Research Article

ROLE OF INTER BATCH CROSSING ON MAINTAINING THE RACIAL CHARACTERS OF BIVOLTINE SILKWORM (*BOMBYX MORI L.*), AT P3 LEVEL

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ABSTRACT

To fulfill the needs of commercial rearers, continuous supply of hybrid layings has to be met by the National Silkworm Seed organization without any hurdles. To meet the demand of the farmers, maintenance of pure races gained major impetus and P3 level maintenance centre was given the major responsibility to cater the needs of P2 multiplication centres of Karnataka, Andhra Pradesh and Tamil Nadu. It is very well established that continuous maintenance of silkworm races over years will result in inbreeding depression causing decline in the expression of quantitative traits at hybrid level. To overcome inbreeding depression, inter batch crossing technique was adopted from 2010 till date and adoption of inter batch crossing at every cycle helped to maintain the race characters without any deterioration over the years. Comparative performance of the productive races from past eight years at P3 level for the expression of characters *viz.*, fecundity, yield/ 100dfls by number and by weight, single cocoon weight, single shell weight, cocoon shell percentage and pupation rate revealed consistency in the expression of quantitative traits without any inbreeding depression. Among the seven quantitative traits, cocoon shell percentage is an important trait that represents productivity of a race which does not change with the season. Hence, the consistency of a race over years can be measured by this trait. The expression of cocoon shell percentage in all races during 2017-18 when compared to 2011-12 data, showed improvement ranging from 2.10 ~ 3.56%. Mean rearing performance of five races showed marginal variation for cocoon shell percentage over the years and it ranged from 22.9 to 24% in CSR2, 20.8 to 22.1% in CSR4, 20.9 to 22.1% in CSR6, 20.4 to 22% in CSR26 and 24.1 to 24.8% in CSR27. The importance of systematic silkworm race maintenance at P3 level in the expression of quantitative characters is discussed.

INTRODUCTION

The productive bivoltine single hybrid CSR2 x CSR4 and double hybrid (CSR2 X CSR27) x (CSR6 x CSR26) revolutionized the Indian sericulture industry from past one and half decades. The genetic composition of their parents combine well to express all their potentiality in their hybrid. The parental breeds developed with great caution, needs to be maintained systematically so that the genotypic expression of quantitative traits in the hybrids should not decline even after many years. It is very well documented that inbreeding of parents over many generations produces negative effects such as increased homozygosity, which leads to increased chance of expression of lethal recessive genes, inbreeding depression and reduction of genetic variance (Falconer, 1960), resulting in the decline of quantitative traits in silkworm *Bombyx mori* L. Occurrence of inbreeding in species which are normally outbred results in loss of genetic diversity and becomes an inherent cause of reduced germinability of lays, loss of viability, vigor and fecundity of progenies (Lande and Schemske, 1985; Charlesworth and Charlesworth, 1987) leading to an inbreeding depression. Inbreeding depression and mutation accumulation may be an important source of extinction of small populations (Lynch *et al*., 1995; Hedrick and Kalinowski, 2000). Further, such parents loose their ability to combine well and resulting in the reduced heterosis for

most of the quantitative traits. Knowing the importance of conservation of genetic value of the parental breeds, interbatch crossing system was introduced during 1997 under JICA programme (Basavaraja, 2001, Basavaraja, *et al.*, 2001 & 2002). Under this technique minimum of 15 ~ 30 dfls/ race has to be maintained and minimum of three ~ five previous source has to be reared with 3~ 5 replication / source. While conducting inter batch crossing, crossing always carried out between two sources. This system has reduced inbreeding depression as it reduces homozygosity. Keeping these in mind, the detailed methodology followed in conserving the genetic worth of the productive bivoltine breeds viz., CSR2, CSR4, CSR6, CSR26 and CSR27 at P3 level over last eight years is discussed.

MATERIALS AND METHODS

The productive bivoltine breeds *viz.*, CSR2, CSR4, CSR6, CSR26 and CSR27 developed during JICA Phase I, were reared in four seasons of the year as depicted in Figure 1.

A minimum of 15 dfls in CSR4 and maximum of 30 dfls per race in CSR2, CSR6, CSR26 and CSR27 were brushed cellular by following all the standard rearing technologies of Basavaraja *et al.,* 2002. Stringent selection for rich fecundity, good hatching, egg laying pattern, chorion colour and healthiness of the new born larvae were given at every cycle. After 3rd moult, 250 larvae / replication in all the races were retained so that budgeting of quality leaf to all the batches can be ensured uniformly. During rearing, all measures were taken to maintain hygienic conditions in and around the rearing house. Proper care was taken during spinning and required temperature, humidity and air current was provided so that the important economic trait like pupation percentage is unaffected. The rearing performance of all the breeds for fecundity, Yield/ 100 dfls by number, by weight, single cocoon weight, single shell weight and cocoon shell percentage during four rearings *viz.*, May~ June, August~ September, November ~ December and February~ March were compiled from 2010-11 to 2017-18. Comparison with regard to the expression of traits over the years was carried out. In order to know if there is any decline in the expression of economic traits, each year mean rearing data was compared to that of previous year data by following the formula:

$$\text{Increment/Decrement} = \frac{(G1 - G2)}{G2} \times 100$$

G1 = Previous generation;

G2 = To be compared generation

Further, the mean data of 2011-21 over 2017-18 was also compared to know any increment/ decrement over years.

In addition, mean and standard deviation for the expression of characters for the four crops/ year conducted was compiled by adopting the following formula:

$$\text{Mean} : \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x$$

where n is the sample size and the x correspond to the observed valued.

$$\text{Standard Deviation} = \frac{\sum|x-\mu|2}{N}$$

Where ∑sum means "sum of", x is a value in the data set, μ is the mean of the data set, and N is the number of data points in the population.

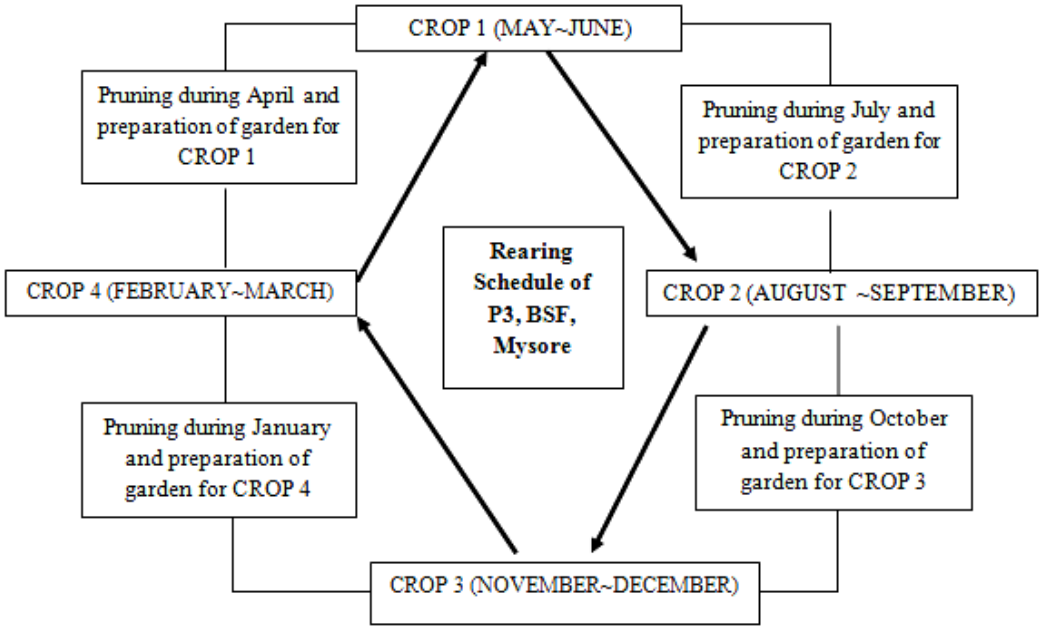

Fig. 1. Schematic representation of the rearing plan of P3, BSF, Mysore

RESULTS AND DISCUSSION

The comparative performance of five productive bivoltine races from 2010-11 to 2017-18 for fecundity, yield/100 dfls by number, by weight, single cocoon weight, single shell weight, cocoon shell percentage and pupation rate are presented in Tables. 1 to 5. The average data clearly indicates marginal variation in the expression of economic traits between years with marginal deviation within generation. The assessment for increment/decrement for all the seven economic traits during 2010~11, 2011~12 , 2012~13, 2013~14, 2014~15, 2015~16, 2016~17 and 2017~18 over that of their previous year and also 2017~18 data over 2011~12 data are presented in Tables 6 to 10.

Among the seven traits taken for the study, almost all the traits except cocoon shell percentage varies between seasons and replication. To know the consistency of a race in the expression of metric characters, cocoon shell percentage acts as a yard stick to measure the consistency of a race and to know whether any race has declined over generations through inbreeding. In this study also, eventhough seven traits are considered, major impetus has be given to cocoon shell percentage as this character's response to fluctuating climate is very much meager. In CSR2, the cocoon shell percentage varied from 23.4 to 23.1; In CSR4 from 22.1 to 21.3;in CSR6 it is from 22 to 21.6; in CSR26 22.0 to 21.1 and in CSR27 it is from 24.4 to 24.2 when the mean data of 2010-11 was compared to that of 2017-18.

Table 1. Mean rearing performance of CSR2 over the years (Mean of 4 rearing)

Year	Fecundity	Yld/ 100 dfls	Yld/ 100 dfls	SCW	SSW	SR%	Pupation Rate (%)
		No.	Wt.(kg)	(g)	(g)		
2010-11	500 ± 28.7	43139 ± 5050	74 ± 12.5	1.776 ± 0.1	0.416 ± 0.02	23.4 ± 0.4	91 ± 3.4
2011-12	492 ± 31.5	37861 ± 6764	62 ± 15.7	1.641 ± 0.2	0.373 ± 0.04	22.7 ± 0.5	85 ± 8.9
2012-13	501 ± 30.4	42466 ± 3262.5	67 ± 4.6	1.625 ± 0.1	0.385 ± 0.03	23.7 ± 0.4	90 ± 2.4
2013-14	519 ± 28.7	43966 ± 3398.0	71 ± 11.1	1.684 ± 0.2	0.404 ± 0.04	24.0 ± 0.7	91 ± 2.8
2014-15	547 ± 36.7	45497 ± 5408.8	72 ± 9.3	1.748 ± 0.1	0.406 ± 0.01	23.2 ± 0.5	92 ± 3.8
2015-16	557 ± 27.7	47214 ± 5474.0	78 ± 13.2	1.749 ± 0.1	0.412 ± 0.02	23.6 ± 0.2	93 ± 2.6
2016-17	596 ± 42.9	47144 ± 4234.2	76 ± 14.6	1.651 ± 0.2	0.389 ± 0.04	23.5 ± 0.5	95 ± 2.9
2017-18	564 ± 22.4	35939 ± 7635.0	59 ± 11.0	1.715 ± 0.2	0.396 ± 0.05	23.1 ± 0.5	96 ± 1.1

Table 2. Mean rearing performance of CSR4 over the years (Mean of 4 rearing)

Year	Fecundity	Yld/ 100 dfls	Yld/ 100 dfls	SCW	SSW	SR%	Pupation Rate (%)
		No.	Wt.(kg)	(g)	(g)		
2010-11	454 ± 22.2	39052 ± 3663	65.05 ± 10.0	1.718 ± 0.04	0.379 ± 0.02	22.1 ± 0.6	91 ± 1.6
2011-12	488 ± 51.9	38856 ± 4672	62 ± 11.6	1.603 ± 0.15	0.333 ± 0.03	20.8 ± 0.4	86 ± 5.9
2012-13	467 ± 30.4	38548 ± 2089	57 ± 4.5	1.539 ± 0.12	0.340 ± 0.02	22.1 ± 1.0	89 ± 2.8
2013-14	452 ± 22.4	36567 ± 2096	50 ± 3.5	1.532 ± 0.18	0.323 ± 0.03	21.1 ± 0.7	84 ± 9.6
2014-15	485 ± 20.1	37433 ± 4495	52 ± 8.5	1.644 ± 0.04	0.361 ± 0.01	22.0 ± 0.4	86 ± 0.3
2015-16	477 ± 28.6	44901 ± 11483	68 ± 18.1	1.596 ± 0.05	0.347 ± 0.01	21.7 ± 0.4	91 ± 7.9
2016-17	458 ± 55.7	42529 ± 12950	60 ± 18.8	1.464 ± 0.14	0.317 ± 0.03	21.6 ± 0.9	92 ± 8.7
2017-18	457 ± 45.4	41961 ± 12119	52 ± 5.0	1.526 ± 0.19	0.325 ± 0.04	21.3 ± 0.4	93 ± 3.8

Maintenance of purity of a race is a crucial task for silkworm breeders as it is very much essential to express hybrid vigour in their hybrids over years as hybrids are contributing enormously for the total silk output. The productive bivoltine races developed during 1997 with an aim to popularise bivotine hybrids in the field was highly successful. The adoption of silkworm race maintenance technology from 1997 onwards helped to retain the original breed characters over a decade inspite of inbreeding and parallels the statement of Coltman *et al*., 1999 and Slate *et*

al., 2000 who reported that modern molecular techniques have allowed indirect genetic measurement of inbreeding depression in wild animals and improvement further. It is the P3, Basic Seed Farm which has to play a major role in conserving the genetic worth of the breeds as it has to supply Dfls to P2, Basic Seed Farms and P2 inturn has to supply P1 dfls to farmers who inturn supply cocoons to Grainages to produce quality dfls of both single and double hybrids. Adoption of inter batch crossing under Silkwormrace maintenance and multiplication has reduced the inbreeding depression of the races in spite of continuous rearing.

Table 3. Mean rearing performance of CSR6 over the years (Mean of 4 rearing)

Year	Fecundity	Yld/ 100 dfls	Yld/ 100 dfls	SCW	SSW	SR%	Pupation rate (%)
		No.	Wt.(kg.)	(g)	(g)		
2010-11	487 ± 16.3	39310 ± 2027	64 ± 4.0	1.717 ± 0.07	0.378 ± 0.02	22.0 ± 0.1	91 ± 2.4
2011-12	497 ± 56.4	42068 ± 5729	67 ± 11.6	1.613 ± 0.11	0.336 ± 0.02	20.9 ± 0.6	91 ± 2.2
2012-13	445 ± 21.3	37590 ± 1479	58 ± 0.7	1.547 ± 0.04	0.339 ± 0.02	21.9 ± 0.7	91 ± 2.1
2013-14	496 ± 17.3	41817 ± 813.3	62 ± 6.8	1.538 ± 0.18	0.339 ± 0.04	22.1 ± 0.5	91 ± 1.0
2014-15	550 ± 55	43265 ± 7161	66 ± 13.8	1.587 ± 0.04	0.342 ± 0.01	21.5 ± 0.4	92 ± 5.9
2015-16	548 ± 30.4	50316 ± 2336	83 ± 7.8	1.609 ± 0.03	0.354 ± 0.01	22.0 ± 0.00	94 ± 2.2
2016-17	528 ± 91.0	41409 ± 3395	62 ± 7.3	1.562 ± 0.09	0.332 ± 0.02	21.3 ± 0.2	96 ± 1.5
2017-18	517 ± 32.3	46262 ± 5624	73 ± 10.7	1.573 ± 0.17	0.339 ± 0.04	21.6 ± 0.5	95 ± 0.7

Table 4. Mean rearing performance of CSR26 over the years (Mean of 4 rearing)

Year	Fecundity	Yld/ 100 dfls	Yld/ 100 dfls	SCW	SSW	SR%	Pupation Rate (%)
		No.	Wt.(kg.)	(g)	(g)		
2010-11	482 ± 4.9	38522 ± 3973	61.33 ± 6.6	1.680 ± 0.02	0.368 ± 0.01	22.0 ± 0.4	91 ± 5.1
2011-12	491 ± 44	41345 ± 4579	62 ± 11.9	1.437 ± 0.11	0.293 ± 0.03	20.4 ± 0.6	93 ± 1.0
2012-13	458 ± 42.6	39329 ± 4010	59 ± 6.1	1.541 ± 0.11	0.317 ± 0.02	20.6 ± 0.9	91 ± 2.3
2013-14	505 ± 41.3	42600 ± 3033	64 ± 10.5	1.534 ± 0.15	0.325 ± 0.04	21.1 ± 0.5	91 ± 3.5
2014-15	508 ± 26.5	41979 ± 1658	64 ± 3.8	1.642 ± 0.03	0.348 ± 0.005	21.2 ± 0.2	91 ± 3.4
2015-16	536 ± 34.3	49426 ± 6100	83 ± 15.2	1.557 ± 0.03	0.342 ± 0.01	22.0 ± 0.4	96 ± 1.3
2016-17	505 ± 78.3	47092 ± 5990	71 ± 13.4	1.516 ± 0.10	0.316 ± 0.03	20.9 ± 0.8	95 ± 2.5
2017-18	475 ± 35.0	42078 ± 4542	62 ± 7.4	1.543 ± 0.15	0.325 ± 0.03	21.1 ± 1.2	95 ± 1.4

Table 5. Mean rearing performance of CSR27 over the years (Mean of 4 rearing)

Year	Fecundity	Yld/ 100 dfls	Yld/ 100 dfls	SCW	SSW	SR%	Pupation rate (%)
		No.	Wt.(kg.)	(g)	(g)		
2010-11	497 ± 23.5	41374 ± 3269	65.79 ± 5.6	1.717 ± 0.03	0.419 ± 0.01	24.4 ± 0.3	92 ± 1.9
2011-12	457 ± 2.8	34523 ± 3206	50 ± 10.1	1.395 ± 0.22	0.338 ± 0.05	24.2 ± 0.2	89 ± 2.5
2012-13	502 ± 41	42570 ± 4064	70 ± 6.8	1.675 ± 0.13	0.403 ± 0.03	24.1 ± 0.5	92 ± 2.5
2013-14	533 ± 42	43546 ± 4619	67 ± 12.6	1.645 ± 0.22	0.404 ± 0.06	24.5 ± 0.4	88 ± 3.9
2014-15	549 ± 58.1	44483 ± 6868	66 ± 11.5	1.691 ± 0.04	0.417 ± 0.01	24.6 ± 0.3	93 ± 7.3
2015-16	572 ± 42.8	47208 ± 9292	79 ± 16	1.679 ± 0.06	0.417 ± 0.01	24.8 ± 0.3	95 ± 4.3
2016-17	597 ± 69.5	48545 ± 6089	78 ± 16.3	1.662 ± 0.13	0.405 ± 0.03	24.4 ± 0.5	94 ± 4.1
2017-18	553 ± 70.7	47057 ± 9999	75 ± 9.5	1.706 ± 0.20	0.413 ± 0.06	24.2 ± 0.8	94 ± 2.1

Perusal of the data clearly indicates marginal variation in the expression of characters, the pupation rate in all the bivoltine breeds was above 85% and conforming to the set norms of 85% (Tables 1 to 5). Improvement in yield/ 100dfls by number & weight, single cocoon weight, single shell weight and cocoon shell percentage was recorded in all the races when compared over 2011~12 indicating the role of new technologies adopted during silkworm rearing and mulberry cultivation (Tables 1 to 5).

Table 6. Percentage of increment / decrement in the expression of economic characters in CSR2 over the previous year

Year	Fecundity	Yld/ 100 dfls	Yld/ 100 dfls	SCW	SSW	SR%	Pupation rate
		No.	Wt.				
2011-12 v/s 10-11	-1.60	-12.24	-16.50	-7.60	-10.51	-3.31	-6.93
2012-13v/s 11-12	1.78	12.16	8.64	-0.99	3.29	4.64	6.44
2013-14 v/s 12-13	3.54	3.53	5.81	3.63	4.94	1.16	0.77
2014-15 v/s 13-14	5.40	3.48	0.92	3.79	0.43	-3.23	0.69
2015-16 v/s 14-15	1.88	3.77	8.34	0.06	1.66	1.62	0.93
2016-17 v/s 15-16	7.09	-0.15	-1.49	-5.59	-5.76	-0.32	2.00
2017-18 v/s 16.17	-5.45	-23.77	-22.65	3.89	1.99	-1.60	1.46
2017-18 v/s 11-12	**14.58**	**-5.08**	**-4.24**	**4.51**	**6.38**	**2.10**	**12.79**

Table 7. Percentage of increment / decrement in the expression of economic characters in CSR4 over the previous year

Year	Fecundity	Yld/ 100 dfls	Yld/ 100 dfls	SCW	SSW	SR%	Pupation rate
		No.	Wt.				
2011-12 v/s 10-11	7.32	-0.50	-5.34	-6.68	-12.14	-5.89	-5.31
2012-13 v/s 11-12	-4.26	-0.79	-7.10	-4.00	1.95	6.38	3.17
2013-14 v/s 12-13	-3.16	-5.14	-11.93	-0.44	-4.86	-4.41	-5.55
2014-15 v/s 13-14	7.25	2.37	2.63	7.28	11.76	4.02	2.86
2015-16 v/s 14-15	-1.55	19.95	31.53	-2.89	-3.95	-1.25	5.51
2016-17 v/s 15-16	-4.14	-5.28	-12.12	-8.29	-8.72	-0.35	1.18
2017-18 v/s 16.17	-0.22	-1.34	-12.39	4.25	2.61	-1.62	1.06
2017-18 v/s 11-12	**-6.36**	**7.99**	**-14.97**	**-4.80**	**-2.48**	**2.41**	**8.13**

Table 8. Percentage of increment / decrement in the expression of economic characters in CSR6 over the previous year

Year	Fecundity	Yld/ 100 dfls	Yld/ 100 dfls	SCW	SSW	SR%	Pupation rate
		No.	Wt.				
2011-12 v/s 10-11	2.21	7.01	5.20	-6.09	-11.12	-5.22	0.63
2012-13v/s 11-12	-10.56	-10.64	-14.06	-4.08	0.97	4.91	-0.69
2013-14 v/s 12-13	11.52	11.25	6.96	-0.57	-0.07	0.68	0.33
2014-15 v/s 13-14	10.89	3.46	7.52	3.15	0.81	-2.49	1.43
2015-16 v/s 14-15	-0.45	16.30	25.29	1.42	3.73	2.33	2.17
2016-17 v/s 15-16	-3.56	-17.70	-25.37	-2.95	-6.28	-3.30	1.54
2017-18 v/s 16.17	-2.13	11.72	17.48	0.72	2.18	1.41	-1.09
2017-18 v/s 11-12	**3.92**	**9.97**	**8.57**	**-2.47**	**1.04**	**3.35**	**3.71**

Table 9. Percentage of increment / decrement in the expression of economic characters in CSR26 over the previous year

Year	Fecundity	Yld/ 100 dfls	Yld/ 100 dfls	SCW	SSW	SR%	Pupation rate
		No.	Wt.				
2011-12 v/s 10-11	1.87	7.33	1.17	-14.42	-20.46	-7.29	1.89
2012-13 v/s 11-12	-6.87	-4.87	-4.79	7.20	8.38	1.23	-2.40
2013-14 v/s 12-13	10.33	8.32	7.79	-0.45	2.37	2.55	0.47
2014-15 v/s 13-14	0.54	-1.46	0.12	7.07	7.16	0.24	-0.30
2015-16 v/s 14-15	5.62	17.74	30.71	-5.22	-1.58	3.90	6.01
2016-17 v/s 15-16	-5.78	-4.72	-15.25	-2.63	-7.60	-5.23	-0.96
2017-18 v/s 16.17	-5.99	-10.65	-11.94	1.81	2.69	1.08	-0.66
2017-18 v/s 11-12	**-3.36**	**1.77**	**0.23**	**7.36**	**11.03**	**3.56**	**1.97**

Table 10. Percentage of increment / decrement in the expression of economic characters in CSR27 over the previous year

Year	Fecundity	Yld/ 100 dfls	Yld/ 100 dfls	SCW	SSW	SR%	Pupation rate
		No.	Wt.				
2011-12 v/s 10-11	-8.14	-16.56	-24.37	-18.74	-19.35	-0.72	-2.67
2012-13 v/s 11-12	9.80	23.31	39.72	20.08	19.48	-0.41	3.05
2013-14 v/s 12-13	6.23	2.29	-3.81	-1.76	0.19	1.76	-4.40
2014-15 v/s 13-14	3.10	2.15	-1.94	2.80	3.09	0.41	5.91
2015-16 v/s 14-15	4.19	6.13	21.20	-0.72	0.06	0.81	1.53
2016-17 v/s 15-16	4.33	2.83	-1.54	-1.03	-2.88	-1.91	-0.13
2017-18 v/s 16.17	-7.45	-3.07	-4.05	2.66	2.10	-0.62	-0.34
2017-18 v/s 11-12	**20.96**	**36.31**	**50.89**	**22.32**	**22.44**	**0.00**	**5.43**

Analysis for increment /decrement in all the five productive popular bivoltine races revealed not much variations over their ancestors (Table 6 to 10). The increase / decrease in the expression of traits in all the five races may be attributed for variable environment rather than increment/ decrement caused due to inbreeding. Comparison between 2017~18 rearing performance to that of 2011~ 12 data, all the five races expressed better for majority of the traits taken for the study in general and for cocoon shell percentage in particular as it has not shown decrement in all the five races (Table. 6 to 10). With fluctuating environmental conditions, all the characters except Cocoon shell percentage showed both increment and decrement over their previous generation and also in the comparison between 2011-12 v/s 2017~18 performance. The marginal improvement in the performance in all the five races during 2017~18 over that of 2011~12 can be attributed for inter batch crossing, rearing management and good quality mulberry leaf. This finding also corroborates the proposal of Walsh (2005) who opined that the vigour is resulted from bringing together the maximum number of dominant gens and the dominant genes in the homozygous condition were the best combination for heterotic effect in their respective hybrids.

CONCLUSIONS

Systematic silkworm race maintenance through inter batch crossing under Silkworm race maintenance and multiplication helps to maintain the race characters without any deterioration over many generations.

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