 x HTP5 (54.98), and GEN3 x GEN2 (50.66) while during Oct-November crop four hybrids namely CSR50 x CSR51 (56.39), FC1 X FC2 (55.83), CSR16 x CSR17 (53.61) and HTO5 x HTP5 (50.29) were found promising scoring EI value more than fifty. As far as overall performance is concerned 4 hybrids only out of 10 scored average EI value >50 with FC1 x FC2 (61.66) occupied the top position followed by HTO5 x HTP5 (55.44), CSR50 x CSR51 (50.78) and CSR16 x CSR17 (50.71).

Multiple traits evaluation index method enables identification of superior breed or hybrid from an array of breeds, while considering cumulative effect of most of the yield and associated attributes. The method have been used extensively by the silkworm breeder in many studies ((Naseema Begum 2000) [13], (Quadir *et al.,* 2000) [18], (Suresh Kumar *et al.*, 2006) [23], (Nazia Choudhary *et al.,* 2006) [14], (Ganaie *et al.,* 2012) [5], (Nisar *et al.*, 2013) [16], and (Nooruldin *et al.,* 2014) [17]. Multiple trait evaluation index improves the precision selection of silkworm breed from a collection of breeds providing due considerations to all the yield contributing attributes (Bhargava *et al.*, 1994) [2]. The stability of a breed or hybrid is highly influenced by the genotype and environment interaction which is very well documented both for plant and animal species (Griffing and Zsiros 1971) [6]. Therefore, selection of a hybrid requires due considerations both for genotype and its performance under diverse agroclimatic conditions (Rahman and Ahmed 1988) [19]. In the present study different hybrids from different regions of the country were selected and evaluated with respect to different seasons under Odisha condition. The bivoltine single and double hybrids used in this experiment exhibited considerable degree of variability in their expression in Odisha. The result of the present study indicated that FC1 x FC2 has scored average EI values >50 for the maximum of 9 individual traits viz., single cocoon weight, single shell weight, shell ratio, cocoon yield by weight and number, average filament length, non breakable filament length, reelability and average neatness particularly with respect to overall performance irrespective of seasons. The better performance of FC1 x FC2 in several economic characters may be attributed to its capacity to overcome deleterious environmental effect in widely varying agro climatic conditions and stable polygenic expression than

single crossed hybrid. The argument is well documented by (Raje Urs *et al*., 2009) [20] (Virk *et al*., 2011) [25] Lakshmanan *et al*., 2012) [9] (Seshagiri *et al*., 2016) [22] (Ramprakash *et al*., 2017) [21] and (Ashraf *et al*., 2019) [1].

Finally from the above study it can be concluded that FC1 x FC2, HTO5 x HTP5, CSR50 x CSR51, CSR16 x CSR17 and GEN3 x GEN2 generally performed well in different seasons in Odisha. FC1 x FC2, bivoltine double hybrid which is quite popular in South/North India ranked first for its overall performance in Odisha conditions also.

Table 1: Mean performance of the hybrids during Feb-Mar crop (Data pooled over same seasons of 2018 and 2019):

Hybrids	Larval wt (g)	ERR by NO	ERR by Wt (kg)	SCW (g)	SSW (g)	SR%	FL (m)	AVg. NBFL (m)	Reel ability %	Avg Neat ness%	Avg EI#
FC1 x FC2	38.38 (49.81)	6922 (36.58)	12.70 (53.23)	1.532 (59.64)	0.345 (70.51)	22.60 (62.50)	1050 (62.39)	1050 (64.95)	75 (57.63)	81 (63.51)	58.08
Gen3 x Gen2	38.80 (52.04)	8156 (62.05)	15.11 (66.15)	1.684 (70.76)	0.303 (57.94)	20.67 (54.55)	954 (57.21)	668 (49.74)	74 (45.89)	77 (40.02)	55.63
HTO5 x HTP5	40.51 (61.00)	7456 (47.59)	12 (49.44)	1.431 (52.26)	0.288 (53.55)	20.11 (52.24)	1078 (63.91)	1078 (66.06)	74 (48.33)	77 (40.02)	53.47
CSR16 x CSR17	39.46 (55.51)	8100 (60.90)	14.33 (61.98)	1.296 (42.40)	0.277 (50.15)	21.36 (57.38)	820 (49.98)	410 (39.46)	74 (45.89)	80 (57.63)	52.13
CSR50 x CSR51	39.61 (56.28)	8144 (61.82)	13.78 (58.99)	1.325 (44.52)	0.293 (54.94)	22.13 (60.57)	593 (37.73)	425 (40.06)	72 (28.27)	80 (57.63)	50.08
APS45 x APS12	39.98 (58.23)	7767 (54.02)	12.11 (50.04)	1.372 (47.95)	0.263 (45.82)	19.08 (48.02)	747 (46.04)	534 (44.40)	76 (60.57)	77 (40.02)	49.51
Dun6 x Dun22	36.11 (37.87)	7500 (48.51)	10.67 (42.28)	1.256 (39.50)	0.234 (37.08)	17.85 (42.96)	890 (53.76)	875 (57.98)	76 (63.51)	79 (51.76)	47.52
CSR2 x CSR4	34.25 (28.11)	7656 (51.72)	10.00 (38.70)	1.286 (41.70)	0.261 (42.26)	20.29 (53.01)	864 (52.35)	695 (50.81)	74 (48.83)	78 (45.89)	45.64
SK6 x Sk7	38.90 (52.86)	7167 (41.62)	10.11 (39.30)	1.312 (43.59)	0.233 (36.98)	15.52 (33.37)	689 (42.91)	589 (46.59)	74 (45.89)	81 (63.51)	44.66
Bcon1 x Bcon 4	38.09 (48.29)	6856 (35.20)	10.22 (39.89)	1.505 (57.67)	0.270 (47.96)	16.02 (35.42)	519 (33.73)	422 (39.94)	75 (54.70)	77 (40.02)	43.28
CD @5%	3.41	696.94	1.34	0.105	0.039	2.2	107.4	31.91	NS	NS	
CV%	5.21	5.4	6.48	4.39	8.32	6.61	7.69	2.78	3.53	2.84	

Data in parentheses are evaluation Indices for traits; # indicates average evaluation indices

Table 2: Mean performance of the hybrids during Aug-Sep crop (Data pooled over same seasons of 2018 and 2019):

Hybrids	larval wt (g)	ERR by No	ERR by Wt (Kg)	SCW (g)	SSW (g)	SR%	Avg F.L. (m)	Avg NB F.L.(m)	Reel ability%	Avg Neat ness%	Avg EI#
FC1 X FC2	37.92 (51.08)	8758 (59.51)	16.84 (63.85)	1.866 (58.82)	0.395 (63.34)	21.24 (61.42)	875 (61.37)	715 (62.04)	75 (58.91)	81 (61.15)	60.15
HTO5 x HTP5	36.45 (46.68)	8337 (51.63)	13.39 (48.32)	1.934 (65.60)	0.376 (58.77)	19.45 (52.22)	830 (55.57)	711 (61.65)	76 (63.60)	77 (45.77)	54.98
Gen3 x Gen2	42.48 (64.71)	8394 (52.71)	14.31 (52.45)	1.812 (53.45)	0.363 (55.80)	20.06 (55.37)	795 (51.05)	568 (47.47)	70 (35.46)	75 (38.08)	50.66
CSR2 x CSR4	41.62 (62.14)	7822 (42.01)	14.30 (52.42)	1.631 (35.45)	0.335 (49.08)	20.62 (58.24)	874 (61.25)	674 (57.98)	71 (40.15)	75 (38.08)	49.68
Dun6 x Dun22	34.16 (39.83)	8592 (56.41)	15.29 (56.84)	1.891 (61.31)	0.339 (50.06)	17.95 (44.51)	755 (45.89)	539 (44.60)	71 (40.15)	78 (49.62)	48.92
CSR50 x CSR51	41.00 (60.29)	7348 (33.14)	10.87 (36.98)	1.773 (49.62)	0.355 (53.89)	20.06 (55.34)	824 (54.84)	588 (49.45)	72 (44.84)	78 (49.62)	48.8
APS45 x APS12	34.31 (40.27)	8543 (55.50)	10.45 (35.08)	1.742 (46.50)	0.319 (45.33)	18.29 (46.25)	806 (52.47)	705 (61.05)	76 (63.60)	75 (38.08)	48.41
CSR16 x CSR17	39.17 (54.80)	7437 (34.80)	12.10 (42.52)	1.728 (45.09)	0.349 (52.40)	20.2 (56.06)	794 (50.92)	496 (40.34)	73 (49.53)	80 (57.30)	48.38
BCon1 x BCon4	34.48 (40.79)	8891 (62.00)	16.85 (63.89)	1.755 (47.82)	0.315 (44.51)	17.7 (43.25)	642 (31.31)	459 (36.67)	74 (54.22)	80 (57.30)	48.18
SK6 x SK7	34.02 (39.41)	8371 (52.28)	13.24 (47.64)	1.640 (36.35)	0.24 (26.81)	14.61 (27.35)	673 (35.31)	480 (38.75)	73 (49.53)	82 (64.99)	41.84
CD @ 5%	1.59	709.16	1.59	0.11	0.023	1.65	8.82	11.07	3.09	3.61	
CV%	2.49	5.05	6.79	3.635	4.075	5.09	0.65	1.09	2.48	2.71	

Data in parentheses are evaluation Indices for traits; # indicates average evaluation indices

Table 3: Mean performance of the hybrids during Oct-Nov crop (Data pooled over same seasons of 2018 and 2019):

Hybrids	Larval Wt (g)	ERR By No	ERR by Wt (Kg.)	SCW (g)	SSW (g)	SR%	Avg F.L.(m)	Avg NB F.L.(m)	Reel ability%	Avg Neat Ness %	Avg. E.I#
CSR50 x CSR51	37.61 (57.90)	8933 (56.06)	16.44 (62.22)	2.000 (68.21)	0.382 (55.66)	21.31 (55.06)	893 (52.29)	501 (50.82)	76 (46.84)	75 (58.57)	56.39
FC1 X FC2	36.31 (42.34)	9694 (63.45)	17.44 (69.97)	1.852 (55.32)	0.421 (63.09)	22.67 (61.31)	885 (51.68)	443 (45.72)	76 (46.84)	75 (58.57)	55.83
CSR16 x CSR17	35.78 (36.11)	8511 (51.96)	14.83 (49.73)	1.843 (54.55)	0.385 (56.17)	20.85 (52.90)	774 (39.00)	774 (74.82)	78 (67.92)	73 (52.92)	53.61
HTO5 x HTP5	37.14 (52.28)	8506 (51.90)	14.94 (50.59)	1.789 (49.88)	0.361 (51.44)	20.33 (50.33)	969 (61.27)	484 (49.32)	76 (46.84)	68 (38.79)	50.29
Dun6 x Dun22	36.91 (49.61)	8422 (51.10)	14.67 (48.44)	1.788 (49.77)	0.362 (51.86)	20.25 (50.16)	944 (58.41)	472 (48.27)	75 (36.30)	74 (54.80)	49.87
CSR2 x CSR4	36.83 (48.61)	6844 (35.77)	14.39 (46.29)	1.711 (43.09)	0.317 (43.14)	22.32 (59.71)	908 (54.30)	454 (46.69)	77 (57.38)	75 (58.57)	49.36
APS45 x APS12	38.08 (63.50)	7461 (41.76)	13.89 (42.42)	1.851 (55.27)	0.363 (52.02)	19.57 (46.98)	865 (49.39)	556 (55.65)	75 (36.30)	70 (44.44)	48.77
Gen3 x Gen2	36.34 (42.84)	6556 (32.96)	12.78 (33.81)	1.828 (53.28)	0.398 (58.81)	21.79 (57.27)	960 (60.24)	480 (48.97)	76 (46.84)	70 (44.44)	47.95
SK6 x SK7	36.17 (40.71)	9083 (57.52)	14.93 (50.48)	1.633 (36.32)	0.278 (35.55)	16.94 (34.82)	810 (43.12)	405 (42.38)	77 (57.38)	75 (58.57)	45.68
BCon1 x BCon4	38.30 (66.10)	9083 (57.52)	14.36 (46.06)	1.610 (34.32)	0.261 (32.24)	16.17 (31.26)	695 (29.99)	348 (37.37)	77 (57.38)	65 (30.32)	42.25
CD@5%	NS	1079.21	1.95	0.08	0.014	0.97	18.09	58.85	NS	3.66	
CV%	2.56	7.63	7.71	2.69	2.37	2.8	1.22	7.02	2.03	2.99	

Data in parentheses are evaluation Indices for traits; # indicates average evaluation indices

Table 4: Overall performance of the hybrids (Data pooled for all the crop seasons of 2018 and 2019):

Hybrids	larval wt(g)	ERR By No	ERR byWt (Kg)	SCW (g)	SSW (g)	SR%	Avg F.L.(m)	Avg NB F.L.(m)	Reel ability%	Avg Neat ness%	Avg. E.I.#
FC1 X FC2	37.37 (49.05)	8765 (66.99)	15.92 (71.74)	1.793 (63.93)	0.395 (65.05)	22.08 (62.08)	936 (61.46)	736 (61.30)	74.72 (51.07)	81.33 (63.92)	61.66
HTO5 x HTP5	37.54 (50.40)	8228 (51.02)	13.73 (48.90)	1.775 (61.16)	0.352 (54.33)	19.93 (51.60)	993 (67.04)	792 (66.33)	75.81 (64.17)	77 (39.47)	55.44
CSR50 x CSR51	39.37 (64.88)	8141 (48.45)	13.68 (48.35)	1.691 (48.18)	0.353 (54.69)	20.97 (56.67)	770 (44.85)	635 (52.22)	73.38 (35.01)	79.67 (54.51)	50.78
CSR16 x CSR17	37.87 (53.05)	7999 (44.22)	13.64 (47.92)	1.687 (47.61)	0.349 (53.54)	20.69 (55.28)	796 (47.43)	560 (45.48)	74.98 (54.30)	80.33 (58.28)	50.71
Gen3 x Gen2	39.29 (64.29)	7611 (32.69)	13.86 (50.18)	1.749 (57.19)	0.365 (57.61)	20.87 (56.19)	903 (58.08)	556 (45.12)	73.36 (34.74)	77 (39.47)	49.56
Dun6 x Dun22	35.65 (35.47)	8305 (53.34)	14.11 (52.88)	1.734 (54.77)	0.327 (48.19)	18.85 (46.31)	824 (50.22)	580 (47.28)	74.23 (45.23)	79.33 (52.63)	48.63
CSR2 x CSR4	38.23 (55.90)	7953 (42.86)	13.48 (46.20)	1.594 (33.21)	0.339 (51.22)	21.23 (57.94)	815 (49.32)	608 (49.79)	74.43 (47.65)	78.33 (46.99)	48.11
APS45 x APS12	36.95 (45.77)	7955 (42.92)	12.16 (32.37)	1.711 (51.34)	0.325 (47.72)	18.96 (46.83)	802 (48.10)	701 (58.15)	75.57 (61.30)	77.33 (41.35)	47.58
BCon1 x BCon4	36.73 (44.01)	8560 (60.92)	14.53 (57.22)	1.683 (46.91)	0.284 (37.61)	16.75 (36.06)	653 (33.24)	410 (32.00)	75.29 (58.01)	77 (39.47)	44.54
SK6 x SK7	35.87 (37.18)	8415 (56.59)	13.29 (44.24)	1.610 (35.70)	0.254 (30.03)	15.72 (31.03)	724 (40.27)	525 (42.33)	74.51 (48.54)	81.33 (63.92)	42.98
CD @5%	1.23	418.92	1.03	0.06	0.01	0.87	102.84	71.51	NS	NS	
CV%	1.93	3	4.38	2.15	2.3	2.6	7.35	6.88	2.97	9.76	

Data in parentheses are evaluation Indices for traits; # indicates average evaluation indices

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