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Khasru Alam
Regional Sericultural Research Station, Koraput, Odisha, India

Harish Babu
Regional Sericultural Research Station, Kalimpong, West Bengal, India

Siraj Monir
Visva Bharati University, Birbhum, West Bengal, India

V Sivaprasad
Central Sericultural Research and Training Institute, Berhampore, West Bengal, India

Corresponding Author:
Khasru Alam
Regional Sericultural Research Station, Koraput, Odisha, India

Evaluation of bivoltine silkworm breeds (*Bombyx mori* L.) for cocoon and associated characters under Koraput conditions, Odisha

Khasru Alam, Harish Babu, Siraj Monir and V Sivaprasad

Abstract
The prime objective of this study was to evaluate fourteen native strains of silkworm, *Bombyx mori* L., available with Regional Sericultural Research Station, Koraput based on different quantitative traits. Silkworm breeds like Kora1 to Kora10, SK6, SK7, BCon1 and BCon4 were evaluated under the study in three main crops (May-June 2020; July-August 2020; October-November 2020) in Koraput conditions Odisha. The rearing performances of the breeds were documented for analysis and multiple trait evaluation index values were utilized to determine the best performing breed. Six breeds (Kora1, Kora2, Kora3, Kora6, Kora7 and Kora9) has performed very well under Koraput conditions with mean EI values >50. The result indicated that there were considerable variations with respect to the different cocoon and associated characters amongst the evaluated breeds in different seasons. Two breeds namely Kora2 and Kora10 has scored average EI values >50 for the maximum of 6 individual traits *viz*., fecundity, hatching%, cocoon yield by weight and number, single shell weight, shell ratio, particularly with respect to mean performance of the breeds. Therefore the identified breeds can be used as resource materials in various silkworms breeding programme for synthesis of superior season and region specific hybrids.

Keywords: bivoltine silkworm breed, evaluation, Odisha

Introduction
Sericulture the agro industrial avocation stands for livelihood opportunity to the millions of people in the country besides earning of foreign exchange. However bulk of the Indian silk comes from the multivoltine or multi x bivoltine breeds which are very much suitable for the handloom industry. Even though lot of research break through has yielded many productive bivoltine breeds (Mano *et al.*, 1991) [10], (Hong *et al.*, 1992, Thiagarajan *et al.*, 1993) [7, 20], (Datta *et al.*, 2001) [4], (Basavraja *et al*., 2013) [2], but sustenance of the Indian silk industry lies with the development of silkworm breeds having capacity to produce import substitute bivoltine silk. Many a times it was found that breeds performing well in laboratory suffers badly under adverse environmental conditions causing wide gap between realized cocoon yield in laboratory and field. Therefore, choice of a breed/hybrid depends not only on the genotype but also on its performance under diverse environmental conditions (Rahman & Ahmed, 1988) [15]. The biological as well as cocoon related Characters in silkworms are known to influence greatly by temperature, humidity, rearing seasons and genetic constitution of silkworm strains etc. (Rajesh *et al.*, 2010) [16]. Seasonal influence on the performance of a silkworm breeds are prominent if there is differences in the environmental components, which in turn may affect the genotypic expression in the form of phenotypic output such as cocoon weight, and cocoon shell ratio etc. (Nacheva *et al.* 1989) [12]. Many of the yield and associated traits of the silkworm controlled both by genes as well as by environmental factors. Almost all the biological process in silkworm including rates of biochemical and physiological reactions are known to influence very much by environmental factors and determines the quality and quantity of cocoon crop. Therefore utmost importance may be given to Continuous development, evaluation, renewal and change of existing breeds/hybrids with new or superior breeds or variety with reference to diverse climatic factors for qualitative and quantitative improvement in silk production. The state Odisha experiences wide variation in temperature, humidity and rainfall but still continuous efforts are in place to promote bivoltine sericulture in the state unfortunately there is no specific breed or hybrids for the state that have gained popularity in the practical field. Keeping the above aspects in view, the seasonal performance of fourteen pure breeds were assessed by using Multiple trait evaluation index (E.I.) to identify

promising breeds so as to use as future breeding materials for better cocoon yield and productivity.

Materials and Methods

In the present study, ten bivoltine pure breeds *viz*., Kora1 to Kora 10, SK6, SK7, BCon1 and BCon4 drawn from the stock maintained at Regional Sericultural Research Station, Koraput were selected to assess their performance under Koraput conditions in different rearing seasons. The laying of all the pure breeds was incubated in properly disinfected room while maintaining 80-85% humidity and 25˚C temperature. Uniformly developed layings were selected, packed and subjected to black boxing for uniform and ideal hatching. The newly hatched larvae were maintained with finely chopped fresh mulberry leaves. The young larvae were reared at a temperature of 26˚C to 28˚C and relative humidity of 85-90%. The rearing of all the breeds were carried out in a completely randomized design (CRD) with three replications each consists of 300 larvae maintained after third instars by following the standard rearing techniques of (Krishnaswami 1978) [9]. While rearing larvae were provided with three feeding of fresh mulberry leaves harvested from the well maintained garden of the station till the onset of spinning. Further certain disinfectants like lime bleaching powder etc. were used as precautionary measures to keep the rearing environment disease free. Once the larvae attains maturity were mounted in plastic collapsible mountages following all the standard protocol of mounting. Finally harvesting of the cocoons was carried out on $6^{th}/7^{th}$ day of spinning. The data pertaining to different biological traits of silkworm *viz*. Fecundity, hatching %, effective rate of rearing by number and weight, single cocoon weight, single shell weight and SR% were measured and analysed. The data generated in respect of different traits was pooled, analyzed statistically and subjected further to multiple trait evaluation index using the following formula (Mano *et al*., 1993) [11].

Evaluation index (E.I.) = A-B/C x 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 Discussion

14 (fourteen) pure breeds were evaluated at RSRS, Koraput, their comparative performances, statistical analysis along with evaluation index for different cocoon and associated parameters are presented in Table-1, 2, 3 and 4.

During May-June crop, performance of the breeds revealed that among 14 breeds Kora 2 scored highest values for fecundity (500.33), ERR by number (8911) and SR% (20.89) whereas Kora 4 for single cocoon weight (1.504 g) and single shell weight (0.300 g), Kora 8 for ERR by weight (13.11 kg) and SK 7 for hatching % (96.76). Breeds like SK7 scored least values for ERR by number (7100), ERR by weight (7.89 kg), Kora 6 for single cocoon weight and single shell weight (1.201 g, 0.232 g), SK6 for hatching % (88.81), BCon1 for SR% (18.29) and BCon4 for fecundity (401).

Similarly in July-August crop Kora2 scored highest values for hatching %, single shell weight and SR% (96.46, 0.250 g, 19.01) whereas Kora 6, 8, and 9 recorded highest values for single cocoon weight (1.684 g), ERR by weight (15.02 kg) and fecundity (445) and SK7 recorded highest values for ERR by number (8944). The breed BCon4 recorded lowest values for both single shell weight and SR% (0.230 g, 12.73), Kora4 for both ERR by number and weight (5288, 6.67 kg), Kora10 for fecundity (413), Kora8 for hatching % (93.24) and Kora2 for single cocoon weight (1.361).

During October-November crop the breed Kora2 scored highest values for Hatching % (97.83), ERR by number (9488), ERR by weight (16.78 kg), Single shell weight (0.370 g) and SR% (22.50) respectively. Whereas breeds like Kora6 and Kora9 scored highest values for single cocoon weight (1.785 g) and fecundity (498). Both Kora9 and BCon4 scored lowest values for the characters like hatching % (94.20) single cocoon weight (1.225 g), single shell weight (0.208 g) and SR% (13.42). The breeds like Kora5, Kora6 and Kora9 recoded lowest values for ERR by weight (10.44 kg), ERR by number (8144) and hatching % (94.20).

With respect to the mean performance of the breeds Kora2 exhibited maximum values for the characters hatching % (96.20), ERR by number (8848), single shell weight (0.298 g) and SR% (20.80). Whereas Kora6 and Kora8 scored maximum values for single cocoon weight (1.557 g) and ERR by weight (13.79 kg) and Kora9 for fecundity (480). Kora4 and BCon4 recorded lowest values for the characters ERR by number (7137), ERR by weight (9.81 kg), single shell weight (0.216 g) and SR% (15.04). But Kora8, Kora9 and BCon1 registered lowest values for fecundity (385), single cocoon weight (1.372 g) and hatching% (93.49) respectively.

The present research findings based on evaluation index (E.I) revealed that eight breeds *viz*., Kora2 (61.32), Kora4 (58.47), Kora8 (52.73), Kora10 (52.33), Kora9 (52.22), Kora3 (51.43) Kora7 (51.14) and Kora5 (50.41) were performed well during May-June crop. During July-August crop seven breeds were found to be good performer namely kora9 (55.30), Kora2 (54.39), Kora7 (53.13), Kora6 (52.77), SK6 (52.39), Kora10 (51.99) and Kora8 (51.22). While during October-November crop Kora2 (65.77), Kora3 (55.84), Kora4 (53.93), Kora1 (53.43), SK6 (50.46), Kora6 (50.41) and BCon1 (50.06) were found promising scoring EI value more than fifty. As far as mean performance of the breeds are concerned 6 breeds only out of 14 scored average EI value >50 with Kora2 (63.39) occupied the top position followed by Kora3 (53.53), Kora10 (53.13), Kora6 (52.43), Kora7 (51.08) and Kora1 (50.54)

Multiple traits evaluation index method helps in identification of superior breeds or hybrids from an array of breeds, while considering cumulative effect of most of the yield attributing characters. The method have been used widely by the silkworm breeder in many studies, (Ganaie *et al*., 2012) [5], (Nisar *et al*., 2013) [13], and (Nooruldin *et al*., 2014) [14], Khasru *et al*., 2020) [8]. Multiple trait evaluation index facilitate the precision selection of silkworm breed from a collection of pool of breeds while giving due weight age to all the yield contributing attributes (Bhargava *et al*., 1994) [3]. The stability of a breed or hybrid is influenced greatly 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 breed requires due considerations both for genotype and its performance under diverse agro climatic conditions (Rahman and Ahmed 1988) [15]. In the present study different breeds were selected and evaluated with respect to different seasons under Odisha

condition. The breeds evaluated in this experiment exhibited considerable degree of variability in their expression in Odisha under different seasons. Similar results on varietal difference for the studied characters of silkworm *Bombyx mori* have also been reported by many authors (Rangaiah *et al.*, 1995) [17], Ahsan *et al.*, 2000) [1]. The variation observed in the cocoon and associated characters in the present study may be attributed to the genetic constitution of the genotype and the degree of their expression to the rearing environment in which the breeds were exposed during rearing. Since most of the commercially important quantitative traits in silkworm are under complicated polygenic control via the influence of the environment (Rao *et al.*, 2006, Salehi *et al.*, 2010b) [18, 19]. Therefore, the present attempt on evaluation of some bivoltine silkworm breeds with respect to important cocoon associated traits has in fact yielded rich information, to identify potential breeds that can be used for preparation of suitable hybrid for the best interest of the silk industry.

Finally from the above study it can be concluded that out of 14 breeds six breeds (Kora1, Kora2, Kora3, Kora6, Kora7 and Kora9) has performed very well under Koraput conditions with mean EI values >50. Further, two breeds namely Kora2 and Kora10 has scored average EI values >50 for the maximum of 6 individual traits *viz*., fecundity, hatching %, cocoon yield by weight and number, single shell weight, shell ratio, particularly with respect to mean performance of the breeds. Therefore, the breeds shown greater performances can be used as future breeding materials for silkworm breed improvement programme.

Table 1: Performance of the breeds during May-June crop

Breeds	Fecundity	Hatching	ERR by number	ERR by wt (kg)	SCW (g)	SSW (g)	SR%	EI
K1	474.33 (55.36)	93.15 (47.44)	7166.67 (35.79)	9.00 (41.02)	1.355 (54.017)	0.259 (48.081)	19.47 (48.00)	47.10
K2	500.33 (62.89)	94.30 (52.80)	8911.11 (66.38)	12.00 (60.76)	1.355 (54.066)	0.288 (64.274)	20.89 (68.07)	61.32
K3	438.33 (44.94)	94.69 (54.63)	8022.22 (50.79)	10.33 (49.79)	1.349 (53.079)	0.272 (55.625)	19.69 (51.11)	51.43
K4	499.00 (62.50)	92.38 (43.86)	7822.22 (47.29)	9.89 (46.87)	1.504 (76.134)	0.300 (71.082)	20.43 (61.58)	58.47
K5	472.33 (54.78)	93.13 (47.35)	7555.56 (42.61)	9.56 (44.67)	1.316 (48.240)	0.269 (53.785)	20.42 (61.42)	50.41
K6	468.33 (53.62)	93.98 (51.32)	7755.56 (46.12)	10.67 (51.98)	1.201 (31.257)	0.232 (33.544)	19.65 (50.50)	45.48
K7	451.67 (48.80)	95.30 (57.48)	8333.33 (56.25)	10.78 (52.72)	1.313 (47.845)	0.256 (46.609)	19.49 (48.30)	51.14
K8	453.33 (49.28)	95.34 (57.67)	8266.67 (55.08)	13.11 (68.07)	1.284 (43.501)	0.250 (43.297)	19.77 (52.21)	52.73
K9	499.33 (62.60)	94.21 (52.38)	7977.78 (50.01)	11.78 (59.30)	1.254 (39.057)	0.253 (44.953)	20.12 (57.25)	52.22
K10	473.67 (55.17)	95.35 (57.72)	8500.00 (59.17)	12.00 (60.76)	1.349 (53.177)	0.252 (44.217)	18.63 (36.10)	52.33
SK6	438.67 (45.04)	88.81 (27.17)	7266.67 (37.55)	8.22 (35.90)	1.341 (51.894)	0.272 (55.625)	19.39 (46.90)	42.87
SK7	404.67 (35.20)	96.76 (64.30)	7100.00 (34.62)	7.89 (33.70)	1.357 (54.263)	0.271 (54.705)	19.01 (41.51)	45.47
BCon1	406.00 (35.58)	89.98 (32.64)	8233.33 (54.49)	9.22 (42.48)	1.310 (47.302)	0.240 (37.776)	18.29 (31.30)	40.22
BCon4	401.33 (34.23)	94.39 (53.25)	8766.67 (63.84)	10.67 (51.98)	1.302 (46.167)	0.256 (46.425)	19.31 (45.73)	48.81
CD	6.38	1.08	1085.45	2.05	0.124	0.034	2.05	
CV%	0.83	0.69	8.13	8.58	5.622	7.96	4.110	

Data in parentheses are evaluation Indices for traits.

Table 2: Performance of the breeds during July-Aug crop

Breeds	Fecundity	Hatching	ERR by number	ERR by wt (kg)	SCW (g)	SSW (g)	SR%	EI
K1	418.00 (40.65)	96.01 (61.23)	8311.11 (52.63)	11.89 (47.37)	1.417 (33.022)	0.226 (46.654)	15.97 (56.94)	48.36
K2	428.67 (51.88)	96.46 (65.72)	8144.00 (51.09)	11.59 (46.02)	1.361 (26.551)	0.250 (61.907)	19.01 (77.57)	54.39
K3	418.00 (40.65)	95.47 (55.70)	7122.22 (41.68)	10.28 (40.08)	1.575 (51.063)	0.243 (57.549)	15.41 (53.13)	48.55
K4	423.67 (46.62)	93.44 (35.18)	5288.89 (24.81)	6.67 (23.75)	1.503 (42.804)	0.228 (47.961)	15.20 (51.70)	38.97
K5	417.67 (40.30)	94.89 (49.86)	6200.00 (33.20)	10.56 (41.38)	1.619 (56.049)	0.247 (60.382)	15.26 (52.17)	47.62
K6	424.67 (47.67)	94.59 (46.85)	8633.33 (55.59)	12.78 (51.39)	1.684 (63.433)	0.243 (57.767)	14.45 (46.66)	52.77
K7	425.00	94.37	8544.44	13.83	1.623	0.247	15.22	53.13

	(48.02)	(44.59)	(54.78)	(56.17)	(56.506)	(59.946)	(51.89)	
K8	431.33 (54.69)	93.24 (33.12)	8844.44 (57.54)	15.02 (61.55)	1.622 (56.354)	0.231 (49.922)	14.27 (45.40)	51.22
K9	445.00 (69.07)	94.22 (43.08)	8522.22 (54.57)	14.73 (60.21)	1.640 (58.485)	0.236 (53.191)	14.72 (48.49)	55.30
K10	416.00 (38.55)	94.80 (48.91)	8622.22 (55.49)	13.78 (55.92)	1.592 (52.928)	0.243 (57.549)	15.62 (54.58)	51.99
SK6	436.33 (59.95)	96.25 (63.66)	8355.56 (53.04)	13.56 (54.94)	1.593 (53.080)	0.217 (40.770)	13.66 (41.30)	52.39
SK7	433.67 (57.14)	94.23 (43.14)	8944.44 (58.46)	12.22 (48.88)	1.562 (49.579)	0.215 (39.245)	14.06 (44.02)	48.64
BCon1	417.00 (39.60)	95.72 (58.23)	8800.00 (57.13)	13.67 (55.41)	1.540 (46.990)	0.210 (35.976)	13.64 (41.17)	47.79
BCon4	441.33 (65.21)	94.98 (50.74)	8422.22 (53.65)	14.00 (56.93)	1.594 (53.156)	0.203 (31.182)	12.73 (34.97)	49.41
CD	6.45	1.04	1581.33	2.78	0.131	0.029	1.80	
CV%	0.90	0.65	11.78	10.92	5.03	7.56	7.210	

Data in parentheses are evaluation Indices for traits.

Table 3: Performance of the breeds during October-November crop

Breeds	Fecundity	Hatching	ERR by number	ERR by wt (kg)	SCW (g)	SSW (g)	SR%	EI
K1	481.00 (55.11)	94.92 (42.64)	9066.67 (55.47)	14.00 (55.64)	1.437 (45.95)	0.302 (57.731)	20.94 (61.48)	53.43
K2	482.33 (55.34)	97.83 (68.50)	9488.89 (64.26)	16.78 (72.26)	1.644 (57.96)	0.370 (74.264)	22.50 (67.78)	65.77
K3	486.00 (55.98)	95.43 (47.19)	9488.89 (64.26)	14.33 (57.63)	1.561 (53.11)	0.302 (57.568)	19.37 (55.15)	55.84
K4	496.33 (57.76)	97.35 (64.21)	8300.00 (39.51)	12.89 (48.99)	1.683 (60.19)	0.301 (57.324)	17.97 (49.52)	53.93
K5	475.00 (54.08)	94.60 (39.83)	8455.56 (42.75)	10.44 (34.36)	1.287 (37.24)	0.262 (47.795)	20.29 (58.87)	44.99
K6	476.33 (54.31)	95.18 (45.01)	8144.44 (36.27)	14.11 (56.30)	1.785 (66.15)	0.285 (53.415)	15.96 (41.40)	50.41
K7	455.67 (50.74)	96.17 (53.78)	8555.56 (44.83)	11.00 (37.69)	1.315 (38.82)	0.257 (46.655)	19.55 (55.88)	46.91
K8	271.00 (18.89)	96.53 (56.91)	8644.44 (46.68)	13.22 (50.98)	1.282 (36.95)	0.245 (43.642)	19.05 (53.87)	43.99
K9	498.00 (58.04)	94.20 (36.26)	8188.89 (37.20)	10.89 (37.02)	1.255 (35.34)	0.253 (45.678)	20.11 (58.16)	43.96
K10	479.33 (54.83)	96.23 (54.26)	8355.56 (40.67)	11.56 (41.01)	1.433 (45.71)	0.265 (48.610)	18.48 (51.58)	48.09
SK6	432.00 (46.66)	97.11 (62.06)	8944.44 (52.92)	13.24 (51.07)	1.619 (56.47)	0.249 (44.782)	15.42 (39.23)	50.46
SK7	433.00 (46.83)	94.92 (42.64)	9277.78 (59.86)	13.88 (54.91)	1.583 (54.42)	0.215 (36.394)	13.58 (31.84)	46.70
BCon1	425.33 (45.51)	94.76 (41.28)	9155.56 (57.32)	13.28 (51.35)	1.668 (59.34)	0.277 (51.542)	16.61 (44.04)	50.06
BCon4	427.67 (45.91)	95.23 (45.42)	9188.89 (58.01)	13.19 (50.78)	1.548 (52.352)	0.208 (34.602)	13.42 (31.20)	45.47
CD	13.48	0.90	425.1	1.329	0.123	0.036	2.05	
CV%	1.78	0.56	2.88	6.08	4.91	8.02	1.770	

Data in parentheses are evaluation Indices for traits.

Table 4: Mean performance of the breeds

Breeds	Fecundity	Hatching	ERR by number	ERR by wt (kg)	SCW (g)	SSW (g)	SR%	Avg. EI	Rank
K1	457.78 (55.08)	94.69 (48.71)	8181.48 (48.02)	11.63 (47.77)	1.403 (40.534)	0.264 (55.301)	18.79 (58.36)	50.54	6
K2	470.44 (59.99)	96.20 (70.33)	8848.00 (61.66)	13.46 (64.03)	1.428 (44.695)	0.298 (71.364)	20.80 (71.69)	63.39	1
K3	447.44 (51.07)	95.20 (55.94)	8211.11 (48.62)	11.65 (47.93)	1.505 (57.857)	0.272 (59.171)	18.15 (54.12)	53.53	2
K4	473.00 (60.98)	94.39 (44.36)	7137.04 (26.63)	9.81 (31.60)	1.552 (65.785)	0.276 (61.133)	17.87 (52.21)	48.96	8
K5	455.00 (54.00)	94.21 (41.71)	7403.70 (32.09)	9.85 (31.93)	1.407 (41.250)	0.259 (52.969)	18.66 (57.47)	44.49	14
K6	456.44	94.59	8177.78	12.52	1.557	0.255	16.68	52.43	4

	(54.56)	(47.16)	(47.94)	(55.68)	(66.557)	(50.742)	(44.38)		
K7	444.11 (49.78)	95.28 (57.17)	8477.78 (54.08)	11.87 (49.91)	1.417 (42.869)	0.253 (50.053)	18.09 (53.68)	51.08	5
K8	385.22 (26.95)	95.03 (53.62)	8585.19 (56.28)	13.79 (66.97)	1.396 (39.310)	0.242 (44.699)	17.58 (50.34)	48.31	9
K9	480.78 (63.99)	94.21 (41.73)	8229.63 (49.00)	12.22 (53.04)	1.372 (35.224)	0.247 (47.296)	18.32 (55.23)	49.36	7
K10	456.33 (54.52)	95.46 (59.71)	8492.59 (54.39)	12.44 (55.02)	1.447 (47.953)	0.253 (50.053)	17.58 (50.29)	53.13	3
SK6	435.67 (46.50)	94.06 (39.55)	8188.89 (48.17)	11.30 (44.84)	1.516 (59.703)	0.242 (44.699)	16.16 (40.87)	46.33	11
SK7	423.78 (41.90)	95.30 (57.46)	8440.74 (53.33)	11.33 (45.09)	1.465 (51.041)	0.225 (36.376)	15.55 (36.86)	46.01	12
BCon1	416.11 (38.92)	93.49 (31.35)	8729.63 (59.24)	12.06 (51.58)	1.495 (56.031)	0.240 (43.744)	16.18 (41.03)	45.99	13
BCon4	423.44 (41.77)	94.87 (51.21)	8792.59 (60.53)	12.40 (54.59)	1.466 (51.192)	0.216 (32.400)	15.04 (33.48)	46.45	10
CD	6.01	2.05	700.77	1.24	0.081	0.018	0.822		
CV%	0.81	0.38	5.06	6.22	3.354	4.414	2.810		

Data in parentheses are evaluation indices for traits.

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