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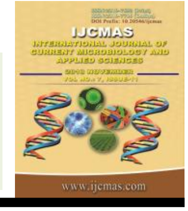

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Selection Response for the Expression of Quantitative Traits in the Mulberry Silkworm *Bombyx mori* L.

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A B S T R A C T

Selections for quantitative traits are paramount importance to achieve the desired breeding objectives in breed evolving programmes through hybridization. In the light of the above, an experiment was conducted utilizing six different aboriginal silkworm races namely, C_{108}, NB_4D_2, Pure Mysore (PM), Nistari, zebra and knobbed belonging to two voltinistic groups by rearing them under standard laboratory conditions for six different generations during three seasons of the year. At the parental generations (denoted as P_1), the harvested cocoons were grouped into two batches wherein, one batch of cocoons were exposed to mass selection and another batch of cocoons were exposed to individual selection by recording data for four important traits namely, cocoon weight, shell weight, filament length and pupation rate. The pooled data was statistically analyzed for analysis of variance (ANOVA) and the results have clearly demonstrated that, the individual (Cellular) selection has resulted in higher increase in the three economic traits *viz*, cocoon weight, shell weight and filament length significant ($P<0.05$), wherein mass selection resulted in significant ($P<0.05$) improvement in pupation rate across six generations. The data also revealed that the selection response is high (>96%) during pre-monsoon season in multivoltine races than the bivoltine races. The obtained data will determine to understand the suitability of selection response for using in genetics and breeding programmes for the production of high yieldable and superior silk content silkworm breeds/hybrids. It is concluded with responses to selection hereby importance of two selection method is discussed in the light of silkworm selection and hybridization programmes.

Introduction

Silkworm, *Bombyx mori* is an important model organism for various fields such as, scientific, medical and agriculture, *etc.*, Silkworm is characterized by four distinct developmental stages namely, egg, larva, pupa and adult. The developmental period from larva to adult in silkworm involves the morphological entrainment and degree of rethymic changes at onset of metamorphosis. Sericulture in India, besides providing occupation to about six million people, provides impetus to chief cottage industry. Today, India stands next only to China in global raw silk production. The history of sericulture clearly indicates that silkworm culture was practiced in the Chinese provinces during 2500 BC (Kuhn, 1988). Sericulture began forty five centuries ago in north-eastern part of China along the banks of Hwang Ho River (Hirobe, 1968). In the Indian sub-continent, the concept of production of bivoltine silk is realized during 1970's and four bivoltine races namely NB7, NB18, KA and NB_4D_2 become popular at field level.

During 1980's to 2000 several research institutes have made revolutionary work and evolved new productive (CSR series), resistant and season specific breeds/races (bivoltine and multivoltine races) through various concept of conventional breeding and cross breeding approaches in India. The majority of raw silk production from the multivoltine oriented, which is qualitatively inferior in respect to the yield. It is very pertinent to produce more number of productive breeds of bivoltine and cross breeds, which are capable of producing higher quality silk and meet international grade. Henceforth, success of breeding programmes is depends on selection methods and parental materials. As per the selection is considered, there are various avenues of selection like, through biochemical, molecular, tissue level, cell level, morphological, physiological, genetical selection (cellular, mass, family, *etc*), *etc.* Further, improvement for traits is paramount step in any breeding programme, which are directly connected to the success in sericulture industry depends on few factors like trait, breed, seed and feed. However, reproductive traits are considered a vital to the egg producers, while cocoon producers are interested in improved production potential, cocoon shell percentage and disease resistant (Singh *et al.,* 1998). On the other hand, as suggested by Seidavi *et al.,* (2008) that, the selection is one of the best breeding approaches in silkworm breeding. Moreover, individual selection in parent lines can improve their offspring performance. But, this improvement is effected to environmental factors specially season (Seidavi, 2010) and concluded his finding with responses to selection for important resistance traits in silkworm pure lines at spring is higher than autumn significantly.

Further, correlation between pedigree and mass selection and traits silkworm (Singh *et al.,* 2011) Suresh Kumar *et al.,* (2013) suggested that, selection is important for breeding materials for development of hybrids suitable to West Bengal. Few researches were done on response to selection in three commercial pure lines with oval cocoon in silkworm *Bombyx mori* (Hajian *et al.*, 2011).

However, based on the review of literature survey, selection response method is paramount importance in silkworm breeding approach, which is also conducted for several improvement aspects in other insects, animals, poultry, *etc*, like, swine breeding (Chen *et al.*, 2007), response to selection with an optimum selection and multilevel (Bijma and Muir, 2006, Van Vleck *et al.*, 2007 and Bijma *et al.*, 2007a), bases for individual versus family selection systems (Lush, 1947), theory of limits in artificial selection (Robertson, 1960), influence of selection and mating systems on larval weight in Tribolium (Wilson *et al.*, 1968) genetic gain by selection in annual egg production of the Fowl (Kinney *et al.*, 1970 &), *etc.* Generally, when two selected races/strains were crossed in next generation hybrids of selected races become more productive/resistant than compare to the crosses made of unselected strains/races. Henceforth, it is understood through available literature in relation to selection methods are play a vital role for deciding the ultimate outcome/production/resistant races under several generations. Thereby, it is in this context, the present research programme is framed/proposed relevant to the response to the selection of cellular and mass rearing during three seasons/six generations for four quantitative traits of the silkworm *Bombyx mori*.

Materials and Methods

The present investigation has been carried out on six silkworm commercial pure races/strains, which were drawn from the Germplasm Bank of Department of Sericulture, University of Mysore, Mysuru. The selected races/mutants belonging to two voltinistic group's eggs were incubated with 25±10˚c and relative humidity of 80±5% and simultaneously black boxing was followed on 8^{th} day to achieve uniformity in hatching.

The standard rearing was conducted during three season *viz.*, pre-monsoon, monsoon and post-monsoon and larvae hatched from each layings were reared separately under uniform laboratory conditions as described by Yokoyama, (1963) and Krishnaswami, (1978).

The rearing was conducted under standard laboratory conditions for six different generations during three seasons of the year and evaluated for four important quantitative traits to understand the suitability of selection response for using in genetics and breeding programmes for the production of high yielding and superior silk content silkworm breeds/hybrids.

At the parental generations, the harvested cocoons were grouped into two batches wherein, one batch of cocoons were exposed to mass selection and another batch of cocoons were exposed to individual selection by recording data for four important traits namely, cocoon weight, shell weight, filament length and pupation rate., The following formulae were adopted for analysis of selection response by manually to determine the improvement/response for selection during six generation.

Improvement of selection response at F1 over P1 generation

Value of F1 – value of P1 = improvement at F1 over P1 generation

Percentage improvement of selection response at F1 over P1 generation

[Value of improvement at F1 over P1 / P1 value] x 100 = % improvement at F1 over P1 generation

Improvement of selection response at F2 over F1 generation

Value of F2 – value of F1 = improvement at F2 over F1 generation

Percentage improvement of selection response at F2 over F1 generation

[Value of improvement at F2 over F1 / F1 value] x 100 = % improvement at F2 over F1 generation

Improvement of selection response at F3 over P1 generation

Value of F3 – value of P1 = improvement at F3 over P1 generation

Percentage improvement of selection response at F3 over P1 generation

[Value of improvement at F3 over P1 / P1 value] x 100 = % improvement at F3 over P1generation

Improvement of selection response at F3 over F2 generation

Value of F3 – value of F2 = improvement at F3 over F2 generation

Percentage improvement of selection response at F3 over F2 generation
[Value of improvement at F3 over F2 / F2 value] x 100 = % improvement at F3 over F2 generation

Improvement of selection response at F4 over P1 generation

Value of F4 – value of P1 = improvement at F4 over P1 generation

Percentage improvement of selection response at F4 over P1 generation

[Value of improvement at F4 over P1 / P1 value] x 100 = % improvement at F4 over P1 generation

Improvement of selection response at F4 over F3 generation

Value of F4 – value of F3 = improvement at F4 over F3 generation

Percentage improvement of selection response at F4 over F3 generation

[Value of improvement at F4 over F3 / F3 value] x 100 = % improvement at F4 over F3 generation

Improvement of selection response at F5 over P1 generation

Value of F5 – value of P1 = improvement at F5 over P1 generation

Percentage improvement of selection response at F5 over P1 generation

[Value of improvement at F5 over P1 / P1 value] x 100 = % improvement at F5 over P1 generation

Improvement of selection response at F5 over F4 generation

Value of F5 – value of F4 = improvement at F5 over F4 generation

Percentage improvement of selection response at F5 over F4 generation

[Value of improvement at F5 over F4 / F4 value] x 100 = % improvement at F5 over F4 generation

Improvement of selection response at F6 over P1 generation

Value of F6 – value of P1 = improvement at F6 over P1 generation

Percentage improvement of selection response at F6 over P1 generation

[Value of improvement at F6 over P1 / P1value] x 100 = % improvement at F6 over P1 generation

Improvement of selection response at F6 over F5 generation

Value of F6 – value of F5 = improvement at F6 over F5 generation

Percentage improvement of selection response at F6 over F5 generation
[Value of improvement at F6 over F5 / F5value] x 100 = % improvement at F6 over F5 generation

The obtained data pertaining to four quantitative traits of six generation from the experiment thereby were statistically analyzed through OPISTAT statistical package.

Results and Discussion

The success of selection is monitored by the degree to which the desired trait is transmitted to the succeeding generation and nature of selection is to be given due to consideration at appropriate developmental stages for pursuing selection in desired direction, while improving or evolving high productive breeds or hybrids of the silkworm *Bombyx mori*. The results of the selection response with the improvement & percent improvement across six generation studies utilizing two each of bivoltine, multivoltine and mutants of the silkworm *Bombyx mori* depicted in the Table 1. It shows rearing performance and improvement across six generation through cellular rearing method for four quantitative traits of the silkworm (Figures 1–4). The results in regard to cocoon weight of C108 race recorded of 1.88g at P1 level followed by NB_4D_2 (1.75g), PM (1.03g), Nistari (0.88g), zebra (1.60g) and knobbed (1.510g).

Whereas an increase of 1.91g at F1 generation in C_{108} and showed improvement of 0.03g over the P1. Further, all other races also showed increase of cocoon weight at F1 compare to the P1 level (Fig. 1). Moreover, there was a slight increase in F2 (1.94g), F3 generation (1.96g), F4 (1.99g), F5 (2.01) and F6 (2.11g), which showing improvement of 0.06g (F1 over P1), 0.03g (F2 over F1), 0.08g (F3 over P1), 0.02g (F3 over F2), 0.11g (F4 over P1), 0.03g (F4 over F3), 0.13g (F5 over P1), 0.02g (F5 over F4), 0.23g (F6 over P1), 0.1g (F6 over F5) with the percent improvement of 12.23% at F6 over P1and 4.97% at F6 over F5 respectively.

Further, an average was made across the six generation and recorded of 1.98g cocoon weight in C_{108} race. More interestingly, for the traits like shell weight (Fig. 2) and filament length (Fig. 3) showed the same trend of increase g/mtr from P1 level of 0.315g shell weight & 900mtr filament length to the F6 generation of 0.401g shell weight & 1201mtr length of filament respectively. But, the trend of increasing g/mtr was not evident in case of pupation rate (Fig. 4) instead decreasing of pupation rate consistently in every generation from P1 (93.11%) level to F6 generation (91.05%) in C_{108} race. Further, the same trend of increasing g/mtr traits like cocoon weight, shell weight and filament length was observed and decreasing phenomenon was noticed in case of pupation rate in NB_4D_2 race, Pure Mysore, Nistari, zebra & knobbed races/mutants through cellular selection rearing method (Table 1). Few investigators have worked for selection for region and season specific breeds/hybrids are He and Oshiki (1984), Nirmal Kumar (1995), Sudhakar Rao (2003), Suresh Kumar *et al.*, (2013), *etc*.

Further, the data in regards to Table 2 showing rearing performance and improvement over the generations through mass rearing method for the four quantitative traits (cocoon weight, shell weight & filament length) of the silkworm *Bombyx mori*. The results for trait cocoon weight recorded of 1.88g at P1 level, 1.95g at F1 generation & 1.98g during F2 generation recorded accordingly, but during F3 generation, it was noticed 1.88g cocoon weight occurring of inbreeding depression at F3 & again it was increased for 2.00g at F4 generation then again showing inbreeding depression during F5 of 1.90g) & F6 of 1.82g respectively. However, interestingly this trend of heterosis at F1 (1.95g), F2 (1.98g) & F4 (2.00g) occurred at the same time, the trend of inbreeding depression was evident at F3 generation (1.88g), F5 (1.90g) & F6 (1.82g) compare to earlier generations in C_{108} race and this was relevant with the results of Dobzhansky, (1950), who has worked on origin of heterosis through natural selection in populations *Drosophila pseudobscura*.

Table.1 Rearing performance & improvement over the generations by cellular rearing for four quantitative traits of the silkworm

RACES	Traits	mean ± at P1 level	F_1	Improv. at F_1 over P_1	% improv. at F_1 over P_1	F_2	Improv. at F_2 over P_1	% improv. at F_2 over P_1	Improv. at F_2 over F_1	% improv.at F_2 over F_1	F_3	Improv. at F_3 over P_1	% improv. at F_3 over P_1	Improv. at F_3 over F_2
C_{108}	CW	1.88±0.02	1.91±0.01	0.03	1.59	1.94±0.05	0.06	3.19	0.03	1.59	1.96±0.06	0.08	4.25	0.02
	SW	0.315±0.005	0.320±0.006	0.005	1.58	0.329±0.009	0.014	4.44	0.009	2.81	0.332±0.05	0.017	5.39	0.003
	FL	900±3.01	952±2.05	52	5.77	963±1.89	0.07	7	11	1.15	971±2.00	71	7.89	8
	PR	93.11±0.19	93.00±0.21	-0.11	-0.118	92.11±1.01	-1	-1.07	-0.89	-0.95	92.59±0.51	-0.52	-0.56	0.48
NB_4D_2	CW	1.75±0.06	1.88±0.18	0.13	7.43	1.92±0.12	0.17	9.71	0.04	2.13	1.98±0.15	0.23	13.14	0.06
	SW	0.33±0.006	0.310±0.1	-0.02	-6.06	0.328±0.06	-0.002	-0.60	0.018	5.81	0.330±0.11	0	0	0.002
	FL	895±2.05	898±1.81	3	0.33	920±1.51	25	2.79	22	2.45	950±0.61	55	6.14	30
	PR	94.48±0.19	94.21±0.25	2.73	-0.28	94.01±0.15	-0.47	-0.49	-0.2	-0.21	93.65±0.14	-0.83	-0.89	-0.36
PM	CW	1.03±0.04	1.08±0.06	0.05	4.85	1.10±0.08	0.07	6.79	0.02	1.85	1.12±0.10	0.09	8.74	0.02
	SW	0.128±0.06	0.130±0.02	0.002	1.56	0.133±0.06	0.005	3.90	0.003	2.31	0.138±0.14	0.01	7.81	0.005
	FL	330±3.10	350±1.00	20	6.06	361±1.89	31	9.39	11	3.14	370±1.59	40	12.12	9
	PR	93.04±0.17	93.51±0.15	0.47	0.50	93.89±0.15	0.85	0.91	0.38	0.41	94.61±0.66	1.57	1.69	0.72
Nistari	CW	0.88±0.02	0.91±0.03	0.03	3.41	0.96±0.06	0.08	9.09	0.05	5.49	0.99±0.06	0.11	12.5	0.03
	SW	0.115±0.04	0.126±0.08	0.011	9.56	0.131±0.05	0.016	13.91	0.005	3.97	0.139±0.09	0.024	20.87	0.008
	FL	310±2.00	325±1.08	15	4.84	336±1.90	26	8.39	11	3.38	355±2.00	45	14.52	19
	PR	91.50±0.04	91.81±0.62	0.31	0.34	92.50±0.15	1	1.09	0.69	0.75	92.90±0.15	1.4	1.53	0.4
zebra	CW	1.60±0.03	1.66±0.28	0.06	3.75	1.70±0.20	0.1	6.25	0.04	2.41	1.78±0.15	0.18	11.25	0.08
	SW	0.220±0.02	0.231±0.05	0.011	5	0.238±0.06	0.018	8.18	0.007	3.03	0.249±0.01	0.029	13.18	0.011
	FL	800±0.15	808±1.05	8	1	815±2.01	15	1.87	7	0.87	830±1.50	30	3.75	15
	PR	90.01±0.26	89.50±0.59	-0.51	-0.56	88.61±0.55	-1.41	-1.55	-0.89	-0.99	87.401±0.5	-2.61	-2.89	-1.21
knobbed	CW	1.50±0.04	1.55±1.05	0.05	3.33	1.60±0.81	0.1	6.67	0.05	3.22	1.60±051	0.1	6.67	0
	SW	0.199±0.03	0.210±0.09	0.011	5.53	0.222±0.05	0.023	11.56	0.012	5.71	0.238±0.08	0.039	19.59	0.016
	FL	790±0.95	799±1.89	9	1.14	808±1.59	18	2.28	9	1.13	821±1.06	31	3.92	13
	PR	91.06±0.08	90.10±0.12	-0.96	-1.05	89.50±1.05	-1.56	-1.71	-0.6	-0.66	88.55±0.11	-2.51	-2.75	-1.06

% improv. at F_3 over F_2	F_4	Improv. at F_4 over P_1	% improv. at F_4 over P_1	Improv. at F_4 over F_3	% improv. at F_4 over F_3	F_5	Improv. at F_5 over P_1	Improv. at F_5 over F_4	% improv. at F_5 over P_1	% improv. at F_5 over F_4	F_6	Improv. at F_6 over P_1	% improv. at F_6 over P_1	Improv. at F_6 over F_5	% improv. at F_6 over F_5	Average of 6 generation
1.03	1.99±0.08	0.11	5.85	0.03	1.53	2.01±0.09	0.13	0.02	1.00	6.91	2.11±0.08	0.23	12.23	0.1	4.97	1.986
0.91	0.349±0.04	0.034	10.79	0.017	5.12	0.376±0.08	0.061	0.027	7.74	19.36	0.401±0.02	0.086	27.30	6.025	6.65	0.351
0.83	999±2.12	99	11	-71	-7.31	1105±2.01	205	106	10.61	22.78	1201±2.10	301	33.44	95	8.68	1032
0.52	92.81±1.51	-0.3	-0.32	0.22	0.24	91.61±1.15	-1.5	-1.2	-1.29	-1.61	91.05±0.51	-2.06	-2.21	-0.56	-0.61	92.19
3.12	2.04±0.26	0.29	16.56	0.06	3.03	2.09±0.12	0.34	0.05	2.45	19.43	2.18±0.08	0.46	24.57	0.09	4.31	2.015
0.609	0.340±0.06	0.01	3.03	0.01	3.03	0.360±0.06	0.03	0.02	5.88	9.09	0.400±0.09	0.07	21.21	0.04	11.11	0.344
3.26	996±2.89	101	11.28	46	4.84	1191±2.01	296	195	19.58	33.07	1200±1.89	305	34.08	9	0.75	1025
-0.38	93.45±0.05	-1.03	-1.09	-0.2	-0.21	93.25±0.15	-1.23	-0.2	-0.21	-1.30	93.10±0.06	-1.38	-1.46	-0.15	-0.16	93.61
1.82	1.13±0.20	0.1	9.71	0.01	0.89	1.15±1.00	0.12	0.02	1.77	11.65	1.25±0.25	0.22	21.36	0.1	8.69	1.138
3.76	0.140±0.01	0.012	9.37	0.002	1.45	0.146±0.06	0.018	0.006	4.28	14.06	0.150±0.07	0.022	17.19	0.004	2.74	0.139
3.49	379±1.61	49	14.85	9	2.43	385±2.65	55	6	1.58	16.67	406±3.05	76	23.03	21	5.45	375
0.77	94.90±0.04	1.86	1.99	0.29	0.31	95.80±0.66	2.76	0.9	0.95	2.96	95.98±0.69	2.94	3.16	0.18	0.19	94.78
3.12	1.05±0.02	0.17	19.32	0.06	6.06	1.11±0.06	0.23	0.006	5.71	26.14	1.20±0.25	0.32	36.36	0.09	8.11	1.036
6.11	0.142±0.05	0.027	23.48	0.003	2.16	0.144±0.05	0.029	0.002	1.41	25.22	0.148±0.08	0.033	28.69	0.004	2.78	0.138
5.56	370±1.40	60	19.35	15	4.22	378±1.05	68	8	2.16	21.93	388±2.06	78	25.16	10	2.64	358
0.42	93.40±0.08	1.9	2.08	0.5	0.54	93.89±0.59	2.39	0.49	0.52	2.61	94.49±0.15	2.99	3.27	0.6	0.64	93.16
4.70	1.85±1.50	0.25	15.62	0.07	3.93	1.86±0.52	0.26	0.01	0.54	16.25	1.84±0.70.3	0.24	15	-0.02	-0.07	1.782
4.62	0.258±0.10	0.038	17.27	0.009	3.61	0.278±0.09	0.058	0.02	7.75	26.36	0.310±0.07	0.09	40.90	0.032	11.51	0.261
1.84	841±0.60	41	5.12	11	1.32	862±1.60	62	21	2.49	7.75	860±1.55	60	7.5	-2	-0.23	836
-1.36	87.01±0.55	-3.01	-3.34	-0.4	-0.46	86.59±0.69	-3.42	-0.41	-0.49	-3.79	86.00±0.05	-4.01	-4.45	-0.59	-0.68	87.52
0	1.68±0.50	0.18	12	0.08	5	1.69±0.89	0.19	0.01	0.59	12.67	1.71±0.15	0.21	14	0.02	1.18	1.638
7.21	0.248±0.15	0.049	24.62	0.01	4.20	0.260±0.06	0.061	0.012	4.84	30.65	0.291±0.15	0.092	46.23	0.031	11.92	0.245
1.61	829±1.049	38	4.94	8	0.97	836±1.44	46	7	0.84	5.82	851±1.45	61	7.72	15	1.79	824
-1.06	87.40±0.52	-3.66	-4.02	-1.15	-1.31	86.50±0.06	-4.56	-0.9	-1.03	-5.01	86.00±0.50	-5.06	-5.56	-0.5	-0.58	88.17

Note: PM= Pure Mysore, Improv. = improvement, P1= Parental generation 1, CW= Cocoon weight, SW= Shell weight, Filament length, PR= Pupation rate & %= Percentage.

Table.2 Rearing performance & improvement over the generations by mass rearing for four quantitative traits of the silkworm

RACES	Traits	mean ± at p1 level	F_1	Impr. at F_1 over P_1	% impr. at F_1 over P_1	F_2	Impr. at F_2 over P_1	% impr. at F_2 over P_1	Impr. at F_2 over F_1	% impr. at F_2 over F_1	F_3	Impr. at F_3 over P_1	% impr. at F_3 over P_1	Impr. at F_3 over F_2
C_{108}	CW	1.88±0.02	1.95±0.15	0.07	3.723	1.98±0.11	0.10	5.319	-0.03	-1.538	1.88±0.16	00	00	-0.1
	SW	0.315±0.005	0.335±0.51	0.023	7.301	0.330±0.50	0.015	4.761	0.005	1.492	0.350±0.11	-0.035	-11.111	0.02
	FL	900±3.01	1000±1.25	100	11.111	995±1.89	95	10.555	-5	-0.5	1001±0.91	-100	-11.111	6
	PR	93.11±0.19	94.09±1.66	1.78	1.911	94.85±0.55	1.74	1.868	0.75	0.807	94.88±0.65	0.77	0.827	-0.97
NB_4D_2	CW	1.75±0.06	1.91±0.15	0.161	9.142	1.87±0.55	0.12	6.857	0.04	2.094	1.95±0.15	0.20	11.428	-0.08
	SW	0.33±0.006	0.326±0.11	-0.004	-1.212	0.320±0.61	-0.01	-3.030	0.006	1.840	0.330±0.55	00	00	-0.01
	FL	895±2.05	980±3.55	85	9.497	990±1.55	95	10.614	10	1.020	999±1.55	104	11.620	-9
	PR	94.38±0.19	94.45±0.55	0.07	0.074	94.50±0.15	0.12	0.127	-0.05	-0.053	94.80±0.15	0.58	0.720	-0.7
PM	CW	1.03±0.04	1.10±0.06	0.07	6.796	1.12±0.05	0.09	8.737	0.02	1.818	1.09±0.16	0.06	5.825	-0.03
	SW	0.128±0.06	0.138±0.01	0.01	7.812	0.140±0.15	0.012	9.375	0.048	25.532	0.131±0.14	0.003	2.343	-0.009
	FL	330±3.10	360±1.55	30	9.090	368±2.61	38	11.515	-8	-2.222	361±1.33	31	9.394	-7
	PR	93.04±0.17	93.55±0.15	.51	0.548	94.23±1.55	1.19	1.279	-.68	-.727	94.60±0.05	-0.56	-0.602	-0.63
Nistari	CW	0.88±0.02	0.99±0.16	0.11	12.5	1.05±0.10	0.17	19.318	0.06	6.061	0.95±0.05	0.07	7.954	-0.1
	SW	0.115±0.04	0.126±0.01	0.01	9.565	0.131±0.05	0.016	13.913	0.005	3.969	0.121±0.15	-0.006	-5.219	-0.01
	FL	310±2.00	340±1.55	30	9.677	365±2.15	55	17.742	25	7.353	341±2.17	31	10	24
	PR	91.50±0.04	92.00±1.11	0.5	0.546	93.25±0.21	1.75	1.912	-1.25	-1.358	93.31±0.17	-0.29	-0.317	2.04
zebra	CW	1.60±0.03	1.74±0.15	0.14	8.750	1.65±0.16	0.05	3.125	0.09	5.172	1.71±0.18	0.11	6.875	0.06
	SW	0.220±0.02	0.290±0.16	0.07	31.818	0.290±0.55	0.07	31.818	00	00	0.298±0.15	-0.078	-35.45	-0.008
	FL	800±0.15	855±1.11	55	6.875	855±1.00	55	6.875	00	00	860±2.15	60	7.5	5
	PR	90.01±0.26	90.55±0.11	0.65	0.722	91.56±0.11	1.55	1.722	-1.01	-1.115	91.50±0.12	-0.51	-0.566	-2.06
knobbed	CW	1.50±0.04	1.61±0.15	0.11	7.333	1.68±0.11	-0.18	-12.00	0.07	4.348	1.58±0.24	0.08	5.333	-0.1
	SW	0.199±0.03	0.210±0.22	0.011	5.527	0.230±0.55	0.031	15.577	-0.02	-9.524	0.221±0.15	0.022	11.055	-0.009
	FL	790±0.95	799±2.00	9	1.139	790±1.55	10	1.266	-1	-0.125	798±0.61	8	1.013	2
	PR	90.05±0.08	91.59±0.11	0.53	0.582	92.06±0.35	1.00	1.098	0.46	0.502	92.65±0.25	0.41	0.450	-1.41

% impr. at F_3 over F_2	F_4	Improv. at F_4 over P_1	% improv. at F_4 over P_1	Improv. at F_4 over F_3	% improv. at F_4 over F_3	F_5	Improv. at F_5 over P_1	Improv. at F_5 over F_4	% improv. at F_5 over F_4	% improv. at F_5 over P_1	F_6	Improv. at F_6 over P_1	% improv. at F_6 over P_1	Improv. at F_6 over F_5	% improv. at F_6 over F_5	Average of 6 generation
-5.050	2.00±0.17	0.12	6.382	0.12	6.00	1.90±0.61	0.02	1.052	-0.1	-5.263	1.82±0.15	-0.06	-3.296	-0.08	-4.395	1.921
6.060	0.390±0.55	0.075	23.809	0.04	11.428	0.352±0.51	0.037	10.511	-0.038	-10.795	0.338±0.08	0.023	6.804	-0.014	-4.142	0.349
0.603	1101±2.15	201	22.333	100	10.010	998±2.15	98	9.819	-103	-10.320	988±1.51	88	8.907	-10.00	1.012	10.13
-1.022	94.88±0.15	1.04	1.117	0.27	0.287	95.25±0.22	2.14	2.246	1.1	1.155	96.55±0.15	3.44	3.563	1.3	1.346	94.795
-4.278	2.05±0.05	0.3	17.142	0.1	5.128	1.90±1.66	0.15	7.895	-0.15	-7.895	1.80±0.14	0.05	2.777	-0.1	-5.55	1.913
-3.125	0.391±0.17	0.061	18.485	0.061	18.484	0.380±0.28	0.05	13.157	-0.011	-2.895	0.361±0.59	0.031	8.587	-0.019	-5.263	0.351
-0.909	1100±0.14	205	22.905	101	10.110	998±1.56	103	10.320	-102	-10220	950±3.15	55	5.789	-48	-5.052	986
-0.740	94.81±0.14	0.13	0.551	0.71	0.756	95.00±0.17	0.62	0.652	0.49	0.515	95.88±0.61	1.5	1.564	0.88	0.918	94.69
-2.678	1.15±0.28	0.120	11.650	0.06	5.504	1.10±0.15	0.07	6.363	-0.05	-4.545	1.09±0.12	0.06	5.504	-0.01	-0.917	1.442
-6.428	0.141±0.10	0.013	10.156	0.01	7.633	0.132±0.11	0.004	3.030	-0.009	-6.818	0.130±0.21	0.002	1.538	-0.002	-1.538	0.144
-1.902	395±1.50	65	19.696	34	9.418	389±0.16	59	15.167	-6	-1.507	370±3.15	40	10.811	-19.00	-5.135	374
-0.668	94.60±0.55	0.96	1.032	0.4	0.427	94.75±1.15	1.52	1.607	0.55	0.582	95.00±0.18	1.96	2.063	0.45	0.473	94.155
-9.523	1.10±015	0.22	25.00	0.15	15.789	0.96±0.21	0.08	8.333	-0.14	-14.583	0.90±0.15	0.02	2.222	-0.06	-6.666	0.993
-7.633	0.132±0.15	0.017	14.782	0.011	9.090	0.120±0.15	0.005	4.166	-0.012	-10.00	0.119±0.11	0.004	3.361	-0.001	-0.840	0.125
6.575	375±1.55	65	20.967	34	9.970	365±1.01	55	15.068	-10.0	-2.739	356±2.30	46	12.921	-9	-2.528	357
2.187	93.65±0.25	2.15	2.349	2.44	2.675	93.75±0.15	2.05	2.191	-0.1	-0.107	94.05±0.15	2.55	2.711	0.5	0.531	92.95
3.636	1.79±0.14	0.19	11.875	0.08	4.678	1.70±0.12	0.1	5.882	-0.09	-5.294	1.65±0.11	0.05	3.030	-0.05	-3.030	1.706
-2.758	0.302±0.15	0.082	37.272	0.004	1.342	0.289±0.16	0.069	23.875	-0.013	-4.498	0.278±0.66	0.058	20.863	-0.011	-3.956	0.291
0.585	865±1.11	65	0.125	5	0.581	860±1.17	60	6.976	-5	-0.581	830±2.15	30	3.614	-30	-3.614	854
-2.249	91.40±1.16	0.39	0.433	0.9	1.005	91.50±1.12	0.49	0.542	0.10	0.110	91.55±0.12	1.54	1.682	1.05	1.147	90.69
-5.952	1.69±0.12	0.19	12.666	0.11	6.962	1.60±0.14	0.10	6.25	-0.009	-0.09	1.58±0.16	0.08	5.063	-0.02	-1.266	1.623
-3.913	0.230±0.24	0.031	1.557	0.009	4.072	0.210±0.59	0.011	5.238	0.02	9.524	0.200±0.24	-0.001	-0.5	-0.01	-5.00	0.217
0.25	820±0.20	30	3.797	22	2.756	800±1.05	10	1.25	-20.0	-2.5	792±1.05	2.00	0.252	-8	-1.010	801
-1.531	92.70±0.14	0.56	0.622	0.05	0.055	92.75±0.24	1.00	1.098	0.35	0.384	92.55±1.04	1.5	1.638	0.5	0.546	92.26

Note: PM= Pure Mysore, Improv. = improvement, P1= Parental generation 1, CW= Cocoon weight, SW= Shell weight, Filament length, PR= Pupation rate & %= Percentage.

Table.3 Selection response through cellular rearing technique for the traits cocoon weight and shell weight of the silkworm *Bombyx mori*

Races / Generations	Traits	C_{108}	NB_4D_2	PM	Nistari	zebra	knobbed
P_1	COCOON WEIGHT(gm)	1.880±0.006	1.773±0.015	1.033±0.009	0.920±0.035	1.607±0.064	1.527±0.013
F_1		1.910±0.006	1.887±0.003	1.070±0.015	0.933±0.028	1.687±0.032	1.553±0.020
F_2		1.920±0.012	1.920±0.012	1.110±0.006	0.970±0.015	1.723±0.034	1.607±0.007
F_3		1.947±0.024	1.987±0.003	1.147±0.027	1.060±0.070	1.800±0.025	1.623±0.028
F_4		1.970±0.025	2.027±0.013	1.133±0.009	1.063±0.019	1.853±0.020	1.693±0.030
F_5		1.993±0.009	2.090±0.006	1.153±0.003	1.140±0.035	1.860±0.023	1.713±0.034
F_6		2.070±0.035	2.163±0.027	1.253±0.003	1.230±0.015	1.867±0.043	1.720±0.015
F- Test		*	*	*	*	*	*
C.D. @ 5%		0.06	0.042	0.039	0.11	0.113	0.07
SE(m) ±		0.02	0.014	0.013	0.036	0.037	0.023
SE(d) ±		0.028	0.019	0.018	0.051	0.052	0.033
C.V. (%)		1.746	1.204	1.972	5.938	3.62	2.437
P_1	SHELL WEIGHT(gm)	0.313±0.002	0.333±0.009	0.127±0.001	0.115±0.000	0.223±0.015	0.199±0.006
F_1		0.320±0.001	0.313±0.009	0.132±0.001	0.126±0.001	0.232±0.001	0.211±0.001
F_2		0.326±0.003	0.328±0.004	0.133±0.000	0.132±0.002	0.238±0.001	0.223±0.004
F_3		0.333±0.002	0.330±0.006	0.137±0.001	0.138±0.003	0.247±0.003	0.240±0.001
F_4		0.347±0.002	0.337±0.004	0.141±0.001	0.142±0.001	0.258±0.003	0.249±0.001
F_5		0.374±0.002	0.357±0.004	0.147±0.001	0.144±0.002	0.277±0.003	0.263±0.002
F_6		0.400±0.001	0.403±0.003	0.152±0.001	0.148±0.001	0.315±0.005	0.293±0.001
F- Test		*	*	*	*	*	*
C.D. @ 5%		0.006	0.018	0.003	0.005	0.019	0.009
SE(m) ±		0.002	0.006	0.001	0.002	0.006	0.003
SE(d) ±		0.003	0.008	0.001	0.002	0.009	0.004
C.V. (%)		0.989	2.986	1.269	2.228	4.124	2.137

Note:*=Significant (P<0.05), N/S=Non-significant (P>0.05), C.D=, SE=Standard error, C.V=

Table.4 Selection response through cellular rearing technique for the traits filament length and pupation rate of the silkworm *Bombyx mori*

Races Generations	Traits	C_{108}	NB_4D_2	PM	Nistari	zebra	knobbed
P_1	FILAMENT LENGTH (mtr)	899.667±0.305	896.333±0.892	332.667±1.454	313.667±3.667	807.667±3.842	791.667±1.662
F_1		952.000±1.155	895.667±2.845	352.000±2.000	326.000±3.215	811.000±5.132	799.667±0.308
F_2		962.667±1.446	920.333±0.360	363.667±1.335	337.333±1.855	822.000±4.726	813.333±3.530
F_3		968.667±1.851	952.333±1.460	371.000±0.577	351.333±6.333	830.333±4.335	824.000±3.512
F_4		999.667±0.301	995.667±0.301	380.000±0.577	351.333±6.333	841.667±4.053	830.333±5.813
F_5		1106.000±1.000	1192.000±1.528	385.000±1.732	371.667±4.410	864.000±4.163	839.667±4.175
F_6		1201.333±1.843	1200.333±0.250	408.333±1.200	377.667±4.334	870.000±9.504	854.333±3.846
F- Test		*	*	*	*	*	*
C.D. @ 5%		3.935	4.279	4.174	13.971	16.627	11.203
SE(m) ±		1.285	1.397	1.363	4.562	5.429	3.658
SE(d) ±		1.817	1.976	1.927	6.451	7.678	5.173
C.V. (%)		0.22	0.24	0.637	2.277	1.126	0.771
P_1	PUPATION RATE	93.150±0.042	94.460±0.034	93.080±0.030	91.573±0.037	90.077±0.042	91.073±0.019
F_1		92.993±0.058	94.220±0.027	93.537±0.042	91.820±0.000	89.687±0.212	90.403±0.297
F_2		92.120±0.024	94.020±0.027	93.890±0.000	92.503±0.028	88.787±0.211	89.270±0.120
F_3		92.503±0.047	93.677±0.015	94.637±0.032	92.903±0.000	87.627±0.309	88.680±0.293
F_4		92.637±0.144	93.463±0.000	94.953±0.022	93.400±0.024	87.437±0.337	87.030±0.299
F_5		91.553±0.019	93.283±0.023	95.863±0.057	93.890±0.000	86.683±0.159	86.487±0.024
F_6		91.117±0.081	93.107±0.007	95.987±0.016	94.420±0.081	86.450±0.400	86.517±0.517
F- Test		*	*	*	*	*	*
C.D. @ 5%		0.218	0.058	0.093	0.103	0.808	0.855
SE(m) ±		0.071	0.019	0.03	0.034	0.264	0.279
SE(d) ±		0.1	0.027	0.043	0.047	0.373	0.395
C.V. (%)		0.133	0.035	0.056	0.063	0.518	0.546

Note:*=Significant (P<0.05), N/S=Non-significant (P>0.05), C.D= Critical difference, SE=Standard error, C.V= Coefficient of variation

Table.5 Selection response through mass rearing technique for the traits cocoon weight and shell weight of the silkworm *Bombyx mori*

Races Generations	Traits	C_{108}	NB_4D_2	PM	Nistari	zebra	knobbed
P_1	COCOON WEIGHT(gm)	1.863±0.022	1.757±0.029	1.047±0.033	0.880±0.006	1.560±0.023	1.543±0.070
F_1		1.960±0.010	1.940±0.025	1.087±0.041	0.987±0.003	1.630±0.110	1.640±0.057
F_2		1.983±0.009	1.880±0.006	1.167±0.037	1.053±0.032	1.640±0.067	1.717±0.037
F_3		1.943±0.084	1.947±0.003	1.093±0.009	0.977±0.015	1.733±0.023	1.607±0.043
F_4		2.047±0.052	2.053±0.032	1.167±0.022	1.120±0.015	1.763±0.065	1.670±0.036
F_5		1.997±0.073	1.927±0.037	1.093±0.052	0.973±0.019	1.710±0.072	1.600±0.087
F_6		1.880±0.060	1.847±0.073	1.113±0.015	0.880±0.100	1.730±0.117	1.550±0.085
F- Test		N/S	*	N/S	*	N/S	N/S
C.D. @ 5%		N/S	0.111	N/S	0.126	N/S	N/S
SE(m) ±		0.053	0.036	0.033	0.041	0.076	0.062
SE(d) ±		0.074	0.051	0.047	0.058	0.108	0.088
C.V. (%)		4.663	3.302	5.148	7.135	7.856	6.685
P_1	SHELL WEIGHT(gm)	0.316±0.003	0.331±0.005	0.124±0.002	0.114±0.000	0.235±0.009	0.199±0.000
F_1		0.337±0.002	0.326±0.003	0.139±0.001	0.128±0.001	0.296±0.003	0.211±0.000
F_2		0.340±0.008	0.322±0.001	0.142±0.004	0.136±0.003	0.307±0.009	0.229±0.003
F_3		0.345±0.011	0.333±0.006	0.134±0.003	0.126±0.003	0.299±0.000	0.229±0.006
F_4		0.359±0.016	0.392±0.004	0.145±0.003	0.135±0.002	0.312±0.006	0.233±0.006
F_5		0.359±0.016	0.389±0.010	0.138±0.007	0.121±0.004	0.300±0.006	0.215±0.010
F_6		0.350±0.005	0.376±0.018	0.135±0.005	0.118±0.001	0.285±0.004	0.213±0.008
F- Test		N/S	*	N/S	*	*	*
C.D. @ 5%		N/S	0.026	N/S	0.007	0.019	0.019
SE(m) ±		0.01	0.008	0.004	0.002	0.006	0.006
SE(d) ±		0.014	0.012	0.006	0.003	0.009	0.009
C.V. (%)		5.112	4.138	5.168	3.308	3.648	4.791

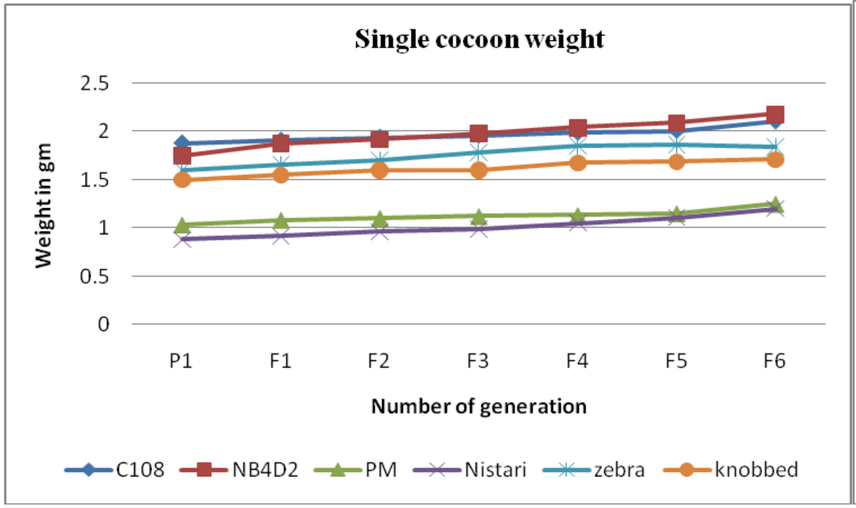
Note:*=Significant (P<0.05), N/S=Non-significant (P>0.05), C.D= Critical difference, SE=Standard error, C.V= Coefficient of variation

Table.6 Selection response through mass rearing technique for the traits filament length and pupation rate of the silkworm *Bombyx mori*

Races	Traits	C_{108}	NB_4D_2	PM	Nistari	zebra	knobbed
P_1	FILAMENT LENGTH(mtr)	897.00±3.00	897.67±1.45	330.67±0.34	314.00±3.51	804.67±4.67	792.33±3.39
F_1		996.67±3.84	975.33±8.97	358.67±4.10	339.00±5.51	854.00±4.93	803.00±4.00
F_2		997.67±1.45	992.67±3.71	368.00±1.73	365.00±2.31	859.00±2.65	823.00±34.01
F_3		1033.67±33.17	999.67±6.36	365.33±4.84	343.67±2.67	864.00±5.57	799.00±0.58
F_4		1081.00±42.19	1103.67±60.94	396.33±1.33	375.00±2.31	868.67±5.24	817.33±3.18
F_5		999.00±0.58	1066.33±66.84	391.33±4.48	366.00±2.65	863.33±6.01	807.67±8.17
F_6		990.33±4.49	984.00±17.01	373.33±4.37	358.67±4.81	832.33±1.86	793.33±2.97
F- Test		*	*	*	*	*	N/S
C.D. @ 5%		62.623	107.39	10.63	11.015	14.229	N/S
SE(m) ±		20.448	35.065	3.471	3.597	4.646	13.468
SE(d) ±		28.918	49.59	4.909	5.087	6.571	19.047
C.V. (%)		3.544	6.057	1.629	1.772	0.947	2.898
P_1	PUPATION RATE	93.140±0.023	94.397±0.009	93.087±0.018	91.330±0.088	90.187±0.182	90.067±0.004
F_1		94.237±0.142	94.490±0.025	93.543±0.003	92.080±0.083	90.553±0.059	91.527±0.041
F_2		94.907±0.036	94.600±0.052	94.217±0.007	92.597±0.653	91.583±0.048	92.097±0.060
F_3		93.837±0.051	93.860±0.014	93.463±0.105	91.243±0.043	89.577±0.221	90.337±0.161
F_4		94.153±0.000	94.577±0.034	94.110±0.058	93.663±0.037	90.553±0.081	90.533±0.142
F_5		95.253±0.026	95.257±0.202	94.443±0.104	93.590±0.042	90.620±0.064	91.103±0.069
F_6		96.567±0.000	95.953±0.037	95.187±0.135	94.127±0.047	91.697±0.099	91.540±0.010
F- Test		*	*	*	*	*	*
C.D. @ 5%		0.186	0.252	0.244	0.774	0.382	0.276
SE(m) ±		0.061	0.082	0.08	0.253	0.125	0.09
SE(d) ±		0.086	0.117	0.113	0.358	0.176	0.128
C.V. (%)		0.111	0.151	0.147	0.473	0.238	0.172

Note:*=Significant (P<0.05), N/S=Non-significant (P>0.05), C.D= Critical difference, SE=Standard error, C.V= Coefficient of variation

Fig.1&2 Showing variation in single cocoon weight & single shell weight through selection response of cellular rearing technique



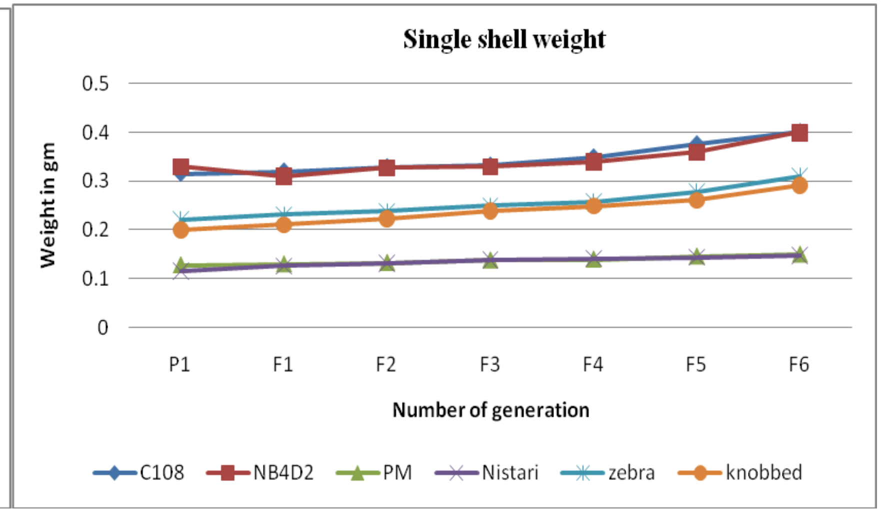
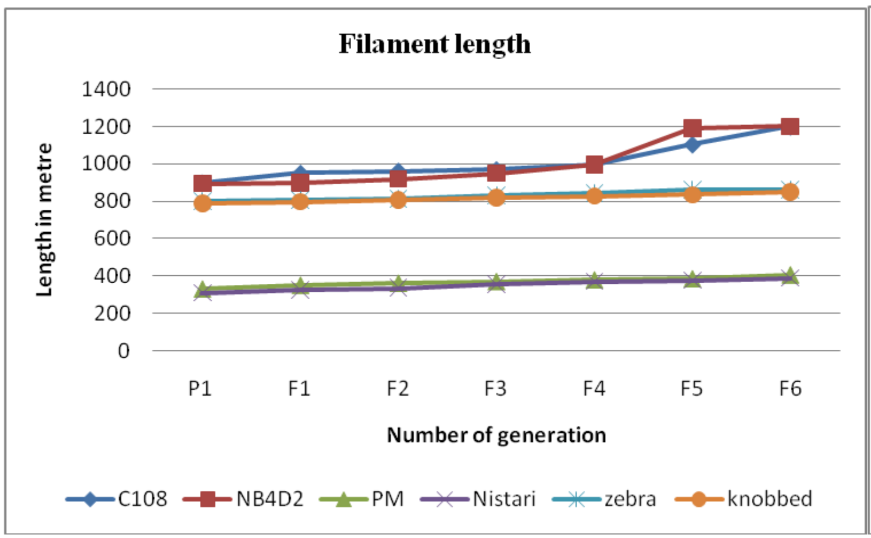


Fig.3&4 Showing variation in filament length & pupation rate through selection response of cellular rearing technique



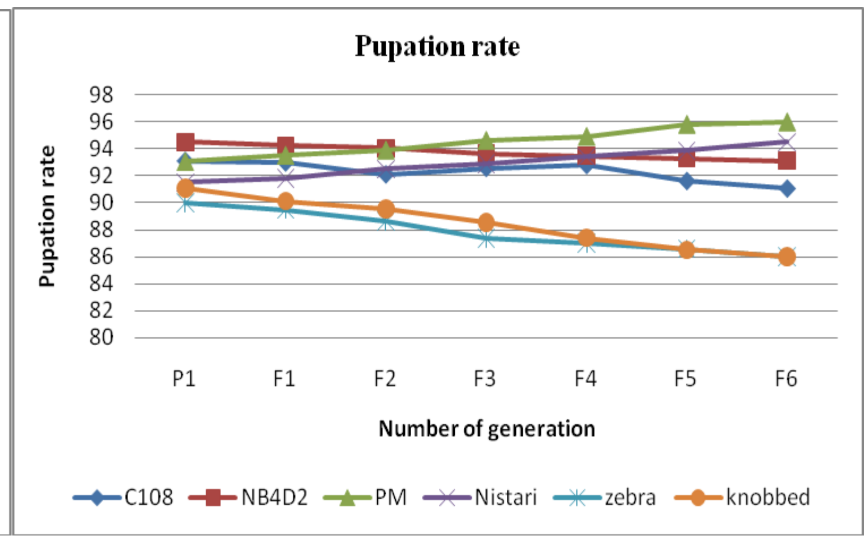


Fig.5&6 Showing variation in single cocoon weight & single shell weight through selection response of mass rearing technique

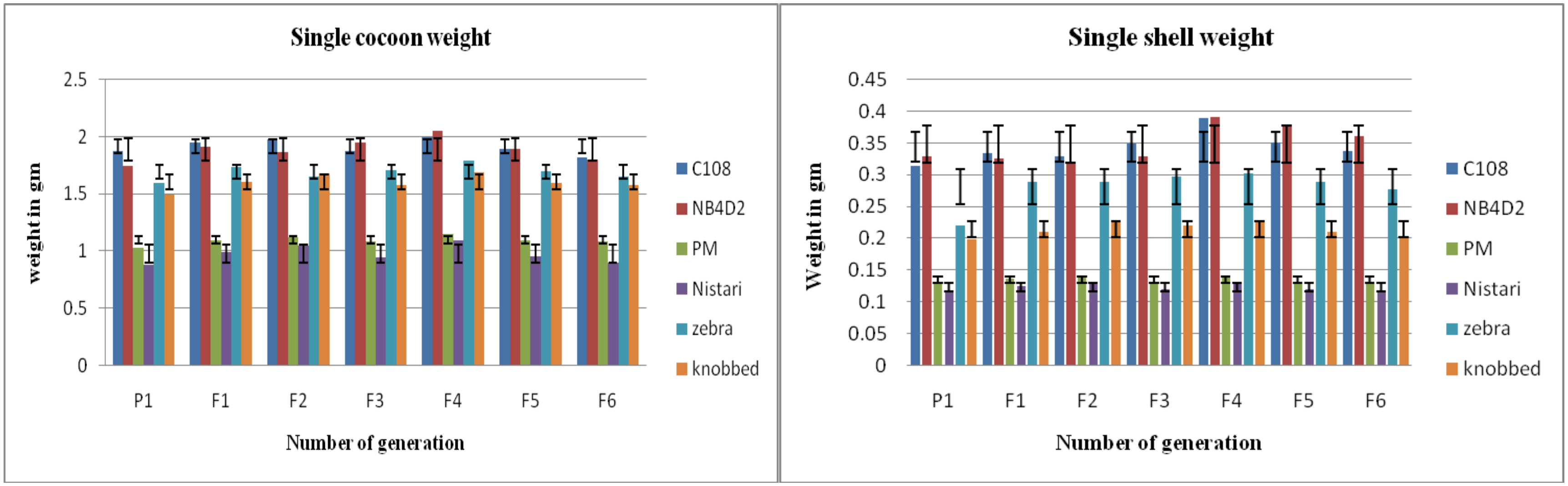


Fig.7&8 Showing variation in filament length & pupation rate through selection response of mass rearing technique

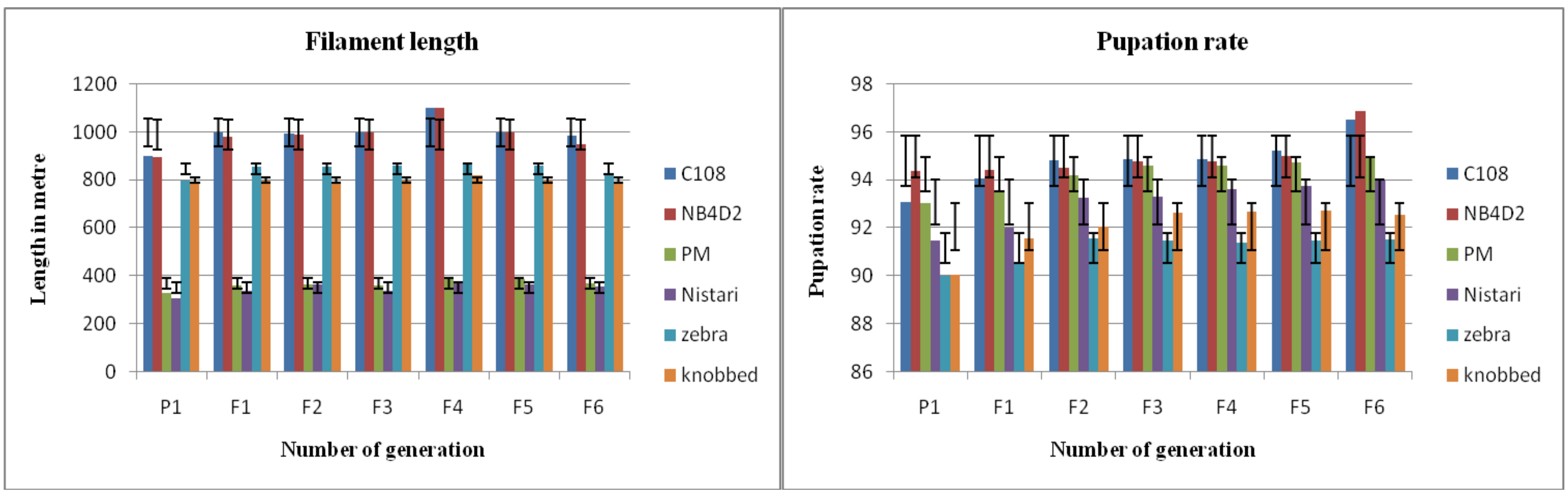


Fig.9 Merit ratio for different tarits between F_6 and P generations through cellular rearing technique in the silkworm *Bombyx mori*

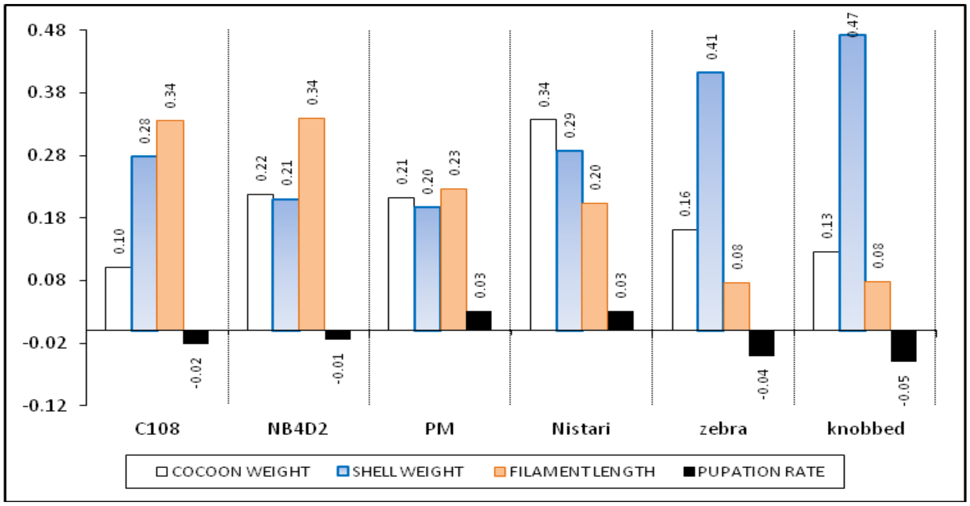
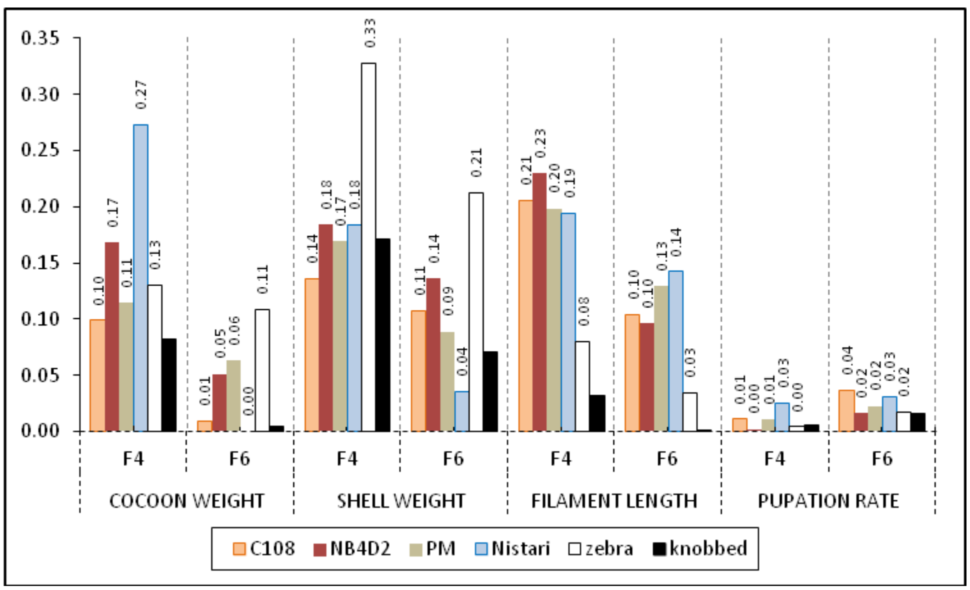


Fig.10 Merit ratio for different tarits between F_4 and F_6 generations through mass rearing technique in the silkworm *Bombyx mori*



However, this kind of phenomenon was also observed for the traits like shell weight (Fig.5 and 6) & filament length (Fig. 7) at from F1 to F6 generations in NB_4D_2, PM, Nistari, zebra & knobbed races/mutants. But, this kind of phenomenon (heterosis & inbreeding depression) was not evident for the trait like pupation rate (Fig. 8) instead there was increasing (heterosis) significantly ($P<0.05$) in pupation rate across the six generations in all the selected races/mutants of the silkworm *Bombyx mori*. The recorded triplicate data was subjected to opistat analysis tool and obtained results in relation to selection response through cellular rearing technique for the traits cocoon weight, shell weight of the silkworm *Bombyx mori* is depicted in table 3. A highest of 2.07g was revealed during F6 generation compare to the rest of generations in C108 race and remaining races were recorded variable in expression of quantitative traits. The C.D @5% value was higher of 0.113 in zebra mutant followed by Nistari (0.11), knobbed (0.07), C108 (0.06), NB_4D_2 (0.042) & PM (0.039) across the six generations. The percent of C.V (%) was higher in case of Nistari (5.938) & minimum of 1.204 was recorded in NB_4D_2 race. Further, same table depicted the shell weight, which is highest expressed in F6 generation for C_{108} (0.100g) among the six generations & C.D @ 5% was seen in zebra mutant (0.019) & remaining races shown variable in percent. Moreover, both the traits (Cocoon weight & shell weight) revealed significant (P<0.05) for the selected races/mutants across the six generations.

Further, the data in regard to selection response through cellular rearing method for the traits filament length and pupation rate is presented in Table 4. The data for the trait filament length clearly shown the C.D @5% value higher of 16.627 in nistari race and remaining races/mutants recorded intermediary values. As such for the trait pupation rate was highest of 0.855 C.D @5% in knobbed mutant & remaining five races/mutants were recorded intermediary values. It is very interesting that, both the traits were shown statistically significant (P<0.05). Moreover, estimates of selection response through mass rearing method for the traits cocoon weight & shell weight was depicted in Table 5. It was clearly shown cocoon weight higher (2.047g) during F4 generation in C108 race & 2.053g maximum was recorded in NB_4D_2 race during same generation. The data for the trait shell weight higher of 0.359g was revealed during F4 & F5 generations in C_{108} alone & NB_4D_2 recorded higher shell weight than C108 during said generations. It is very important to note, the race/mutants (C_{108}, PM, zebra & knobbed) were shown statistically non-significant (P>0.05) except NB_4D_2 & nistari, which were expressed statistically significant (P<0.05). At the same time, on the other hand for the trait shell weight all the selected races/mutants recorded statistically significant except C_{108} & PM were evident with statistically non-significant (P>0.05). Furthermore, Table 6 represented the data with regard to selection response through mass rearing for the trait filament length & pupation rate of the silkworm *Bombyx mori*. All the races/mutants were shown statistically significant (P<0.05) for the both traits (filament length & pupation rate) except knobbed mutant, which was revealed statistically expressed non-significant (P>0.05). Further, Merit ratio for different traits between F_6 and P generations through cellular rearing technique in the silkworm *Bombyx mori* were clear distingushed between the generations and traits selection response (Fig. 9), the ratio for the trait cocoon weight in Nistari, NB4D2 and PM maybe due to Pupation rate, for the trait shell weight in Knobbed and Zebra because of Pupation rate, for the filament length in C108 and NB4D2 probably because of silk gland weight and pupation rate showed higher range for response selection in Nistari and PM. Moreover, merit ratio for different tarits between F_4, F_6 and P generations through mass rearing technique in the silkworm *Bombyx mori* was depicted in Figure 10 showed better expression of the traits for selection response during F4 generation than F6 generation wherein deterioration of traits noticed through mass rearing technique. Several investigators have researched on selection response in silkworm are Hajian *et al.,* (2011).

However, studies of selection response shown variable in results for both the methods, because one of the important method of breeding for silkworm race/strains with polygentically inherited characters is selection for desired characters. There were several investigators, who have worked by utilizing batch/mass as well as individual selection methods to determine even the effect of different disease of the silkworm during many generations for evolutionary studies. Among them, Funada (1968) have observed silkworm resistant to IFV infection by selection method through repeated exposure of the virus & they succeeded finally resistant strains after several generations.

Further, Watanabe, (1967) have exposed for CPV upto 8 generations, but there was not resistant till 4 generation but finally got resistant strains during 5 generation through proper selection procedure. Ultimately, Since, in the present work under the six generations of the selection response utilizing cellular and mass systems revealed considerable increase in selected traits like, cocoon weight, shell weight & filament length, which is well revealed by Falconer and Mackay, (1996) except pupation rate through cellular rearing method.

But, this kind of phenomenon was not observed through mass selection, all the selected traits variable in expression of cocoon weight, shell weight & filament length except pupation rate, which was shown increased considerably across the six generations. Thereby, it is concluded with the response of two selection methods was differed in the expression of the cocoon weight, shell weight and filament across the six generations. On other hand, pupation rate is also responded constant direction expression by cellular as well as mass methods of selection. Hence, cellular as well as mass methods of selection were played an important role, which are constantly helpful for the expression/improvement of desired quantitative traits of the silkworm *Bombyx mori*.

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