Research Article

EVOLUTION OF NEW FOUNDATION CROSSES OF BIVOLTINE SILKWORM HYBRIDS UNDER SEMI TEMPERATE CONDITIONS OF NILGIRIS

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ABSTRACT

Twenty nine newly evolved bivoltine pure breeds maintained at the germplasm stock of Satellite Silkworm Breeding Station of Central Silk board, Coonoor, sixteen oval breeds and thirteen dumbbell breeds, were selected as resource material for the study. The breeds were reared in two seasons, studied their efficiency on rearing and reeling performance based on fourteen cocoon and silk yield parameters; seven each of pre-cocoon, viz., fecundity, fifth age larval duration, total larval duration, pupation rate, single cocoon weight, single shell weight, shell percentage and post cocoon traits - average filament length (AVFL), non breakable filament length (NBFL), denier, renditta, reelability, and neatness. Using these bivoltine breeds (viz., sixteen oval cocoon breeds viz., CSR 2, D1, D2, D 7, CSR 202, CSR 204, CNR 5, CNR 14, CNR 15, SLD 1, SLD 2, SLD 4, Gen 1, Gen 3, CSR 50 and thirteen dumbbell cocoon breeds - CNR 3, SLD 6, SLD 8, SLD 9, D 11, D 13, D 15, D 17, GEN 2, 4 C, CSR 6, CSR 26, CSR 51) forty seven new foundation crosses were prepared in P.O. x P.O (Plain larvae & Oval cocoons) and M. D. x M.D (marked larvae & dumbbell cocoons) fashion among them in all possible combinations of direct crosses. Two Foundation Crosses- FC1 (CSR6 x 26) for dumbbell foundation crosses and FC2 (CSR 2x 27) for oval foundation crosses were kept as control and evaluated the rearing performance of 49 FCs (47 new FCs and 2 control) for two seasons. Analyzed the data on rearing and reeling parameters and short listed them to 14 Foundation crosses for further evaluation and preparation of double hybrids.

INTRODUCTION

The role of sericulture in revolutionizing the Indian economy is note worthy and very promising. Sericulture, the viable agro-based industry aptly matches the socio-economic backdrop of rural India. It is a matter of pride that India being in the second position with regard to the raw silk production, but the gap between the first and the second is very far and wide. Since domestication of silkworm, efforts were being made to evolve silkworm races with greater quantitative traits. Silkworm breeders in sericulturally advanced countries like China, Japan and South korea have been successful in exploiting the silkworms by evolving new races with special and specific traits in a balanced way (Basavaraja, 1996; Nirmal Kumar and Sreerama Reddy, 1998; Datta *et al.*, 2000; Nair Suresh Kumar and Harjeet Singh, 2011; Rajalakshmi, 2014).

Keeping this in view, in 1990s many bivoltine breeding projects were undertaken in the south, in Mysore and Karnataka, and semi temperate belts of India viz., Pampore, Dehra Dun, Kalimpong and Coonoor. Coonoor, in the Nilgiris, of Tamil nadu, being in an high altitude location in the Western Ghats, (1000 -2636 m above MSL), with semi temperate climatic conditions of temperature minimum 4 -12 C, maximum of 12-28 C, humidity 50 - 100 % and annual rain fall 1400 – 1700 mm throughout the year, are different from tropical Indian conditions prevailing in plain areas. The environmental fluctuations were studied, evaluated the best suitable seasons, evolved many productive and potential bivoltine breeds and hybrids and realized the true potential of the bivoltines (Rajalakshmi *et al.*, 1997 and 1998; Chauhan *et al.*, 2000).

Manipulating the climate is tedious and costly and also not advisable in the long run

In India, the introduction of productive bivoltine CSR hybrids (both single, double and triple way cross) for the last two decades brought in a phenomenal impact on the sericulture scenario resulting in increased yield and income for the farmers besides increased output of quality raw silk. Consequently, over the years, the concept of single hybrids pave way for the development of Foundation Crosses and identification of double hybrids in the field, which has revolutionized the Indian silk industry and the economic status of the farmers (Nirmal Kumar *et al*., 1998; Datta *et al.,* 2000; Yamaguchi, 2000; Mal Reddy *et al.,* 2005; Pallavi and Basavaraja, 2007; Rajalakshmi, 2000 and 2014).

MATERIALS AND METHODS

Twenty nine newly evolved productive bivoltine breeds maintained at the germplasm stock of Satellite Silkworm Breeding Station, Coonoor, sixteen oval breeds namely CSR 2, CSR 27, D1, D2, D 7, CSR 202, CSR 204, CNR 5, CNR 14, CNR 15, SLD 1, SLD 2, SLD 4, Gen 1, Gen 3, CSR 50 (Table- 1) and 13 dumbbell breeds - CNR 3, SLD 6, SLD 8, SLD 9, D 11, D 13, D 15, D 17, GEN 2, 4 C, CSR 6, CSR 26, CSR 51 (Table – 2) were selected as resource material for the study.

The selected breeds were brushed in composite and reared in two seasons, studied their efficiency on rearing and cocoon characters based on eight traits, four each of pre-cocoon viz., fecundity, fifth age larval duration, total larval duration, pupation rate, and of post cocoon viz., single cocoon weight, single shell weight, shell percentage, number of cocoons / liter respectively (Table – 1 & 2).

Cocoons of these breeds were selected, crossed in all possible combinations, processed and prepared forty seven new Foundation Crosses, 26 crosses in P.O. x P.O (Plain larvae & Oval cocoons) and 21 crosses M. D x M.D (marked larvae & dumbbell cocoons) . Two popular foundation crosses in the field viz., FC 1 (CSR 6x CSR 26) for dumbbell foundation crosses and FC2 (CSR 2x 27) for oval foundation crosses were kept as control and evaluated the rearing performance of these 47 new FCs (Table – 3 and 4), along with their respective parents in two seasons by following the standard rearing technologies of breeding and race maintenance (Krishnasami, 1978). The layings were brushed in composite of 1000 eggs from 20 dfls to have more effective accumulation of genes in the gene pool. After third moult, each FC batch was replicated to three batches of 250 larvae each. The data on (i) rearing, viz., fecundity, larval duration both fifth age and total; (ii) cocoon viz., pupation rate by counting all the live cocoons for survival, single cocoon weight and single shell weight by assessing 10 cocoons each of male and female; and number of cocoons per liter were recorded.

The observations and data on the rearing performance of 47 Foundation Crosses (FCs) over the parents and their control FCs were compiled on qualitative and quantitative traits, with special reference to the phenotypic characters viz., cocoon uniformity and pupation / survival, and based on the results the 47 FCs were short listed to 14 (8 oval FCs and 6 dumbbell FCs).

Table 1. Rearing Performance of Parents - Ovals

No	Breed	Fec.	V L.D D:hrs	L.D D : hrs	ERR (No.)	S.C.wt. (g)	S.S.wt (g)	S.R. (%)	Coc./ L (No.)
1	CNR - 5	533	7.04	23.12	88.28	1.548	0.328	21.18	98
2	CNR - 14	511	7.04	22.22	94.40	1.486	0.330	22.20	99
3	CNR - 15	498	7.05	23.09	93.87	1.610	0.362	22.51	94
4	SLD - 1	532	7.14	23.18	92.47	1.697	0.353	20.80	96
5	SLD - 2	492	6.18	22.14	92.80	1.631	0.35	21.43	93
6	SLD - 4	567	7.10	23.15	96.80	1.696	0.368	21.72	97
7	D - 1	532	7.09	23.09	92.53	1.844	0.402	21.78	80
8	D- 2	491	7.12	24.03	88.92	1.577	0.367	23.97	96
9	D - 7	535	7.03	23.12	94.02	1.639	0.374	22.81	96
10	CSR -202	472	7.04	23.16	96.13	1.564	0.348	22.28	99
11	CSR- 204	518	7.11	23.10	92.60	1.603	0.361	22.52	95
12	GEN 1	552	7.13	23.18	96.27	1.749	0.371	21.23	84
13	GEN 3	556	7.09	24.10	95.50	1.676	0.396	23.62	88
14	CSR 2	520	7.00	23.12	97.00	1.700	0.388	22.82	82
15	CSR 27	534	7.06	23.18	96.80	1.817	0.420	23.12	78
16	CSR 50	584	7.09	24.00	97.80	1.795	0.398	22.14	80
	Avg.	527	7.02	23.19	94.14	1.665	0.370	22.26	91
	CD@5%	15.62	0.12	0.28	1.47	0.05	0.01	0.47	4.12
	CV %	0.057	0.032	0.023	0.030	0.061	0.070	0.040	0.09

Table 2. Rearing Performance of Parents - Dumbbells

No	Breed	Fec.	V L.D D:hrs	L.D D : hrs	ERR (No.)	S.C.wt. (g)	S.S.wt (g)	S.R. (%)	Coc./ L (No.)
1	CNR - 3	656	7.08	23.12	90.20	1.628	0.338	20.77	111
2	SLD - 6	542	6.15	23.1	88.04	1.525	0.336	22.06	112
3	SLD - 8	512	7.11	23.18	91.15	1.724	0.381	22.18	101
4	SLD - 9	467	7.11	23.1	93.70	1.489	0.323	21.70	111
5	D- 11	587	7.09	23.16	94.60	1.500	0.327	21.77	108
6	D- 13	599	6.22	23.16	91.97	1.462	0.298	20.36	120
7	D - 15	553	7.10	23.07	90.00	1.534	0.332	21.65	117
8	D- 17	548	7.10	23.12	93.75	1.567	0.354	22.60	108
9	GEN -2	465	7.10	24.12	94.02	1.777	0.393	22.09	110
10	4 C	554	7.13	23.20	91.07	1.717	0.344	20.04	105
11	CER 6	538	7.00	24.00	94.60	1.783	0.372	20.84	110
12	CSR 26	563	6.22	24.04	93.60	1.725	0.363	21.02	108
13	CSR 51	613	7.10	24.00	88.80	1.756	0.373	21.59	113
	Avg.	554	6.20	23.41	91.96	1.630	0.349	21.44	110
	CD@5%	28.3	0.21	0.23	1.18	0.06	0.01	0.40	3.61
	CV %	0.10	0.057	0.019	0.024	0.074	0.077	0.036	0.06

RESULTS AND DISCUSSION

The data of average of two trials on the rearing performance and cocoon traits of 16 oval and 13 dumbbell parental breeds are presented in the Table- 1 & 2 respectively. A total of 47 Foundation Crosses were made out of crossing them in plain larvae and oval cocoons (P x O) x (P x O) , 26 crosses and 21 crosses in marked larvae x dumbbell cocoons (M.D.) x (M.D.), their average of performance of two seasons are presented in Table– 3 and 4 respectively. The newly evolved and short listed Foundation Crosses viz., 8 ovals and 6 dumb bells are presented in Table – 5.

i) Fecundity:

Significant variation ($P < 0.05$) in fecundity (i.e., number of eggs / layings) was observed in parents, and their foundation crosses (FCs) both oval type and dumbbell type. The data showed that the fecundity of oval parents ranged from 472 in CSR 202 to 584 in CSR 50 with an average of 527. In oval foundation crosses it ranged from 452 in SLD 1 x SLD 4 to 607 in CSR 2 x CSR 204, with an average of 555 eggs / layings. In dumbbell parents it ranged from 465 (Gen 2) to 613 (CSR 51), where as in their FCs it anged from 410 (D11 x SLD 9) to 621 (D 15 x SLD 6. It is a known fact that the fecundity will be more in dumbbell parents than ovals and also when we cross the phenotypically same type of parents to make their FCs there is a possibility of getting improvement of traits over their parents from a stable foundation, i.e., heterosis (Pallavi and Basavaraja, 2007; Nair Suresh Kumar and Harjeet Singh, 2011).

ii) Larval Duration:

No significant difference ($P< 0.05$) was observed for this trait among parents. An average of six hours was recorded in the 16 oval parents and their 24 foundation crosses. Among ovals it ranged from 22 days 14 hrs (SLD 2) to 24 days and 10 hrs (Gen 3) an average of 23 days and 9 hours and their oval FCs it ranged from 23 days 6 hours (in CSR 2 x Gen 3 and CNR 5 x CNR 14) to 25 days and 20 hours in CSR 2 x SLD 1, an average of 24 days. Among dumbbell parents it ranged from 23.07 (D 15) to 24 days 10 hours (Gen 3), where as in their FCs it ranged from 23.06 (D 15 x SLD 6) to 25 days 04 hours (Gen 2 x 4 C) . The larval duration is directly correlated with the growth and economic cocoon characters in silkworm. When the larval duration exceeds more than one day, there will be considerable variation in their cocoon characters, (Rajalakshmi *et al.*, 1998 and 2000; Chauhan *et al*., 2000) .

iii) Pupation Rate:

The rate of pupation i.e., the number of cocoons with live pupa inside, is considered the most important trait in seed cocoon crops, as far as farmers are concerned because it fetches them more money for their product. Significant variation was registered in the survival ($P < 0.05$) between parents and their FCs. It ranged from 88.28 % ((CNR 5) and 88.92 % in D2, i.e., < 90 % only in 2 oval breeds, with an average of 94.14 % where as in their oval FCs, all but one recorded > 94 % and up to 98 % in Gen 1 x Gen 3 (97.90%) and CSR 2 x Gen 1 (97.80%). There is significant improvement in the rate of pupation in Foundation Crosses.

In dumbbell parents it ranged from 88 % (SLD 6) to > 94 % in D 11, D 17, Gen 2, CSR 6 with an average of 91.96 %, where as in their FCs it ranged from 94.40 (Gen 2 x 4C) to 97.40 (CNR 15 x Gen 2) , with an average of 96 %.

Pupation rate or survival percentage is directly related with the cocoon yield and hence more weight-age has to be given for survival while evaluating the FCs of the hybrids and identifying them for exploitation (Pallavi and Basavaraj, 2007; Moorthy *et al.*, 2011; Bharat Kumar *et al*., 2019).

Table – 3: Performance of Foundation Crosses (Oval)

No	FC s	Fec.	L.D. (D:hrs)	Pup. (%)	S.C.wt. (g)	S.S.wt. (g)	S.R. (%)	Coc./L (No.)
1	CSR 2 x D1	549	24. 04	93.80	1.890	0.437	21.95	64
2	CSR 2 x D2	548	25.08	96.70*	1.838	0.398	21.63	60
3	CSR 2 x D7	574*	24.06	97.50*	1.849	0.427	23.08*	61
4	CSR2xCSR 202	533	25.14	97.20*	1.843	0.419	22.71	62
5	CSR 2 x 204	607*	24.04	96.10*	1.902	0.424	22.29	69
6	CSR 2 x CNR 5	502	24.06	96.90*	1.862	0.410	22.03	64
7	CSR 2 x CNR14	592*	24.04	94.90	1.884	0.412	21.87	66
8	CSR 2 x CNR15	549	24.04	96.90*	1.900	0.419	22.04	63
9	CSR 2 x SLD 1	563	25.20	95.40	1.924	0.414	21.50	65
10	CSR 2 x SLD 2	586*	23.20	95.10	1.887	0.410	21.70	69
11	CSR 2 x SLD 4	550	24.04	97.00*	1.982	0.435	21.95	60
12	CSR 2 x Gen-1	571*	24.06	97.80*	1.863	0.404	21.60	67
13	CSR 2 x Gen -3	533	23.06	97.20*	1.821	0.407	22.35	63
14	GEN 1x GEN 3	578*	23.20	97.90*	1.932	0.444	23.00*	64
15	CNR 5xCNR14	520	23.06	96.10*	1.884	0.395	21.00	71
16	CNR 5xCNR 15	542	24.10	95.10	1.921	0.39	23.30*	69
17	CNR14x CNR15	491	23.15	96.30*	1.802	0.396	21.95	75
18	SLD 1 x SLD 2	489	24.04	87.25	1.789	0.383	21.38	76
19	SLD 1 x SLD 4	452	24.04	95.90	1.937	0.41	21.14	65
20	SLD 2 x SLD 4	573*	23.20	94.40	1.914	0.417	21.79	73
21	D 1 x D 2	551	24.20	95.10	1.891	0.411	21.75	64
22	D 1 x D 7	561	24.00	96.60*	1.981	0.441	22.25	64
23	D2 x D7	574*	24.04	96.90*	1.660	0.385	23.20*	66
24	CSR 202 x 204	462	24.04	96.60*	1.827	0.406	22.21	76
25	CSR 2xCSR 50	573*	24.04	96.96*	1.923	0.442	23.01*	66
26	CSR50xCSR27	538	24.04	94.26	1.969	0.465*	23.60*	65
	Control CSR2 x CSR 27	556	24.04	95.04	1.985	0.449	22.64	65
	Avg	545	24.00	95.84	1.88	0.42	22.16	66.4
	CD 5%	15.61	0.23	0.83	0.03	0.01	0.28	1.85
	CV %	0.07	0.02	0.02	0.04	0.05	0.03	0.07

iv) Single Cocoon Weight (g):

Significant difference (P <0.05) was registered for single cocoon weight of parents and their respective FCs. In oval parents it ranged from 1.486 (in CNR 14) to 1.844 (D 1), with an average of 1.665, highest value of 1.817 in CSR 27 followed by 1.795 in CSR 50. In 24 oval FCs it ranged from 1.660 (D 2 x D 7) to 1.982 (CSR 2 x SLD 4), with an average of 1.880. All FCs except D2 x D7 recorded cocoon weight of > 1.8 to 2.0 g and 9 FCs > 1.9 g. This 13 % of improvement in cocoon weight in oval FCs over their parents is well a significant achievement in the concept of development of FCs.

In dumbbell parents the cocoon weight ranged from 1.462 g (D 13) to 1.777 (Gen 2. Six breeds recorded > 1.7 g viz., 4 C (1.717), SLD 8 (1.724) , CSR 26 (1.725), CSR 51 (1.756) and Gen 2 (1.777) the highest, with an average value of 1.630 where as in their FCs it ranged from 1.774 (D 13 x SLD 8) to 2.048 g (Gen 2 x 4 C), with an average of 1.870. An improvement of 14.7% over parents was registered in their FCs.

Cocoon weight is yet another character having close co-relation with the cocoon yield and thereby with the financial return for the farmers.

v) Single Shell Weight (g):

In single cocoon shell weight, significant difference (P <0.05) was registered, the values ranged from 0.330 g (in CNR 5 and CNR 14) to 0.420 g (CSR 27) with an average value of 0.370. In their oval FCs the values recorded from 0.383 g (SLD 1 x 2) to 0.444 ((Gen 1 x 3) with an average value of 0.420. 18 FCs registered values > 40 for shell weight.

In dumbbell parents the shell weight ranged from 0.298 g (D 13) to 0.393 (Gen 2) with an average of 0.349 and in 5 breeds it is > 0.350 g - CSR 26 (0.363 g) , CSR 6 (0.372),

CSR 51 (0.373), SLD 8 (0.381) and Gen 2 (0.393), the highest, with an average value of 0.349 g, where as in their FCs it ranged from 0.362 g (D13 x D11), to 0.417 g the highest (D 13 x SLD 9) with an average of 0.399 g. 8 foundation crosses recorded > 0. 40 g. An improvement of 14.3% over parents was registered in their FCs.

Table – 4: Performance of Foundation Crosses (Dumbbells)

No	FC s	Fec.	L.D. (D:hrs)	Pup. (%)	S.C.wt. (g)	S.S.wt. (g)	S.R. (%)	Coc./L (No.)
1	D 11 x D17	452	24.2	95.80*	1.895*	0.409*	21.55	101
2	D 11 x CNR 3	426	24.04	97.00*	1.857*	0.387*	20.83	100
3	D 11 x SLD 8	486	24.04	94.70*	1.873*	0.394*	21.02	106
4	D 11 x SLD 9	410	24.12	93.50	1.927*	0.403*	20.91	94
5	D 13 x CNR 3	424	24.04	96.70*	1.871*	0.406*	21.69	90
6	D 13 x SLD 8	388	25.1	96.90*	1.774	0.386	21.76	106
7	D 13 x SLD 9	404	24.06	96.20	1.941*	0.417*	21.49	97
8	D 13 x D 11	488	24.22	96.40*	1.759	0.362	20.57	105
9	D 13 x D 17	425	24.04	94.30	1.896*	0.402*	21.21	95
10	D 15 x GEN 2	502	24.04	97.40*	1.925*	0.411*	21.36	87
11	D 15 x 4 C	556*	23.12	96.60*	1.970*	0.406*	20.62	87
12	D 15 x SLD 6	621*	23.06	94.10*	1.835*	0.387*	21.06	108
13	GEN 2 x 4 C	452	25.04	91.40	2.048*	0.416*	20.31	75
14	GEN 2xSLD 6	499	24.2	94.00*	1.931*	0.399*	20.37	79
15	4 C x SLD 6	567*	23.2	97.40*	1.944*	0.416*	21.38	91
16	SLD 8x SLD 9	525	23.2	90.90	1.719	0.362	21.05	112
17	SLD 8x CNR 3	504	24.04	95.10*	1.803*	0.374	20.74	98
18	SLD 9xCNR3	534	24.06	96.90*	1.820*	0.392*	21.53	97
19	D 17 x CNR 3	505	24.04	96.70*	1.916*	0.399*	20.83	94
20	CSR 51 x 26	577*	24.04	96.40*	1.802*	0.393*	21.78	96
21	CSR 51 x 6	491	23.2	95.20*	1.791	0.387*	21.61	104
	Control CSR 6 x CSR 26	543	24.04	93.52	1.760	0.373	21.19	103
	Avg	487	23.96	95.41	1.87	0.40	21.13	96
	CD 5%	27.49	0.24	0.81	0.04	0.01	0.20	4.11
	CV %	0.13	0.02	0.02	0.04	0.04	0.02	0.10

vi) Shell Ratio (S.R.%) :

No significant variation was registered for cocoon shell ratio of parents and their respective FCs. In oval parents it registered values 20.80 (SLD 1) to 23.97 (D2) with an average value of 22.26, 8 parents recorded more than the average. In 24 oval FCs it ranged from 21.00 (CNR 5 x CNR 14) to 23.60 (CSR 50 x CS 27), with an average value of 22.06. And four FCs recorded > 23 % namely CS R 2 x D7, Gen 1 x Gen 3, CNR 5 x CNR 15 and D2 x D7.

In dumbbell parents the shell ratio ranged from 20.04 % (4 C) to 22.60 % (D 17) with an average value of 21.44 % . In all dumbbell parents the shell ratio was > 20 %, 9 parents recorded > 21 % and 4 parents > 22% . Where as in their FCs it ranged from 20.57 % (D 13 x D 11) to 21.76 % (D 13 x SLD 8), with an average of 21.11 %.

This is in conformity with the earlier findings that though there is significant improvement in the cocoon weight and corresponding shell weight in the respective parents and their foundation crosses, the ratio of shell weight to cocoon weight remain same, without any improvement. (Pallavi and Basavaraja, 2007; Moorthy *et al.*, 2011)

vii) Cocoons / litre (No.) :

Significant difference (P <0.05) was registered for number of cocoons / liter of parents and their respective FCs. In oval parents it ranged from 82 (CSR 2) to 99 (CNR 14, CSR 202), with an average of 91 cocoons per liter. In 24 oval FCs it ranged from 60 in 2 breeds (CSR 2 x D 2), (CSR 2 x SLD 4) to 76 cocoons in (SLD 1 x SLD 2) and (CSR 202 x 204), with an average of 66 cocoons. The improvement of 38 % in cocoons per liter in oval FCs over their parents is a significant achievement in the concept of development of FCs .

In dumbbell parents the number of cocoons per liter ranged from 105 (4 C) to 120 (D 13), with an average value of 110, where as in their FCs it ranged from 75 (GEN 2 x 4C) to 112 (SLD 8 x SLD 9), with an average of 96 cocoons per liter. An improvement of 14.6 % over parents , was registered in their Foundation Crosses.

Table 5. Performance of selected foundation crosses - Ovals

No.	FCs	Fec.	L.D. Total	ERR by No	S.C. wt. (g)	S.S.Wt. (g)	S.R. (%)	Coc./L (No.)
1	CSR 2 x D1	549	24.04	93.80	1.989	0.437	21.95	64
2	CSR 2 x D 7	574	24.06	97.50	1.849	0.427	23.08	61
3	CSR 2x Gen 3	533	23.06	97.20	1.821	0.407	22.35	63
4	SLD1xSLD 2	489	24.04	87.25	1.789	0.383	21.38	76
5	D 1 x D 7	561	24.00	96.60	1.981	0.441	22.25	64
6	D 2 x D 7	574	24.04	96.90	1.660	0.385	23.20	66
7	CSR 2 x 50	573	24.04	96.96	1.923	0.442	23.01	66
8	CSR 50 x 27	538	24.04	94.26	1.969	0.465	23.60	65

Based on the compiled data of two seasons on qualitative and quantitative traits, with special reference to the phenotypic characters viz., visual cocoon uniformity and pupation / survival, the 47 FCs were short listed to 14 FCs of which 8 oval FCs viz., CSR 2 x D1, CSR 2 x D7, CSR 2 x Gen 3, SLD 1 x SLD 2, D1 x D7, D2x D7, CSR 2 x CSR 50 and CSR 50 x CSR 27, (Table – 5) and 6 dumbbell FCs viz., CSR 51 x CSR 6, CSR 51 x CSR 26, D 11 x CNR 3, D11 x SLD 8, D13 x CNR 3, D 13 x SLD 8 (Table- 6).

Table 6. Performance of selected foundation crosses - Dumbbells

No.	FCs	Fec.	L.D. Total	ERR by No	S.C. wt. (g)	S.S.Wt. (g)	S.R. (%)	Coc./L (No.)
1	CSR 51 x 6	491	23.20	95.20	1.791	0.387	21.61	104
2	CSR 51 x 26	577	24.04	96.40	1.802	0.393	21.78	96
3	D11 x CNR 3	426	24.04	97.00	1.857	0.387	20.83	100
4	D 11 x SLD 8	486	24.04	94.70	1.873	0.394	21.02	106
5	D13 x CNR 3	425	24.04	96.70	1.871	0.406	21.69	90
6	D 13 x SLD 8	401	25.1	96.90	1.774	0.386	21.76	106

The well known fact of comparatively better performance of foundation crosses over their parents was well confirmed by the study which is in conformity with the earlier studies (Pallavai and Basavaraj, 2007; Rajalakshmi, 2014; Bharath Kumar Neelaboina *et.al*., 2019).

Foundation Crosses register stable performance which is very essential to generate quality seed cocoons (Rama Mohana Rao *et al*., 1997, Nirmal Kumar *et al.,* 1998). Moreover, references are already available that foundation crosses are superior over parental breeds in terms of fecundity and pupation rate. It is obvious that though the parental breeds are superior, if the same is not reflected in the foundation crosses or hybrids they are of no much use. Therefore in silkworms a large number of foundation crosses / hybrids are evaluated and the promising ones are selected based on the improvement in the economic characters for exploitation in the field for the benefit of the silk industry. The clear cut advantages of foundation crosses viz., easy rearing at P1 seed crop level and inherent genetic potential to produce quality silk will definitely satisfy the need of all the related agencies of silk industry; the egg producers, the seed farmers. Improvement in cocoon productivity and quality is achieved through improved hybrids and silk processing technology leading to the sustenance of Sericulture across the world. (Datta *et al., 2000*, Pallavi and Basavaraja., 2007).

The concept of developing suitable Foundation Crosses by utilizing the genetically and phenotypically similar breeds make the foundation strong and stable so that the double hybrids prepared out of these would survive and adapt well in the fluctuating climatic conditions prevailing in the field than single hybrids because of its wide stable genetic base of four parents. Quality silk > 3 A grade is produced from double hybrids in countries like India, China, Bulgaria etc. (Sivaprasad, 2019) . The double hybrids are preferred over single hybrids due to easy seed crop rearing, stable cocoon yield, adaptability to the fluctuating climatic conditions and high egg yield.

Cocoon uniformity and egg yield characters of these selected FCs will be studied. Further, all direct crosses will be made using these FCs in Dumbbell x Oval pattern, and evaluated in different seasons for evolving productive and potential double hybrids for commercial exploitation in the field.

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