DISCUSSION

The success of selection techniques for improvement of economic characters in any organism depends mainly on the selection of initial (base) resource material and adoption of proper selection breeding technique suitable to the genetic expression of the characters under consideration (Mano, 1992). Therefore, understanding of genetic potential and variability of parent material used in the selection process, the nature of inheritance and expression of characters are very important.

In silkworm, studies have shown that, directional selection for one trait has correlation with the genetic changes with the other quantitative characters. The correlation of some characters were found to be positive and in some negative (Kobari and Fujimoto, 1966). For example, pupation and productive traits which are of high economic value are negatively correlated with each other. Studies have found negative correlation of the floss ratio and lousiness ratio with cocoon shell weight, shell percentage and filament length and positive correlation of the shell weight and shell percentage with filament length and denier. All characters that contribute to the silk yield are quantitative in nature and are controlled by polygenes. Hence, any attempt to improve these characters need an understanding of their inheritance, their response to selection, the relationship of the selected traits with the unselected traits. In silkworm, studies carried out for selection of various traits have shown that, the desirable characters could be changed to breeders choice (Kalpana, et.al., 2003). The selection for single trait has correlation with the genetic change with other traits. Bivoltine pure lines which have been bred for high cocoon yield and high cocoon shell percentage are comparatively low in egg production. Since the correlation
between cocoon shell percentage and egg productivity is negative (Gamo 1976). Similarly, the correlation for some quantitative characters is negative and some is positive (Tsuschiya and Kurashima, 1956 and 1959; Suzuki and Ichimaru, 1961; Kurasawa, 1968 a, 1968 b; Ohi, et al., 1970). It was reported that the F1 hybrids were less variable than parental lines, three way cross and double hybrids in respect to single cocoon weight and cocoon shell weight with in male and female population (Watanabe, 1961 and Dilip Singh 1985). Hence, during the course of maintenance of silkworm breeds, the breeder has to be aware of response of the character for selection of its correlated changes with other economic traits.

Silkworm has been the object of improvement for various quantitative traits that determine the silk quality and silk yield by various workers (Yokoyama, 1957; Hirobe, 1968; Osawa and Harada, 1944, Harada, 1961; Takasaki, 1968; Gamo,1976; Hirobe, 1985). As a result, the characters like cocoon weight (Kobayashi, 1962; Kurasawa,1968 b), cocoon shell weight (Tsuiyiya and Kurashima, 1959; Gamo and Hiraayashi, 1983 and Kobayashi, 1962) and filament length (Miyahara, 1978; Ohi, 1977 and Jayakumar, 1985) has been shown to respond to selection. The correlated changes in the unselected characters when selection is exercised for a particular trait has also been worked out (Ohi et al., 1970; Gamo and Ichiba, 1971; Kurasawa, 1968 a and Nagaraju, 1990). It has been found that for some characters correlation is positive and for some it is negative thus, revealing an important aspect of artificial selection in silkworm breed improvement (Ohi, et al., 1970). However, the rate of progress due to selection of different traits in the population derived from different crossing types has been worked out. Besides, none of the experiments carried out so far to date show the comparative improvement for the selected trait by using different selection methods.
Considering the fact, that the cocoon weight registered an improvement over generations of selection, it is expected that the egg number is also correlated traits (Ohi, et al., 1970). The results of the present study show that the characters like cocoon weight, cocoon shell weight and cocoon shell percentage could be changed by artificial selection with manifold changes in the unselected traits (Chigari, 1991).

Planned development of sericulture lies in the maintenance and multiplication of the authorized silkworm breeds for commercial utilization (Basavaraja, et al., 2002). As a result, several sericultural countries have developed scientific methods to maintain the purity and vigour of the pure races at different levels of maintenance and multiplication (Narasimhanna, 1988).

It is evident that once the silkworm hybrids are authorized for commercial exploitation, the parental breeds are to be properly maintained in the same genetic configuration by up-keeping the original breed characteristics. This will facilitate to maintain the quantitative traits of the breeds and realize the high magnitude of hybrid vigour when F1 hybrids are prepared for commercial exploitation (Basavaraja, et al., 2001). On the other hand, improper maintenance and multiplication will lead to the decline/deterioration of the designated characteristics of the breeds. In the light of the above, the breeds are to be maintained systematically to minimize the loss or change in the original characteristics. The main traits considered for selection to the next generation are pupation rate followed by cocoon characters such as cocoon weight, shell weight, filament length, raw silk percentage, reelability etc. Systematic selection plays a vital role in the process of maintenance at breeders level with its original breed characteristics. At every generation, based on pupation rate and cocoon
uniformity, 50 to 60 cocoons are selected based on cocoon shape, size and compactness of the shell. To avoid continuous inbreeding inter-batch crossing were followed in the replicated batches so that decline in the expression of commercial traits can be avoided (Basavaraja, *et al.*, 2002).

In spite of the availability of all these techniques in the maintenance of original breed characters, application of stringent selection at various multiplication centres resulted in the morphological change in the races followed by genetic drift. It is due to this, most of the bivoltine races behaved differently in different multiplication centres depicting as though each one was a new race. Realizing the drawback, one way system of race maintenance and multiplication was introduced during the 1997 where each multiplication centre has to procure disease free layings from their previous parental multiplication centre. To uphold the efficiency of one way system of silkworm race maintenance, the present study was planned to know the effect of different types of selection on the racial characters so that the outcome of the study helps the silkworm breeders to maintain racial character without any decline or change in the morphological traits.

The study concentrated on the effect of different types of selection on the rearing traits. The selection for cocoon weight did not affect fecundity. However, in CSR2 maximum average fecundity of 564 and 566 (1 ~ 8 and 9 ~ 12 generation) was recorded for directional selection for higher cocoon weight. Similar trend was noticed in CSR4 also, wherein an average fecundity of 530 was noticed when higher cocoon weight was selected at every generation under directional selection. This can be attributed for the selection of higher pupal weight resulting in marginal improvement.
in fecundity. The present work corroborates the work of Sharmila and Kalpana, (2010) who have reported improvement in fecundity when directional selection for pupal weight was applied. From the data it is very much clear that among all the types of selection, directional selection for cocoon weight, shell weight and cocoon shell percentage exhibited slightly higher fecundity than other types of selection.

The total larval duration and fifth age larval duration was unaffected inspite of selection on a particular trait. All the four types of selection expressed almost same total larval duration and fifth age larval duration. The findings clearly indicates that selection for cocoon weight, shell weight and cocoon shell percentage under different selection methods has no impact on the larval period. However, Robertson and Reev, (1950) in their studies ascribed the reduction in larval period to the genetic endowment.

The average cocoon yield/ 10,000 larvae by number in both CSR2 and CSR4 was observed to be above 9000 in all the types of selection except in CSR2 subjected to cyclical selection for shell weight, in CSR4 subjected to directional selection for cocoon weight (9 ~ 12 generation) However, CSR4 exposed to cyclical selection for cocoon weight, shell weight and cocoon shell percentage (9 ~ 12 generation) where slightly lower yield / 10,000 larvae by number was noticed. However, the yield by number recorded for different types of selection was observed to be above the set norms of 8500. The present findings parallels the racial norms set by Basavaraja, et.al., (2002).
The yield/weight is recorded to be above 16 kg. in all the types of selection applied in the breed CSR2 except in cyclical selection for cocoon weight (9 ~ 12 generations) where 15.87 kg / 10,000 larvae has been recorded. While in CSR4, the yield/weight was found to be above 15 kg except in the cyclical selection applied for shell weight (1 ~ 12 generation). The slight marginal decline in the yield/weight in CSR2 and CSR4 subjected to cyclical selection can be attributed for the selection of lower cocoon weight in the alternate cycles has resulted in the decline in cocoon weight in turn affecting the yield/weight as it depends on the yield/number and cocoon weight. Improvement of this trait will certainly contribute to the fitness (Robertson, 1956 and 1966).

The continuous selection for cocoon weight, shell weight and cocoon shell percentage under directional, stabilizing, disruptive and cyclical selections revealed an average cocoon weight of 1.70 g and above in both CSR2 and CSR4 except in CSR4 subjected to stabilizing selection for cocoon weight, cyclical selection for shell weight and cocoon shell percentage where it was above 1.65 g The slight decline in cocoon weight can be attributed to the selection techniques such as selection for average cocoon weight in stabilizing selection and lower cocoon weight in the alternate cycles of cyclical selection, and parallels the findings of Gamo, (1983).

The application of different selection techniques for cocoon weight, shell weight and cocoon shell percentage in CSR2 and CSR4 has not much affected the average shell weight and cocoon shell percentage. The average shell weight of > 40 cg in CSR2 and above 38 cg in CSR4 has been recorded when 1 to 12 generation was considered. Similarly, the average cocoon shell percentage of 22.5 and above in CSR2
and 21.5% and above in CSR4 clearly indicates that there is no deviation from the set norms. The findings clearly shows that shell weight and cocoon shell percentage are genetically controlled and cannot be changed in a homozygous population. However, the slight variability in the traits can be attributed for the seasonal effect such as poor leaf quality (Yokoyama, 1962 and Morohoshi, 1969).

The significant (P < 0.01) variations between generation, breed, generation x breed, selection methods, generation x selection, breed x selection methods and generation x breed x selection method interaction for various rearing traits clearly indicates that the two breeds selected for the study are genetically apart and generation wise variability is mainly due to the environmental effect and because of this generation x breed interaction is highly significant for most of the traits. The four types of selection chosen are entirely different and selection pressure applied for the traits cocoon weight, shell weight and cocoon shell percentage varied and due to this significant difference between selection, generation x selection, breed x selection methods and generation x breed x selection method interaction was noticed. (Watanabe, 1918, 1919; Fukuda, 1960; Fukuda, et al., 1963; Morohoshi, 1969; Sengupta, 1969, 1988; Ueda et al., 1969; Subramanya, 1985; Rajanna 1989; Raju, 1990 and Maribashetty, 1991).

However, utmost care was taken during the study to keep lesser range of difference in selection differential between the selected population and the overall population followed by lesser selection intensity resulted in no difference in the expected and observed selection response. However, the variability in the realized heritability for different selection methods for the target traits cocoon weight, shell
weight and cocoon shell percentage in CSR2 and CSR4 can be attributed for the wide range of variation in the target traits of the previous generation. The variability between generation is mainly because of the fluctuating climatic conditions and not because of the selection pressure and parallels the findings of Jaroonchi, (1972).

The directional selection showed marginal improvement in cocoon weight and shell weight with in a few generations and the improvement was not continuous. However, there was no change in the racial characters since the intensity of selection applied was very meager resulting in lesser selection differential, selection response and heritability. The present findings are contrast to the work of Kalpana et al., (1999) who have reported improvement in filament length after few generation.

Stabilizing selection method has shown good response for the traits cocoon yield/number. Though directional selection method has shown improvement in cocoon weight and shell weight, the character yield/ 10,000 larvae by number in both the breeds has shown slight decline. However it is above the set norms. Marginal reduction in majority of characters was noticed in CSR2 and CSR4 when disruptive and cyclic selection methods were applied. However, the selection of cocoons at random (control) has obtained the results on par with the results of stabilizing selection.

A close scrutiny of the data pertaining to cocoon weight was found to exhibit variation during successive generations of selection. The cocoon weight which has been shown to be moderately heritable (Tsuchiya and Kurashima, 1959; Gamo and Hirabayashi, 1983) was observed to show a positive response to selection and this
corroborates with the findings of Tsuchiya and Kurashima, (1956) and Kurusawa (1968). The directional selection for cocoon weight was found to be sufficient for the concomitant increase for shell weight as suggested by Kurusawa, (1968). The results of the study are in agreement with the findings of Ohi, et al., (1970) and Rajanna and Sreerama Reddy, (1990) who have worked on multiple correlation between the yield components in bivoltine races and established that cocoon weight is correlated positively with shell weight. Moreover, the polygenic nature of the traits in question and the role of artificial selection in changing the mean expression have been convincingly demonstrated in the present study and parallels the work carried out by several workers (Robertson, 1956, Falconer, 1981). The maximum heritability has been recorded for shell weight and shell percentage and confirms the earlier work of Murthy (2007).

The present investigation appears to be the first report on the evaluation of different selection methods on various parameters of bivoltine silkworm breeds in the progeny of subsequent generations. Considering the above facts, the information generated in the study seems to be useful in maintenance of breed characters at breeders level and P4 centres.

The hybrids prepared by utilizing the breeds subjected to different selection techniques has not shown any variability for both rearing and post cocoon parameters as studied at 9th and 12th generation over the control breed. It is very much clear from the study that the genotype of the homozygous population can not be altered through various selection techniques. The measure of hybrid vigour itself is one of the yardsticks to show that the impact of selection on pure breeds has not modified the

From the study, it is evident that application of directional selection for a particular trait has shown improvement in some generation which clearly indicates that improvement is due to favourable season and not due to selection pressure. As the breeds are stabilized, application of directional selection has not shown increasing trend in the targeted trait from generation 1 to 12.

Application of stabilizing selection over generation has also shown marginal variability between generation for the traits cocoon weight, shell weight and cocoon shell percentage. However, the expression of maximum and minimum cocoon weight, shell weight and cocoon shell percentage in some generation is mainly due to environmental effect and not due to selection. In addition, the significant variation between generation can be attributed for seasonal effect.

Pooling of both extreme values (High and low value for cocoon weight, shell weight and cocoon shell percentage) during the application of disruptive selection at every generation in CSR2 and CSR4 has also showed significant difference between generations. As both are stabilized breeds, their response to extreme selection has been nullified by the rearing management and season resulting in no deviation in the expression of original breed characters. Again, the significant variability in cocoon weight, shell weight and cocoon shell percentage is mainly due to seasonal effect.
Selection for high and low values in the alternative cycles (Cyclical) resulted in the significant difference in cocoon weight, shell weight and cocoon shell percentage. This can be attributed for the vigour that is created due to selection of extreme values in the alternate cycles. The significant variation in cocoon weight, shell weight and cocoon shell percentage between generations is also due to seasonal effect and extreme selection pressure.

The significant difference in the cocoon weight, shell weight and cocoon shell percentage between generation in the control is mainly due to seasonal interaction and also due to the inter batch crossing pattern adopted at breeders level.

In spite of application of different methods of selection on cocoon weight, shell weight and cocoon shell percentage in CSR2 and CSR4, the rearing traits are not much affected except for yield/10,000 larvae by weight. The significant difference in yield/weight can be attributed for higher pupation rate in the selected population.

The yardstick to measure the purity of the breed depends on the hybrid vigour and estimation of heterosis and over dominance in the hybrids of different selection methods along with the control at ninth and twelfth generation revealed significant vigour for yield/10,000 larvae by weight, cocoon weight and filament length in all the hybrids indicating that significant vigour is due to higher cocoon weight and pupation rate in the hybrids. The significant heterosis for raw silk percentage in all the hybrids except in the hybrids of cyclical selection can be attributed for the selection of extreme values in the alternate cycles which has resulted in the vigour in the parents and much improvement for the trait is not noticed in the hybrids prepared from cyclical selection applied breeds.
To sum up, application of different methods of selection on an evolved and
stabilized breed at breeders level does not arise. However in a long run, due to
continuous multiplication of the basic stocks to meet the demand of the industry, the
chances of decline in the economic traits may occur. In such situation, the breeders
and maintenance level can utilize the outcome of the present study to maintain the
original characters of a race for many generations.

At any stage of silkworm race maintenance, if cocoon weight or shell weight
debutes without showing improvement in the favourable season also, in such
situation application of directional selection for 4 ~ 5 cycles helps to rejuvenate the
expression of the trait. When once the cocoon weight, shell weight and cocoon shell
percentage reaches the set norm of a breed, then application of directional selection
can be discontinued.

If the racial characters are maintained at a constant level, adoption of inter
batch crossing in the alternate generation and application of stabilizing selection helps
to maintain the breed characters for many generations.

In a population, if there is decline in the economic characters in a particular
cycle, in such situation in order to regain the trait conforming to the racial character,
pooling of high and low cocoon weight, shell weight and cocoon shell percentage
helps to enhance vigour in the next generation and thus the sudden decline in a trait
can be improved and in subsequent generations, stabilizing selection can be adopted.
Whenever maximum expression of quantitative traits are noticed (due to favourable rearing season), in such situation, in order to minimize further increase in the expression of the trait, selection of population nearer to the average or lower cocoon weight, shell weight and cocoon shell percentage during the favourable season and selection for higher cocoon weight, shell weight and cocoon shell percentage during the unfavourable season helps to maintain the racial characters.

The study gives a clear choice to the breeder and basic stock maintenance level to choose the type of selection methodology for maintainence the racial characters.