

## **DISCUSSION**

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The present investigation was designed to study the genetic architecture of existing genetic stocks of Silkworms Bombyx mori L., with respect to components of genetic variation, proportions of the components, combining ability, heterosis and genetic parameters like heritability, correlation and path coefficient analysis for important economic characters of YIELD and YIELD contributing traits using diallel and line x tester analysis.

The present investigation include 5 parent full diallel population and 25 F1 population of line x tester analysis which was presented under the following heads:

Per'se performance,  
 Graphic analysis,  
 component analysis,  
 combining ability,  
 Heterosis, and  
 Genetic parameters.

Per'se performance:

Hybrid performances were found to be highly season specific (MATER - 1). Thus among bi x bi hybrids KS(O) x NB18, NB18 x P5, SF19 x P5, NB18 x SF19, performed very well in Autumn (OCT. - NOV.), while JD6 x NB18, NB18 x KS(O), NB18 x P5, SF19 x KS(O), were found to be superior in performance during Spring (JAN. - FEB.).

However, NB18 x KS(O) and NB18 x P5 performed very well in both the seasons.

AUG. - SEPT. period was considered to be the worst commercial season owing to the prevalence of high temperature coupled with high to very high humidity. Such conditions had always remained the main bottle neck for bivoltine rearing. Therefore, multi x multivoltine crosses were preferred. per'se performance of multi x multi hybrids revealed that CB5 x RAJ, CB5 x G, CB5 x B, B x N, RAJ x G, and RAJ x N, performed better. Similarly for dry summer (MAY - JUNE) multi x bivoltine combinations like CB5 x SF19, CB5 x NB18, N x NB18, G x P5 were better performers.

### Graphical analysis in diallel populations

The present investigation was designed to study the genetic architecture of bivoltine and multivoltine silkworm strains of B. mori L., with respect to graphic analysis of diallel populations on important economic traits such as FEC, LP, LW, PUP, YIELD, SCW, SSW, SR% & FL during OCT.- NOV and JAN.- FEB., in bivoltines and during AUG.- SEPT. in multivoltines. Such analysis was, however, dependent upon a number of assumptions regarding the genetic system being satisfied. One of the assumptions basic to diallel analysis as proposed by Jinks and Hayman (1953), was homozygosity of parents. Dickinson and Jinks (1956) had, however, subsequently examined the effect of removing this restriction. They concluded that although the heterozygosity of parents might bring about departures from homozygous analysis yet most of the genetical analysis could be estimated but with less precision. Kempthorne (1956) too had indicated that it was not essential that the parents should be homozygous but would be sufficient for such studies if they had the same coefficient of inbreeding. Other assumptions basic to diallel analysis were normal diploid status of the organism, the uncorrelated genes distribution, absence of multiple allelism, absence of reciprocal effect and absence of epistasis.

The inbreds used in the present study, were not random sample but were selected on the basis of their genetic divergence (Subbarao, 1991 & Sen, 1992), per'se performance and on desirable traits. As regards the homozygosity of the parents, in the present study, the lines were considerably uniform genetically as they were being maintained through inbreeding and were thus phenotypically homozygous. There was no evidence for lack of multiple allelism but Kempthorne (1956) pointed out that its presence would not markedly alter the validity of the conclusion.

Hayman (1954, a) further, stated that estimates of population parameters for a traits were feasible even when the trait exhibited partial failure of the assumptions. Several workers (Kearsey and Jinks, 1968; Daly & Robson, 1969) pointed out that in studies on quantitative inheritance complete validity of the assumptions were unlikely. When assumptions with regard to parent failed, Hayman (1954, a) suggested that interacting array points lying well off the line of unit slop of  $V_r.W_r$  graph, might be removed from the diallel table until the remaining crosses satisfy the test. The procedure was disputed by Kempthorne (1956) and others on the ground that this would result in loss of randomness of the samples.

Removal of any array was undesirable when the interest of the breeder was confined to a particular set of parents selected for their desirable traits. The analysis might, therefore, be carried out even though the hypothesis were partially fulfilled.

The results obtained in such situation were, however, confined to the material studied under a particular environment (Hayman 1958, a ; Verhalen and Murray 1969) and might not be generalised. Since the present study was conducted utilising bivoltine strains during OCT.- NOV. and JAN.- FEB. seasons and multivoltine strains during AUG.- SEPT. considerable variations in the gene interaction were experienced because of variation in genotypes and the environmental conditions. Environmental effects on gene actions had been reported by Allard (1956) in diallel crosses where he had seen the dominant effect of genes got modified depending upon the presence or absence of epistasis due to environmental changes. Similar observations were reported in E. mori L., by Sengupta et al., (1974).

The comparative performance of graphical analysis during OCT.- NOV. and JAN.- FEB. for bivoltine strains and during AUG.- SEPT. for multivoltine strains revealed that " $t^2$ " was non-significant for all the traits in all the three seasons except FEC during AUG.- SEPT. A review of the graphic analysis ( $V_r$ ,  $W_r$ ) indicated that the points of intersection of the  $W_r$  axis by the regression line was below the origin for LW, SCW, SSW, SR% & FL during AUG.- SEPT.; and PUP, SSW, during OCT.- NOV. as well as YIELD in JAN - FEB. revealed over dominance type of gene action for those traits.

Complete dominance was revealed for YIELD during AUG. -SEPT. as the regression line intercepted the  $W_r$  axis at the place where  $W_r$  axis met  $V_r$  axis i.e. at "0".

The "b" value in the graphic analysis of genetic situation deviated considerably from unity for PUP, SCW, SSW, SR%, ( $P \leq 0.05$ ) during AUG - SEPT.; for FEC, PUP, & FL ( $P \leq 0.01$ ) during OCT. - NOV. and for PUP, SCW, SSW ( $P \leq 0.01$ ) and SR % & FL ( $P \leq 0.01$ ) during JAN.- FEB. showing presence of epistatic interaction in the genetic control of the character. On the other hand, the "b" value did not deviate significantly from unit slope for LW, ( $P \leq 0.05$ ) in AUG.- SEPT. for LP & SCW ( $P \leq 0.01$ ) & SSW ( $P \leq 0.05$ ) during OCT.- NOV. and LW, YIELD, SCW, SSW ( $P \leq 0.01$ ) during JAN.- FEB. revealing absence of non-allelic interaction.

The standardised deviation graph for YIELD in P5 during JAN.- FEB. showed high concentration of dominant genes whereas same breed for same traits during OCT.- NOV. showed high concentration of recessive genes. Similarly in P5 for SR% and FL also low concentration of dominant genes were recorded during JAN.- FEB. but low concentration of recessive genes were seen during OCT.- NOV. Similar variations were observed in NB18 for FEC, LP, PUP, YIELD; JD6 for FEC, LP, YIELD, SR% & FL ; SF19 for FEC., LP, YIELD, SSW, SR% and also in KS(0) for FEC, LW, PUP, SCW. Krishnaswami et al., (1964) in B. mori L., reported over dominance for egg viability, ERR, and shell wt; complete dominance for cocoon wt., partial dominance for SR%. Satenahalli, et al., (1989) registered partial dominance for larval duration, pupal duration and moth emergence and over-dominance for fecundity.

Mukherjee et al., (1994) noticed partial dominance for cocoon yield per 100 laying shell wt. and SR% & over dominance for SCW.

The  $Y_r / W_r + V_r$  graph (standardized deviation graph) further revealed that during OCT.- NOV. high concentration of dominant genes were carried by P5 for LP, LW, PUP, SCW, SSW, SR%, FL; by NB18 for LW, SCW SSW, SR% & FL; by JD6 for PUP & FL & by KS(O) for FEC & FL. During JAN. - FEB. all the traits were having high concentration of dominant genes except FEC, & SR% in P5, NB18 was possessing high concentration of dominant genes for LW, YIELD, SCW, SSW, SR% & FL. JD6 for PUP, SF19, SR% & KS(O) for FL. Among multivoltines CB5 was carrying high concentration of dominant genes for LW, YIELD, SCW, SSW, SR%, & FL; G for FEC, LP, LW, YIELD SCW, SSW, & FL; Raj for LW, PUP, YIELD, SR%; Nistari for FEC and PUP and B for FEC & LP (TABLE : D2).

Hence, among bivoltine strains P5, NB18 & SF19 and in multivoltine, CB5, G & Raj should be given emphasis for hybridization programme.

### Estimates of genetic components

Comparison of the estimates of genetic components revealed that nonsignificant F in all the 3 seasons indicated the presence of ambidirectional dominance and recessive alleles with increasing and decreasing effects appeared to be dominant and recessive to the same extent.

The additive effect for a particular trait (say FEC) became more in a particular season (OCT.- NOV.) whereas the same breeds when utilized in other season (JAN.- FEB.) for the same trait dominant components became more pronounced. Similarly, the ratios such as degree of dominance, distribution of dominant and recessive alleles, no. of gene groups etc., were also found to exhibit different results in different seasons. The silkworm traits such as FEC, (JAN.- FEB.) PUP (OCT.- NOV.), YIELD (in JAN.-FEB. & AUG.- SEPT.) SCW (AUG.- SEPT.) SSW (OCT.- NOV. and AUG.-SEPT.), SR% ( in all 3 seasons) were controlled by over dominance. The over dominance thus revealed might be to a certain extent, be just an apparent case of inflated upwards. Hayman(1954 a) postulated that particular combination of positive and negative genes or complementary type of gene actions of simple correlation between the genes might drastically change the degree of dominance. A partial dominance was converted to an apparent over dominance.

It could thus, be stated that the occurrence of any genotype x environmental interaction might lead to deviation of the values and this affected the estimates of level of dominance etc. Another reason stated by Mather and Jinks (1971) was unless  $u = v = 0.5$  at each locus i.e. symmetry between dominant and recessive alleles, the ratio  $-(H_1/D)^{\dagger}$  would not be a true measure of degree of dominance. Further, Hayman (1954, b) proposed the method of estimating whether  $u = v = 0.5$  or not. In case,  $u = v = 0.5$ , then the ratio  $H_2/4H_1$  would be equal to 0.25. In the present study, this ratio for most of the traits (FEC during OCT.-NOV; HAT%, LP during all the 3 seasons; LW during AUG. - SEPT., PUP during JAN - FEB. and AUG.- SEPT. & SCW & SSW during JAN.- FEB. & AUG. - SEPT; SR% in JAN.- FEB. & OCT.- NOV. and FL in JAN.- FEB. & OCT.- NOV.) were not equal to 0.25 indicating asymmetrical distribution of dominant and recessive genes in the population. One of the reasons for this asymmetrical distribution might be over estimation of degree of dominance in the component analysis.

The major function of heritability estimates was to provide information on the transmission of characters from the parent to progeny.

Such estimates facilitated evaluation of heritability and environmental effects in phenotypic variation, and thus help in selection. Heritability in broad sense was found to be more than

the narrow sense estimates as usual. In all the 3 seasons higher heritability (in narrow sense) were observed in LW, SCW & SSW. Comparatively low heritability was noticed in PUP & HAT% which was influenced by environmental variation. These findings were quite in agreement with the findings of Petkov (1984,a), Nassrillaev and Abbasov (1980), Narasimharaju et al., (1990), Tribhuvan Singh et al., (1994) in B. mori L.

Since YIELD is a complex character and highly influenced by environment in silkworm, moderate to low heritability (both in narrow and broad sense) were observed.

Mather and Jinks (1971) proposed that complementary gene action might suppress the ratio  $h^2/H_2$  which was a measure of number of gene groups that exhibited dominance. Hence, the number of gene groups that were recorded by the present author in the present investigation might not be the actual number. Low estimates, for number of gene groups governing the characters were recorded in the present observation.

Similar conclusions were also reached by Verma (1974) in Pearl millet, Singh & Sharma (1976) in spring wheat & Das and Kumar (1974) in protein content of pea; Siddiqui et al., (1988, a), Sengupta (1991) in A. mylitta D., a tasar silkworm. Nagaraja and Govindan (1994) in eri silkworm; Sarkar, et al., (1991) and Mukherjee et al., (1994) in B. mori L.

The present study of additive gene action for FEC (OCT.-

NOV.) LP, LW, SCW, etc. corroborated with the finding of Jolly et al., (1965) in mulberry silkworm. Satenahalli et al., (1990) studied gene action for pupal wt., pupal duration, moth emergence, fecundity, hatching filament length etc. and advocated reciprocal recurrent selection. It was also inferred by them that these traits were governed by both additive and dominant genetic components.

The present author felt that the difference in revealing relative proportions of additive and non-additive gene effects among different silkworm traits during different seasons might be explained as genotypic x environment interaction, genetic diversity among parents that were chosen for the experiment and also the sampling procedures as well as inbreeding coefficient of the parents.

Preponderance of non-additive gene action for YIELD, as in the present case, was also reported by several workers in various crop plant and animals. Singh et al., (1976), Siddiqui et al., (1988, a), Sengupta (1991) in tasar silkworm. Sengupta et al., (1971, 1974), Jolly, (1983), Pershed et al., (1986) Mukherjee et al., (1994) in B. mori L.

It could be said that both the additive as well as non additive gene action were equally important. The traditional system of developing hybrid varieties was to exploit the non-additive components only. Consequently, it would be desirable to use a breeding procedure that could exploit additive component,

in addition to the utilisation of the non-additive gene effect.

Thus, a type of population breeding approach which would maintain a high level of heterozygosity, would be the most desirable. Therefore, recurrent selection would be the most appropriate scheme since it maintained high level heterozygous condition due to inter-crossing of selects which could consequently provide an opportunity for new recombinants that would lead to breaking of undesirable linkage blocks despite the accumulation of favourable additive genes.

## COMBINING ABILITY

## I. Combining ability in Diallel population

The choice of the parents for hybridization was one of the critical and most difficult task for a breeder. It was a common experience that certain combinations "nick" to produce many superior offsprings while other equally promising parents produced disappointing results (Allard 1960). The ability of the parents to combine well would therefore depend on complex interactions among the genes which might not be adjudged by mere per' se performance and adaptation of the parents. Griffing (1956,b) had described methods of evaluating combining ability of parents and their crosses of diallel progenies which implicated the average performance of a breed or a strain in a series of crosses (gca) and the deviation from the performance predicted on the basis of gca referred to as sca (Allard, op cit.).

In the present study the significant mean sum of squares due to gca and sca for various characters during OCT. - NOV. and JAN.-FEB in respect of bivoltines and AUG. - SEPT. for multivoltines indicated that both additive and non-additive type of gene actions were playing important roles in the inheritance of those traits. However, higher magnitude of sca variances compared to gca for all the traits except FL during OCT.- NOV., HAT%, SCW and SSW during JAN.- FEB. & LW during AUG. - SEPT. suggested predominant role of non-additive variance.

similar type of observations were recorded for broiler traits in chicken by Pati et al. (1975), Aggarwal et al., (1979) and for egg production traits in chicken by Roy et al., (1980) and Reddy and Mohapatra (1975), while in A. mylitta D. by Siddiqui et al., (1988, b).

Similar observations for various traits in B. mori L. were also reported by Per shad et al., (1986), Datta & Pershad (1988), Tayade (1989).

The gca effects were more than the sca effect for FL, (OCT.-NOV.), HAT%, SCW, SSW & FL, during JAN.- FEB. and LW during AUG.-SEPT. revealed the influence of higher magnitude of additive gene action for these traits. The same contention had also been confirmed by Tomer et al., (1992) while working in Asiatic cotton and also by Kumar et al., (1994) in protein & methionine contents of lenticeles.

Reciprocal effect was found to be nil in bivoltines for all the traits in both the seasons; while significant effect could be registered in YIELD, SR.%, FL, SSW in multivoltine crosses during AUG. - SEPT.

On the basis of the above results the present author opines that the reciprocal effect was mainly due to maternal influence ascribable to cytoplasmic sources. Tayade (op cit.), Datta (op cit.) and Pershad (op cit.), corroborate the same view for various other quantitative traits in B. mori L.

The author was also of the opinion that the occurrence of reciprocal difference in multivoltine breeds indicated that the parents selected for diallel crosses were not isogenic rather were derived from different pedigree.

So far gca effects were concerned during OCT.- NOV., NB18 was found to be the best general combiner for LW (1.41), SCW (0.064), SSW (0.020), SR% (0.516) and FL (29.34). This was followed by P5 for PUP (34.66) and KS(O) for high FEC (9.49) and shorter LP (-0.140).

During JAN.- FEB. also the breed NB18 was recorded to be the best general combiner for FEC (6.29), shorter LP (-0.153), LW (1.67), YIELD (610.62), SCW (0.045), SSW (0.015), SR% (0.331) & FL (34.27), JD6 was recorded to be the best general combiner for PUP (73.89).

During AUG.- SEPT. among multivoltines, Nistari was recorded to be the best general combiner for high PUP (252.76) and shorter LP (-0.257); CB5 for HAT% (1.330) and FL (62.45); G for FEC (9.56), LW (0.227), YIELD (253.35), SCW (0.083), SSW (0.012) and B for higher SR% (31.52).

The bivoltine parents viz., NB18, P5, JD6 & KS(O) and multivoltine parents, such as Nistari, CB5, G & B, having higher gca values for above stated traits, should be considered for development of population or for initiating crosses for pedigree breeding.

The specific combining ability effect for different crosses had indicated that no single cross was containing all the attributes in desired direction. Desirable sca effect for any cross combination need not necessarily depend on the level of gca effect of parents. Generally, high x low, high x medium, & medium x low gca combinations exhibited high sca effects. Some times, in some cases, high x high and low x low crosses also showed very high sca effect.

During OCT.- NOV. : High sca effect were observed in -

P5 x JD6 for FEC. (med. x med.) ,  
 KS(O) x NB18 for LP (high x low), PUP (med. x low),  
 JD6 x NB18 for LW (med. x high),  
 P5 x SF19 for YIELD (med. x med.)  
 NB18 x KS(O) for SCW (high x low), FL (high x med.), and  
 SF19 x NB18 for SSW (low x high).

During JAN.- FEB. : High sca effects were observed in :-

NB18 x KS(O) for FEC (high x low),  
 SF19 x NB18 for LP (Med. x high),  
 SF19 x P5 for LW (Low x med.),  
 P5 x KS(O) for PUP (med. x low ),  
 SF19 x KS(O) for YIELD (low x low)and  
 JD6 x KS(O) for SCW (low x low).

It is interesting to note that seasonal variations in the gca effects of breeds were manifested into difference in sca effects, thus conforming that the "Gene expression could be altered with the change in the environment" Safuji, (1983).

In multi x multi during AUG.- SEPT. high sca effects were obtained in -

Raj x CB5 for FEC (low x med.,)

Raj x G for LP (med. x low),

Raj x N for LW (med.x low), SCW (low x low),

B x Raj for PUP (low x med.) YIELD (low x med.),

G x Raj for SSW (high x low) and

CB5 x Raj for SR% (med. x low).

Further, crosses showed low sca against high significant gca such as, in KS(O) x P5 for FEC, KS(O) x JD6 for LP, P5 x KS(O) for PUP, KS(O) x P5 for YIELD during OCT.- NOV; NB18 x P5 for LW, JD6 x NB18 for PUP, NB18 x P5 for SCW & SSW, NB18 x KS(O) for FL, during JAN - FEB.; G x CB5 for FEC, G x Raj for LW, N x Raj for PUP, G x CB5 for YIELD, SCW & SSW, B x CB5 for SR% & CB5 x G for FL, suggested more additive gene action.

Thus, it was seen that the crosses with high " specific combining ability effects" for different parameters in all the three seasons involving the combination of parents with low x low gca & accounted for complementary gene action; high gca x low

gca indicated dominant type of inter-actions and high x high as additive x additive type of gene action.

Components of variance contributable to larger sca in magnitude than for gca indicated non-additive gene action which could facilitate heterosis breeding programme for that particular trait (Tomar & Singh, 1992 ; Kumar et al., 1994).

Based on the combining ability study of diallel populations it could be inferred that the parents NB18, KS(O), P5 & SF19 and among bivoltine crosses KS(O) x NB18 & its reciprocal, P5 x SF19 & SF19 x NB18 for OCT. - NOV., NB18 x KS(O), P5 x KS(O), SF19 x KS(O) and JD6 x KS(O) for JAN. - FEB should get due consideration for the exploitation of bi x bivoltine hybrids for Autumn & Spring , while Raj, B, G, and its hybrids, B x Raj and Raj x N, CB5 x Raj should be exploited as multivoltine hybrids during AUG. - SEPT. seasons (Table: D1).

### Combining ability in line x tester population

The gca values of line x tester analysis revealed that no single parent had high gca values for all the traits as had been assumed in the studies of Datta and Pershed (1988) and Subbarao & Sahai (1989). In the parents G, the gca : sca variance for FEC, LP & PUP in Raj for LW, Nistari for SCW, SSW & SR% CB5 for FL were more than unity ( $>1$ ) and hence these traits were governed predominantly by additive components of heritable variance. The gca : sca ratio was observed to be less than unity ( $<1$ ) in the rest of the breeds including bivoltines, hence, such traits were governed by non-additive components (Tomar & Singh, 1992).

High sca values were observed in :-

Raj x KS(0) for FEC (low x low),

G x P5 for HAT% (low x low), for LW (med. x med.),

N x NB18 for LP (low x low),

CB5 x JD6 for PUP (high x low),

Raj x P5 for YIELD (low x high),

Raj x NB18 for SCW (high x low), SSW (high x low),

CB5 x KS(0) for SR% (med. x low) and

Raj x JD6 for FL (med. x low).

Parents having moderate or low gca (e.g. G and P5 for LW) producing high sca suggested epistatic gene action.

Cross such as CB5 x JD6 involving at least one high general combiner (CB5) exhibited high sca effect for PUP indicated the involvement of additive x dominant type of interaction.

Similarly, Raj x P5 containing (P5 high gca) high sca effect for YIELD also depicted dominant type of interaction. The high gca of Raj and P5 brought down small sca for SCW in Raj x P5 suggested more additive gene action. Raj & JD6 were also possessing high gca effect producing small sca for SSW indicated more additive gene action. Low general combiners such as CB5 and KS(O) for SR% produced high sca effect were suggesting inter allelic inter action in the form of complementary gene expression which might be due to genetic diversity in the form of heterozygous loci. Low gca effects for FL in Raj and JD6 produced high sca effects suggested complementary type of gene action.

Further, the crossing of different geographic races was directly associated with transgressive breeding. By means of crossing and genetic recombination, it was possible to combine desirable polymeric genes within an individual, there by ensuring that the characters of interest would become more manifested than in either parents or, in otherwords, achieved positive transgression. The probability of transgression increases if the crossing involved varieties such as Indian origin tropical multivoltines like - Nistari, CB5, Raj, G and B and exotic bivoltines viz. P5, NB18, JD6, SF19 and KS(O) which were widely different genetically, geographically or in terms of productivity (Guzhov, 1989).

Thus, the combining ability of multi x bivoitine hybrids in line x tester design depicted that the crosses having high sca effect such as Raj x KS(O) for FEC, G x P5 for LW, CB5 x JD6 for PUP, Raj x P5 for YIELD, Raj x NB18 for SCW & SSW and Raj x JD6 for FL should be considered as good combinations for developing commecial hybrids. (Table: D1). Parents containing high gca effects such as G for FEC, CB5 for PUP, Raj for LW, SCW, SSW among lines and P5 for YIELD, NB18 for LW, PUP, & FL, SF19 for SR% and JD6 for shorter LP might be considered for the development of populations for initiating crosses for pedigree breeding because the ability was atleast partly fixable (Bandyopadhyay, 1990).

## HETEROSIS

The exploitation of hybrid vigour in maize (East and Hayes, 1912) brought about the revolution in the production in U.S.A. and other countries. The principle was applied in boosting up the yield and useful YIELD contributing traits in various crop plants. This approach was very much remunerative in boosting the egg production of leg horns (Ayyagari et al., 1979; Batra et al., 1973), in the production of milk of brown swiss x shiwal Acharya and Bhat 1983). Cross breeding was extensively used in silkworm improvement as a means of exploiting heterosis (Nagraju et al., 1996).

The present study indicated that the degree of heterosis, during JAN - FEB. and OCT.- NOV, which were the favourable seasons of silkworm rearings, was comparatively lesser than that of degree in AUG.- SEPT. and MAY - JUNE. This was because of the fact that during favourable season the full gene expression of the parents as well as the hybrids facilitated the traits to attain almost same level.

On the contrary, the case became just reverse during the unfavourable seasons like AUG. - SEPT. and MAY - JUNE when the hybrid values remained much higher as compared to the performance of parents.

This phenomenon of higher level of heterosis in adverse seasons as explained by Cunningham (1984) was because of heterozygous superiority.

The same observations had also been reported in B. mori L., by Nagaraju et al., (1996). Another reason for achieving more heterosis in multi x bivoltine hybrids during MAY - JUNE was that the parents were chosen from distant geographical regions of the world which was a key point in sericulture industry.

In fact, the genetical explanation of heterosis were explained by several workers such as (i) Favourable dominance theory which inferred that F1 generation was likely to contain higher proportion of favourable dominant genes than either parents. Undesirable recessive genes were largely masked in the F1 generation. (ii) second theory, discussed at length by Lerner (1954, b) was "Genetic homeostasis" which stated that heterozygosity, Per'se was the explanation.

Lerner considered that evolution had established obligate levels of heterozygosity which had greater ability to remain within the normal paths of development and that natural selection tended to favour intermediate rather than extreme phenotypes. (iii) A third theory said that heterosis resulted from the interaction between genes at the same locus and to this the term over dominance was applied (Bowman 1977). Lastly, it was assumed that there was no single genetic explanation of heterosis.

In the present investigation efforts have been made to combine the best traits such as shorter larval period, high survival of polyvoltine/multivoltine strains and YIELD & YIELD contributing traits of bivoltine strains for evolving high yielding superior silkworm varieties for commercial use.

Moreover, genotype - environmental interaction influencing the level of heterosis had been dealt with by different authors in different animals (Sang 1964; Griffing and Zsiros 1971; Knight 1973; Orozco 1976; Ruban et al., 1988; Santiago et al., 1989, Ehiobu and Goddard, 1989).

In our study number of crosses showed were more for mid parent heterosis rather than better parent heterosis as usual. Moreover, from the analysis it appeared that the superiority of the hybrids were because of the combinations of favourable expression of the attributes present in the parental varieties and hence these could be considered as instances of "combinational - heterosis". (Hagberg, 1952; Ramanujan et al., 1964; Williams and Gilbert 1960).

On the other hand, the negative heterosis was obtained in many crosses for several characters which revealed that the genetic interaction between the gene system of those parental population were not favourable. Similar observations were made by Tayade, (1987); Nacheva (1980); Sengupta et al., (1971, 1974); Yokoyama (1974); Ghosh et al., (1993); Das et al., (1994) in Bombyx moriL. Sengupta et al., in Tasar silkworm (1987).

It was further observed by the author that the FEC during all the four seasons in all most all types of crosses was not positively significant. The reasons for no heterosis for fecundity in the present study could be attributed to the FEC of mother moths which were crossed to produce the F1 progeny. (Ghosh et al., 1996).

Thus, the study of heterosis revealed that the hybrids should not be selected merely on the basis of the degree of heterosis but they should be selected by considering the per se performance of the hybrids also. Table: D1 showed that some season specific hybrids which faired well in respect of Per'se performance as well as in heterosis, could be further exploited on commercial level for different metric traits .

### Genetic variability

Estimates of genetic variability and genetic advance were obtained for important quantitative traits separately for bivoltine and multivoltine genetic stocks to achieve information on the nature of gene action involved for evaluating a selection scheme for the improvement of population or for developing new breeding approaches.

Selection was the most important aspect for formulating a breeding plan in choosing the parents for subsequent generation on which the improvement was based. For practicing an effective selection in the base population the members of the population should possess genetically determined variation that could be utilised for gradual improvement of a particular trait in the population.

It was, therefore, imperative to accumulate the adequate information on the existence of a total variability in a population as to how much of this was caused due to the difference in genetic make up of individuals that could be measured by mean, range and coefficient of variability.

A measure of the comparative performance of bivoltine and multivoltine stocks revealed that high values of phenotypic and genotypic variances were registered for YIELD followed by PUP and low values for SSW & SCW.

In Bivoltines maximum phenotypic variability was experienced for yield, followed by PUP, SSW, FEC, FL, but in case of multivoltines, FL was noticed to contain more phenotypic variability followed by SSW, YIELD, FEC & PUP.

High values of heritability, in bivoltine, were recorded for SSW followed by SCW. But, in multivoltines, SCW registered higher heritability followed by SSW.

The author was of the opinion that main reasons for obtaining different results in different population was due to G x E interaction. As it was obvious that in the plains of West Bengal (specially where this experiment was conducted) bivoltine were hard to survive throughout the year which had resulted in the non-expression of all the genes during un-favourable season. On the contrary, the multivoltines since, are tropical in origin could thrive well even in high temperature that facilitated the expression of the traits favourably even under stressed environment.

The findings obtained in multivoltines were quite agreeable with Safuji et al., (1983) who observed variations in the various yield attributes of the silkworm in different seasons such as, high heritability for silk FL and shell contents in favourable seasons as compared to unfavourable ones. This contention was further confirmed by Sengupta (1991) who wrote in his thesis (personal communication) that differences in observation of traits could be attributed to the differences in materials used, location and seasons.

Therefore, the present author too corroborated the same idea. Since heritability measures the relative contributions of genetic and environmental difference to phenotypic variation, the heritability estimates should have been changed with the above factors (Comstock & Robinson, 1948; Lush, 1949; Robinson *et al.*, 1949, Comstock *et al.*, 1958).

The utility of estimates of heritability was further increased when it was used in conjunction with the selection differential, the amount that the mean of the selected lines exceeded the mean of the entire group and genetic advance was commonly predicted as the product of the heritability ratio and the selection differential.

Simultaneously, the genetic advance from selection when expressed as percent of the mean was the product of (i) selection differential measured in terms of phenotypic standard deviation (ii) genetic coefficient of variation and the square roots of the heritability ratio. Burton (1952) further revealed that  $GCV \times K$  could provide information concerning the maximum effect of selection. It was evident that the traits such as PUP and YIELD in bivoltines and FL in multivoltine showed high genotypic coefficient of variation with low heritability must be attributing for environmental influence on their expressions. SCW, SSW had high heritabilities while these traits revealed comparatively less genetic coefficient of variability.

Fisher's (1930) quantitative genetic model had been variously interpreted, modified and extended over past few decades by many workers. (O'Donald, 1967; Price, 1970; Slatkin 1970; Bulmer, 1971; Cavalli-sforza and Feldman, 1976, 1978; Emlen, 1980; Lande 1982; Cheverud 1984; Roff and Mousseau, 1987; Mousseau and Roff 1987). Two principal components of these models were heritability and genetic covariance matrix.

But for the present discussion we confined ourselves to heritability only, the additive components of polygenic variation, dictated, in large measure, the rate at which genetic change would occur. Early analysis of quantitative genetic variation suggested that the directly associated traits with fitness should have low heritability.

Here, two main points could be reflected (i) whether any pattern was there in the variation of heritability (?) and (ii) the traits directly associated with fitness had relatively low heritability.

Roff and Mousseau (1987) categorized the traits in 4 groups (1) Morphological (2) Behavioural (3) Physiological and (4) Life history traits. They had also stated that all of these traits might fall within the purview of life history theory, but they had coined the term "life history traits" - for FEC, viability, survival and the development rate, which were directly and invariably concerned with fitness.

In the present investigation two classes of characters were chosen keeping in view their applied importance.

The traits like FL, SCW, SSW, SR% and LW were morphological traits while PUP, LP, and FEC, which were related to fitness of the population were life history traits. Traits such as PUP and LP that were closely associated with fitness of life history would possess lower heritability while FEC in the present observation should moderate heritability. The morphological traits such as SCW, SSW, SR% and FL, on the other hand showed moderately higher to highest heritabilities both in multivoltine and bivoltine.

Giesel et al., (1982), in *Drosophila* had noticed high heritability for quantitative traits such as egg production and longevity.

In *A. mylitta*D., Sen et al., (1976) observed 99% heritability for SR%, 87.94% for SCW, 85.89% SSW and 78.2% for FEC. Siddiqui et al., (1985) observed maximum heritability for cocoon wt. followed by shell wt., shell ratio, larval wt. and fecundity. Siddiqui & Sengupta (1994) had further observed high heritability with moderate G.A. for shell wt, followed by filament length among the technological traits.

Similarly, in *Bombyx mori* L. Petkov and Yolov (1979, 1980) and Petkov (1981, a) reported high heritability for FL. Ozdzenska and Kremky (1987) observed high heritability for hatchability, survival rate and cocoon yield. Moderately high heritabilities for cocoon wt, silk richness and shell wt, had also been reported by Nassirillaev and Abbasov (1980).

Narasimharaju *et al.*, (1990) described moderate heritability with high genetic advance for filament length followed by shell weight. Singh *et al.*, (1994) showed maximum heritability in SSW (80.20%) followed by pupal weight (78.5). Sen *et al.*, (1995) had shown high heritability and moderate genetic advance for larval weight, SCW, and high heritability with high genetic advance in multivoltine silkworms.

In the present investigation characters such as, SSW/ (in bivoltine) and SCW, SSW & FL (in multivoltine) showed high heritability with high genetic advance suggesting additive gene effect. On the other hand, traits such as SCW (Bivoltine) and LW, YIELD and SCW (multivoltine) had high heritability with low genetic advance, were the traits governed by non-additive (intra and inter allelic inter action) gene effects.

Hence, progeny testing and recurrent selection might be helpful to improve these traits.

### Correlation studies

Comparative performance of inter-relationship revealed that genotypic correlations were higher than phenotypic correlation except PUP vs YIELD (multivoltine) wherein phenotypic values were greater than genotypic ones because of inter environmental interaction. Selection for improving yield was often based on selection for the component character. Further, the ultimate characters showed high interactions with environment and were thus not amenable to direct selection. But several component characters having higher heritability were generally less subjected to environmental fluctuation and were thus better suited to direct selection for indirect improvement of yield. Hence the information on the association between components and yield and among the component traits had of greater relevance for rational manipulation of the component traits.

In the present investigation the larval span in both multi as well as bivoltine populations established a negative correlation with PUP indicating that longer LP was not desirable for higher survival.

This could be evidenced by the fact that multivoltine strains had shorter larval span with better survivals, while the bivoltines had comparatively longer larval span.

Further, LW had positive and close relation with yield, SCW, SSW, SR% while the PUP had close relation with YIELD at both levels.

These results corroborated the findings made by Dang Din Dan (1982) who also reached at the similar conclusion. Present results further confirmed the findings of Ozdzenska and Kremky (1987) who observed positive significant genotypic correlations between SCW and silk richness in B. mori which expressed that improvement on cocoon would lead to increase in SSW and subsequently FL too.

In tasar silkworm, A. mylittaD., Sen et al., (1976) reported genetic correlation in higher magnitude than phenotypic correlation. Siddiqui et al., (1985, 1989) reported considerable difference between genotypic and phenotypic correlation. Sengupta (1990) revealed greater affinity between LW and SCW, LW and SSW, LW and SR% and LW and FL.

In the present investigation author had observed higher affinity both at phenotypic and genotypic level between LW and SCW, SSW, FL in respect of bivoltine population and in multivoltine, LW had high correlation with YIELD, SCW, SSW. Similar type of conclusions were also made by Giridhar et al., (1995).

It was worth mentioning that the improvement in one character would cause simultaneous change in the other characters. Moreover, if the genetic correlation was positive, then the selection practiced for the improvement of one character would automatically result in the improvement in the other, even though the direct selection for its improvement had not been made.

On the other hand, if it was, negative, then selection for the improvement of one character, if successful, would result in a decline in the other(Jain, 1982).

Thus, the overall observation lead to the conclusion that the major yield components were LW, PUP, SCW, SSW. Moreover, these traits did not have any negative association with each other. Such a situation was beneficial to the breeder in the sense that when selection pressure is applied in respect of a particular trait it would not have any detrimental effect.

Therefore, the genetic gain in each one of these traits would directly bring a positive improvement on silk yield. Close correlation among SCW vs LW, PUP vs LW, SCW vs LW were observed by Shamachary et al., (1980) in B.mori. Hence, it was suggested that high values of significant correlation for LW, YIELD, SCW, SSW, should get proper emphasis during selection.

### Path analysis

Path coefficient analysis is the standard partial regression coefficient which measures the direct and indirect influence of the variable upon another and correlation coefficient could be separated into components of direct and indirect effects (Dewey and Lu 1959). The path analysis was useful in finding direct and indirect causes of association and allowed a detailed examination of specific forces acting to produce a given correlation and measure the relative importance of each factor. The results of the present investigation revealed that PUP in bivoltine and SCW in multivoltine had registered the highest direct and positive effect on YIELD. SCW in multivoltine exhibited a negative phenotypic correlation directly on YIELD. These two traits had also positive indirect effect through LW, in case of bivoltine and HAT%, LP, LW, & SSW in multivoltine. In case of multivoltine, the PUP had substantial positive effect on cocoon YIELD but via LW and HAT% it had negligible positive indirect effect.

In both the cases, i.e. multivoltine & bivoltine population LW had moderately direct positive effect on YIELD. It had an indirect positive effect via PUP in case of bivoltine whereas in multivoltine, it had an indirect positive effect via HAT%, PUP, SCW & SSW.

Thus, from the above finding, it could be said that LW, PUP, SCW, & SSW had the inherent association with cocoon yield and thus merit prime importance in selection programmes for cocoon YIELD - improvement in B. mori. Similar results had also been obtained by Yan (1983), Yang (1987) and Yan (1989) in B. moriL.

Therefore, proper attention should be given to LW, PUP, SCW and SSW in the selection programme for the improvement of cocoon YIELD in silkworms.

Table : D1: BEST CROSS COMBINATIONS IN TERMS OF PER'SE PERFORMANCE,  
SCA EFFECTS & HETEROTIC RESPONSES DURING DIFFERENT  
SEASONS FOR VARIOUS ECONOMIC TRAITS.

ECONOMIC TRAITS	BEST CROSSES		
	PER'SE	SCA	HETEROSIS
OCTOBER. - NOVEMBER.			
FEC	P5xJD6, KS(O)xP5, KS(O)xNB18, JD6xSF19.	P5xJD6, P5x NB18, JD6xP5, JD6xSF19.	P5xJD6, JD6xSF19, JD6xNB18.
HAT%	P5xKS(O), KS(O)xP5, P5xJD6, P5xSF19.	KS(O)xNB18, P5xJD6, KS(O)xP5.	P5xJD6, P5xKS(O).
LP	KS(O)xNB18, SF19xNB18, SF19xJD6, NB18xKS(O).	KS(O)xNB18, NB18xSF19, P5xKS(O).	KS(O)xNB18, SF19xNB18, NB18xJD6.
LW	NB18xP5, NB18xJD6 KS(O)xJD6, JD6xNB18.	JD6xNB18, P5xJD6, KS(O)xJD6, SF19xNB18	KS(O)xJD6, SF19xJD6, NB18xJD6.
PUP	SF19xP5, KS(O)xNB18, P5xJD6.	KS(O)xNB18, SF19xP5 JD6xNB18, P5xJD6.	KS(O)xNB18, NB18xKS(O)
YIELD	SF19xP5, KS(O)xNB18 NB18xP5.	P5xSF19, KS(O)xJD6, JD6xSF19, P5xNB18.	KS(O)xNB18, NB18xKS(O) NB18xJD6.
SCW	NB18xKS(O), P5xNB18, SF19xP5.	NB18xKS(O), SF19xNB18, JD6xNB18.	NB18xKS(O), SF19xJD6.
SSW	NB18xSF19, NB18xKS(O) P5xNB18.	SF19xNB18, NB18xKS(O), JD6xP5.	NB18xSF19, NB18xKS(O), P5xJD6.
SR%	NB18xSF19, P5xJD6, NB18xP5, SF19xNB18.	JD6xP5, P5xJD6, SF19xNB18.	P5xJD6, NB18xSF19.
FL	NB18xSF19, NB18xKS(O), JD6xNB18.	NB18xKS(O), SF19xP5, SF19xNB18.	SF19xP5, P5xSF19.

cont. D1

JANUARY - FEBRUARY.

FEC	P5xNB18, NB18xP5, JD6xSF19.	NB18xKS(O), NB18xP5, P5xKS(O).	NB18xKS(O), P5xNB18.
HAT%	NB18xP5, P5xKS(O), JD6xP5, SF19xP5.	JD6xSF19, JD6xKS(O), JD6xNB18.	JD6xSF19, NB18xSF19.
LP	JD6xNB18, NB18xKS(O), SF19xNB18, KS(O)xNB18.	SF19xNB18, SF19xP5, KS(O)xNB18.	JD6xNB18, SF19xNB18.
LW	NB18xKS(O), SF19xP5, SF19xNB18, NB18xP5.	SF19xP5, KS(O)xNB18, NB18xKS(O).	SF19xKS(O), KS(O)xSF19
PUP	SF19xNB18, P5xJD6, P5xKS(O).	P5xKS(O), SF19xNB18, P5xJD6, SF19xKS(O).	SF19xNB18, SF19xKS(O).
YIELD	NB18xKS(O), SF19xNB18, NB18xP5, P5xNB18	SF19xKS(O), JD6xKS(O), NB18xKS(O), KS(O)xNB18	JD6xSF19, NB18xKS(O), SF19xNB18.
SCW	JD6xP5, NB18xP5, JD6xNB18.	JD6xKS(O), SF19xP5, JD6xP5, SF19xKS(O).	JD6xP5, SF19xP5.
SSW	NB18xP5, JD6xNB18, SF19xP5, SF19xKS(O).	SF19xKS(O), SF19xP5, JD6xNB18.	SF19xP5, SF19xKS(O), P5xKS(O).
SR%	SF19xKS(O), NB18xP5, SF19xP5, JD6xNB18.	KS(O)xSF19, SF19xKS(O), JD6xNB18.	SF19xKS(O), NB18xP5.
FL	NB18xP5, JD6xNB18, NB18xKS(O), KS(O)xNB18.	JD6xP5, JD6xSF19, KS(O)xSF19.	P5xJD6, JD6xP5.

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cont. D1

MAY-JUNE.

FEC	GxP5, NxP5, GxSF19.	RAJxKS(O), NxP5, NxSF19.	NxSF19, NxP5.
HAT%	CB5xJD6, CB5xKS(O), GxP5, GxSF19.	GxP5, NxJD6, RAJxP5, CB5xJD6.	NxJD6, NxNB18.
LP	NxNB18, NxJD6, NxKS(O), NxSF19.	NxNB18, BxP5, CB5XSF19, CB5xP5.	NxJD6, NxKS(O).
LW	RAJxNB18, GxP5, GxNB18, RAJxP5.	GxP5, RAJxNB18 NxKS(O), BxJD6.	RAJxNB18, GxNB18.
PUP	CB5xSF19, CB5xP5, NxSF19, CB5xJD6.	CB5XJD6, CB5xSF19, GxJD6, RAJxP5.	RAJxP5, RAJxNB18, BxNB18.
YIELD	CB5xP5, CB5xSF19, RAJxP5, NxSF19	RAJxP5, GxJD6, CB5xSF19, NxSF19.	RAJxP5, RAJxNB18, BxP5.
SCW	RAJxNB18, RAJxP5, RAJxJD6, GxKS(O).	RAJxNB18, CB5xSF19, CB5xKS(O), NxSF19.	RAJxJD6, GxKS(O)
SSW	RAJxNB18, RAJxJD6, RAJxP5, CB5xKS(O).	RAJxNB18, BxJD6, CB5xKS(O), CB5xSF19.	RAJxJD6, BxJD6 CB5xKS(O).
SR%	CB5xSF19, RAJxNB18, BxJD6.	CB5xKS(O), RAJxNB18, NxSF19, BxJD6.	BxJD6, CB5xKS(O).
FL	CB5XNB18, CB5xSF19, RAJxJD6.	RAJxJD6, GxSF19. NxP5, BxJD6.	CB5xSF19. CB5xKS(O), GxSF19.

cont. D1

AUG.- SEPT.

FEC	CB5xRAJ, CB5xG, GxN, BxCB5.	RAJxCB5, BxCB5, GxN, CB5xRAJ.	CB5XRAJ, RAJxCB5.
HAT%	CB5xRAJ, CB5xN, CB5xG, RAJxB.	RAJxB, CB5xRAJ, NxRAJ, CB5xG.	CB5xRAJ, CB5xN.
LP	RAJxN, NxCB5, BxRAJ, RAJxB.	RAJxG, GxCB5, NxRAJ, BxRAJ.	RAJxN, NxG, NxB.
LW	CB5xG, RAJxG, BxG, GxRAJ.	RAJxN, CB5xN, NxCB5, RAJxG.	CB5xG, RAJxG.
PUP	BxN, BxRAJ, RAJxB, BxCB5.	BxRAJ, RAJxG, BxN, CB5xG.	BxRAJ, BxCB5, RAJxB.
YIELD	RAJxG, CB5xG, BxG, RAJxB.	BxRAJ, RAJxG, CB5xG, GxCB5.	RAJxG, RAJxB, CB5xRAJ, BxG.
SCW	CB5xG, BxG, RAJxG, GxRAJ.	RAJxN, GxRAJ, CB5xG, BxG.	BxG, CB5xG, NxRAJ.
SSW	BxG, CB5xG, RAJxG, GxRAJ.	GxRAJ, RAJxN, BxG, BxRAJ.	RAJxB, BxG, GxRAJ, RAJxG.
SR%	CB5xB, CB5xRAJ, BxRAJ, RAJxG.	CB5xRAJ, GxRAJ, BxRAJ, BxCB5.	RAJxG, CB5xRAJ, CB5xB.
FL	GxCB5, BxRAJ, CB5xN, CB5xG.	BxRAJ, CB5xN, NxRAJ, CB5xB.	BxRAJ, NxRAJ, RAJxB.

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TABLE : D2 : SEASONAL VARIATIONS IN THE STANDARDISED DEVIATION GRAPH  
( $Y_r/W_r+V_r$ ) OF DIALLEL POPULATIONS.

NAME OF THE BREED	FEC	HAT%	LP	LW	PUP	YIELD	SCW	SSW	SR%	FL
JAN.- FEB.										
P5	HR	HD	HD	HD	HD	HD	HD	HD	LD	LD
NB18	LD	ERD	HRD	HD	LD	HD	HD	HD	HD	HD
JD6	HR	LR	LD	LR	HD	LRD	LR	LR	LD	LR
SF19	HLR	LD	HR	LR	LR	LR	LR	HD	HD	LR
KS(O)	HLR	HR	LD	LR	LD	LR	HLD	LR	LR	HD
OCT.- NOV.										
P5	HR	HD	HD	HD	HD	HR	HD	HD	LR	LR
NB18	HR	LR	HR	HD	LR	LD	HD	HD	HD	HD
JD6	LR	HD	LD	LR	HD	LD	LR	LR	LR	HD
SF19	HR	HD	LD	LR	LR	LD	LR	LR	HR	LR
KS(O)	HD	HD	LD	LD	LRD	LR	HR	LR	LR	HD
AUG.- SEPT.										
N	HD	LD	LD	LR	HD	LDR	LR	LR	LR	LR
CBS	LR	HD	LR	HD	HLD	HD	HD	HD	HD	HD
RAJ	LR	HD	LR	HD	HD	HD	LR	LR	HD	LD
G	HD	LRD	HD	HD	LD	HD	HD	HD	LR	HD
B	HD	LR	HD	LRD	LR	LRD	HR	HR	HR	LR

HD = HIGH CONCENTRATION OF DOMINANT GENES.

HR = HIGH CONCENTRAN OF RECESSIVE GENES.

LD = LOW CONCENTRATION OF DOMINANT GENES.

HDR = HIGH CONCENTRATION OF DOMINANT & RECESSIVE GENES.

LRD = LOW CONCENTRATION OF RECESSIVE & DOMINANT GENES.

HLD = HIGH & LOW CONCENTRATION OF DOMINANT GENES.

HLR = HIGH & LOW CONCENTRATION OF RECESSIVE GENES.

TABLE : D3 : ESTIMATES OF DEGREE OF DOMINANCE THROUGH GRAPHIC, COMPONENT & COMBINING ABILITY.

QUANTITATIVE TRAITS	SEASONS	DEGREE OF DOMINANCE		COMBINING ABILITY gca/sca
		GRAPHIC	COMPONENT	
FEC	JAN.- FEB.	PD	PD	-0.016
	OCT.- NOV.	PD	OD	-0.508
	AUG.-SEPT.	PD	OD	0.107
HAT%	JAN.- FEB.	PD	PD	1.360
	OCT.- NOV.	PD	PD	0.360
	AUG.-SEPT.	OD	PD	0.170
LP	JAN.- FEB.	PD	OD	0.243
	OCT.- NOV.	PD	OD	0.109
	AUG.-SEPT.	PD	OD	0.032
LW	JAN.- FEB.	PD	PD	0.945
	OCT.- NOV.	PD	PD	0.029
	AUG.-SEPT.	OD	PD	1.290
PUP	JAN.- FEB.	PD	OD	0.015
	OCT.- NOV.	OD	OD	0.029
	AUG.-SEPT.	PD	OD	0.097
YIELD	JAN.- FEB.	OD	OD	0.248
	OCT.- NOV.	PD	OD	0.843
	AUG.-SEPT.	CD	OD	0.031
SCW	JAN.- FEB.	PD	OD	1.402
	OCT.- NOV.	PD	PD	0.770
	AUG.-SEPT.	OD	OD	0.444
SSW	JAN.- FEB.	PD	PD	1.346
	OCT.- NOV.	OD	OD	0.373
	AUG.-SEPT.	OD	OD	0.438
SR%	JAN.- FEB.	PD	OD	0.547
	OCT.- NOV.	PD	OD	0.194
	AUG.-SEPT.	OD	OD	0.756
FL	JAN.- FEB.	PD	PD	-142.557
	OCT.- NOV.	PD	PD	2.680
	AUG.-SEPT.	OD	PD	0.903

OD = OVER DOMINANCE; PD = PARTIAL DOMINANCE

CD = COMPLETE DOMINANCE;

< 1 = NON-ADDITIVE GENE ACTION.

> 1 = ADDITIVE GENE ACTION.