5. DISCUSSION

5.1. Screening of *Solanum melongena* against four major insect pests

5.1.1. Screening for resistance to *Leucinodes orbonalis* as a fruit borer :

The damage index has been generally more during 1991-92 on weight basis than on number basis despite there are some overlappings. The findings agrees with the results of Lal *et al.* (1976).

Contrary to the result of 1991-92, in the subsequent year (1992-93) susceptible reaction is found to be more as is evident from the Tables 6 and 7. The varieties R-14, Sufal, Pusa Purple Round, Rajkrishna, Pyratuni, Krishnanagar Hybrid Variety '90, KB-2 are highly susceptible both on number and weight basis.

It is clear from the observations that the varieties NIL, Nurki, Shyamla Dhepa, Kalo Dhepa, IR-8- Baramasi, BLP, BB_1, Murshidabad Local and Navkiran possess fairly resistance characters against *L. orbonalis*. Panda *et al.* (1971) and Lal *et al.* (1976) have reported that Pusa Purple Round, Pusa Purple Long, PPC and Black Beauty are susceptible to the shoot and fruit borer *L. orbonalis* which is in agreement with the present finding (Tables 6 and 7).

A general fact revealed from the summarised data in Tables 6 and 7 is that the Indo-American hybrids (R-14, L-13 and Sufal) are usually highly susceptible to this pest. This finding of susceptibility corroborates the earlier observation of *Subbaratnam et al.* (1981), Mandal *et al.* (1994, 1995).

Panda *et al.* (1971) have reported that Muktakeshi suffers more than 40% damage even during winter months and is to be considered under susceptible grade. This grading is corroborated by the present findings on the varietal performance. On the basis of fruit number, PPC appears to be tolerant, although susceptible on weight basis. Such variable tolerance reaction was also reported by Dhankhar *et al.* (1977) from Haryana and Subbaratnam *et al.* (1981) from New Delhi. On the other hand Lal *et al.* (1976) have made a report on the PPC cultivar from Himachal Pradesh showing variation from fairly resistant to tolerant on number and weight bases respectively. Such differences may be due to the local agroclimatic influence at different experimental locations and also during different years. Nevertheless, most of the authors reported tolerance of this variety from different localities emphasizing a sound genetic basis of the cultivar for tolerance.

An analysis of the present data reveals the fact that PPL, PPR and Indo-American hybrids show susceptible to highly susceptible reaction to the insect pest. This is in agreement with the findings Panda *et al.* (1971), Lal *et al.* (1976) and Subbaratnam *et al.* (1981). Despite climatic variation, similar observation on the susceptibility gives a possible indication of a genetic basis for lack of resistance of the concerned varieties.

While the variety Nurki is recorded as fairly resistant under North Bengal climate both on number and weight bases, it has been found to be highly susceptible under the climatic conditions of Himachal Pradesh (Lal *et al.*, 1976) in Western India.

***L. orbonalis* as a shoot borer :**

Grade index of Subbaratnam *et al.* (1981) was used for measuring the degree of shoot borer infestation in different cultivars of brinjal. The perusal of the data presented in Table 9, clearly indicated the variance in the degree of resistance or tolerance towards the borer pest and as such relative susceptibility reaction was graded into tolerant, moderately tolerant, susceptible and highly susceptible groups.

The variation in the relative susceptibility of the cultivars may depend on the physical, chemical and genotypic variations which cause differential ovipositional preferences by the shoot borer (Panda and Das, 1974). Generally, the dense pubescent varieties have long, tuft and erect trichomes on the leaf surface which are disadvantageous both for ovipositing moths and the young hatching larvae. On the dense pubescent varieties, the just-hatched larvae can hardly reach the normal boring site (apical shoot) as a result of which they perish on the way. Thorny varieties are also less preferred by moths for egg laying (Panda and Das, 1974).

5.1.2. Screening for resistance to jassid, aphid and spotted leaf beetle :

In the present investigation Pusa Kranti has shown moderate tolerance. A number of workers have also reported field resistance of some varieties including Pusa Kranti to jassid attack (Mote, 1978; Bindra and Mahal, 1981; Subbaratnam and Butani, 1981; Mote, 1982 and Subbaratnam *et al.*, 1983).

Grade indexing after Subbaratnam *et al.* (1981) as shown in Table 9 and also the analysis of variance for relative susceptibility to major insect pests (Table 8) have shown significant variation among the 41 genotypes screened for jassids, aphids and spotted leaf beetle.

The different category of susceptibility of the brinjal cultivars to the degree of attack of these pests observed even in the same season might be related to the different resistance factors. The notable physical factors might be the hairiness, the density of hairs, trichomes, offering resistance against these pests (Subbaratnam *et al.*, 1983). Inheritence of hairiness and other characters associated with jassid resistance in American cotton is also reported by Bhat *et al.* (1982).

There have been slight variation in the population dynamics and incidence of the insect-pests during 1991-92 and 1992-93, which apparently seems to be due to the differences in weather conditions during the crop growing season. Temperature, relative humidity and rainfall were different in the two years of observation. The differences are expected to have variable influence on the egg plant varieties and hence, the differential incidence of the insect pests. Such findings are evident also from the observations of Mall *et al.* (1991) regarding the influence of climatological factors on the incidence of these pests on brinjal. Moreover, it is probable that the biochemical basis of host resistance also plays a part in conferring high or fair resistance in the concerned varieties with respect to pest species. Such a basis of resistance in brinjal to insect pests have already been studied and established by Bajaj *et al.* (1989) and some other workers.

Mean performance for 41 cultivars (as referred in Tables for their sequences) with respect to relative susceptibility and yield attributes are clearly presented graphically (Fig. 32-34). In most of the varieties the highest range of variation (80.84-136.17) for days to borer attack in fruit and the lowest range of variation for larvae/ft as observed are similar to those documented by Dhankhar *et al.* (1977). These authors further have reported that percent infested fruits in normal crop and days to borer attack on fruits in ratoon crop of brinjal exhibit the highest range of variation. Considering the yield attributes as well as susceptibility to the pest, Kalo Dhepa, Shyamla Dhepa and Navkiran may be recommended for profitable cultivation in the agro-environment of the terai region of North Bengal, even without any obligation for pesticidal treatment.

5.2. Variability studies

5.2.1. Variability for some important vegetative characters :

The data presented in Table 19 indicates a narrow difference between phenotypic and genotypic coefficients of variation for the characters like plant height at first flowering, plant height at first harvesting, number of secondary branches/pl, days to flowering and days taken from transplanting to first picking of fruits along with marketable yield/pl. Such a situation becomes apparent when environmental influence is minimal on the expression of these characters. This suggest that the genetic variability contributes largely to the total variances, and therefore, the genetic variability of the selected cultivars opens-up ample scope for effective improvement through breeding.

Higher estimates of phenotypic and genotypic coefficients of variation have been obtained for number of primary and secondary branches/pl. Similar results have also been reported by Kabir and Som (1993) in brinjal.

Heritability indicates the accuracy with which genotype can be identified by its phenotypic performance. Although the GCV and heritability (in broader sense) are not sufficient to determine the amount of variation (Burton, 1952). The amount of heritable variation can be determined with greater accuracy when heritability along with genetic advance is studied. In the present study, genetic gain was high for number of secondary branches and number of primary branches/pl.

Selection of individual plants based on number of secondary branches/pl and marketable yield which showed high genotypic coefficient of variation, heritability and genetic advance might, therefore, be effective for improvement in brinjal.

5.2.2. Variability for some reproductive characters :

Results (Table 20) reveal a wide range of variation for all the tested reproductive components which agree with the findings of Singh *et al.* (1974) and Kabir and Som (1992).

Narrow difference between phenotypic and genotypic coefficients of variation has been noticed for fruit circumference, number of marketable fruits/pl and total yield/pl during 1992-93. This implies less environmental interference on the expression of these characters. This again, suggests that major contribution of genetic variability towards the total variance providing ample scope for effective improvement. Higher estimates of GCV and PCV have been obtained for the number of marketable fruits/pl and average weight of fruit. The results corroborate the findings of Mandal and Dana (1992), Kabir and Som (1993) and Bora and Shadeque (1993) in brinjal crop and Anuradha and Gowda (1990) in Gladiolus.

Number of marketable fruit/pl, average weight of fruit and total yield/pl have shown higher estimates of heritability and genetic advance corroborating the findings of Singh *et al.* (1974). As GCV and heritability (in broader sense) are not sufficient to determine the amount of heritable variation which can be determined with greater accuracy when heritability along with genetic advance is studied. Hence, for further breeding programme, due consideration has to be given on these reproductive components for successful prediction in future breeding programme, atleast for these economic attributes.

5.2.3. Susceptibility components towards the attack of *L. orbonalis* :

Higher value of phenotypic variance (PV) as compared to the genotypic variance (GV) have been expressed by all the host characters. Similarly, phenotypic co-efficients of variability (PCV) have shown higher value than the genotypic co-efficients of variability (GCV). This has been a general trend of expression as evident from the Table 21 and agrees with the findings of Dhankhar *et al.* (1977) for these characters.

High heritability has been recorded for all the test-characters considered. Heritability estimates combined with high genetic advance are more useful in eliminating the susceptible varieties, otherwise selecting the best cultivar.

Result suggests that genotypic variation, in the present cultivars for these characters is probably due to a high additive genetic effects. Therefore, the selection on phenotypic basis for these characters backed by high heritability and genetic advance would be more effective in achieving desired results by employing suitable plant breeding methods.

5.3.Correlation and path analysis

5.3.1. Correlation co-efficient of some vegetative characters with marketable yield in brinjal :

Phenotypic, genotypic and environmental correlation coefficients for vegetative characters are given in the Tables 22 and 23 respectively for both the years of study. Results reveal that plant height at first flowering is associated significantly positively with the plant height at first harvesting, number of primary branches, number of secondary branches and marketable yield in brinjal. This may be concluded that the first flowering stage is the full vegetative or transitional phase when the plants enter into the reproductive stage. In this study the primary branches show positive correlation with the secondary branches during both the years of observation from the view point of genotypic and phenotypic correlations. This might be due to better accumulation of carbohydrate with in the plant. Number of primary branches enhances the number of secondary branches. This positive correlation may be due to the better photosynthetic activity of the plant.

Marketable yield/pl has highly significant positive genotypic association with the plant height, and number of secondary branches/pl and negative association with the days to 50% flowering, at both genotypic and phenotypic levels during 1992-93 (Table 23). This association is quite in agreement with the findings of Mandal and Dana (1992). The plant height at the first flowering shows a positive correlation at both genotypic and phenotypic levels with the marketable yield during both the years of observation. This may be due to the better fruit setting from the flowers of first flowering and may be also due to the translocation of metabolite from source to sink zone. Number of secondary branches also shows a positive correlation with the marketable yield. This may be concluded that the higher number of primary branches and secondary branches increase the number of flowers and ultimately cause positive effect on yield. Asna *et al.* (1988) have also provided a similar explanation for the solanaceous minor fruit, cape goose berry (*Physalis peruviana L.*). Earlier reports of significant positive correlations of yield/pl with plant height (Sinha, 1983; Sharma *et al.*, 1985) and with the number of branches/pl (Srivastava and Sachan, 1973; Sinha, 1983) are corroborative from the present observation.

From the above discussion it could be concluded that, selection criteria based on number of primary and secondary branches and plant height at first flowering can give a better success for improvement of fruit yield. Breeding for such plant type can be achieved for maximum selection pressure for these characters.

Path analysis for vegetative characters (genotypic level) :

In the Table 24 the correlations between yield on one hand and the various characters on the other have been partitioned into direct and indirect effects.

If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and a direct selection through this trait will be effective. In this case the secondary branches/pl account for direct effect on yield (0.604) almost to the total correlation (0.635). So, the varieties having more number of secondary branches should be selected for better yield.

If the correlation coefficient is positive but direct effect is negative or negligible, the indirect effect seems to be the cause of correlation. In such situation indirect causal factors are to be considered simultaneously for selection. In this case plant height at first harvesting (- 0.221), primary branches/pl (- 0.037) and days to flowering (- 0.042) had negative direct effect but positive correlations viz. 0.215, 0.262 and 0.019 respectively.

Direct and indirect effects of different vegetative parameters are indicated in the Table 25 during 1992-93 observation.

Almost similar results have been obtained in respect of secondary branches/pl. Plant height at first flowering and plant height at first harvesting, suggesting that these characters are to be included while selecting the plant type.

Residual effect is also very high during 1992-93 (0.739) indicating a similar trend of observation during both the years. This suggests that before conclusion additional number of other characters may be included in the study.

Slight variation among the vegetative characters of the 41 cultivars might be due to environmental factors although observations remains similar in both the years.

Correlation coefficient may be negative but the direct effect is positive and high. Under these circumstances, a restricted simultaneous selection model has to be followed, i.e. restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect (Singh and Kakar, 1977). Here in case of days taken from transplanting to picking had very negligible but positive direct effect (0.089) with negative (-0.056) total correlation with marketable yield.

The residual effect (0.739) determines how best the causal factors account for the variability of the dependent factor, the yield in this case. Its estimate being 0.739, the independent variables explain only 27% of the variability in yield. The reason seem to be very low and non-significant correlations of days to flowering, days from transplanting to picking and plant height at first harvesting.

Path analysis for some vegetative characters (phenotypic level) :

Path analysis for some vegetative characters at phenotypic level is presented for 1991-92 and 1992-93 in the Tables 26 and 27 respectively. Maximum direct negative effect was observed for the characters days taken from transplanting to picking (-1.941), and plant height at first flowering (-0.906) during 1991-92. Maximum positive direct effect has been expressed by days to flowering followed by secondary branches/pl, and plant height at first harvesting. Similar results have also been observed during 1992-93 (Table 27) in respect of secondary branches/pl where direct effect (0.727) and phenotypic correlation with marketable yield have been of highest value (0.742). It may, therefore, be suggested that for selection of high fruit yield in brinjal, days to flowering, and number of secondary branches/pl will have to be considered as the effective morphological characters.

In the present study the residual effect was only 0.241 during 1991-92. This implies that the remaining characters to be included in the study had negligible effect on yield. Residual effect is quite high during 1992-93 (0.635) indicating that other characters have to be included while predicting yield potential. This is in contrary to the earlier results and might be due to slight variation in the edaphic characters and meteorological parameters.

Path analysis for some vegetative characters (environmental level) :

From Table 28, it is evident that the correlations between yield on one hand and the various characters on the other, have been partitioned into direct and indirect effects at environmental level. Direct effects for all the characters studied have been negligible which implies only negligible environmental effect. On the other hand residual effect is very high suggesting a non-significant correlation of the characters on yield for both the years of study during 1991-1992 (Table 28) and 1992-93 (Table 29).

Correlation coefficient of some reproductive characters with total yield :

Correlation matrix for some reproductive characters are presented in Tables 30 and 31 for the years 1991-92 and 1992-93 respectively. The results show that fruit length, fruit circumference, fruit number and fruit weight have a positive correlation with the total yield of brinjal. Thus, it appears that increase in any one of the above mentioned characters would increase the yield. This is true for both the years of observation and at both genotypic and phenotypic levels. The yield components exhibit varying trend of association among themselves. Number of fruits/pl shows a significant negative correlation with the fruit diameter indicating that factors favouring lower fruit diameter would increase the number of fruit/pl

(Khurana *et al.*, 1988). That the number of fruit/pl has a significant positive correlation with the yield of the plant (Sinha, 1983) is corroborated in the present finding. Sharma *et al.* (1985) and Mandal and Dana (1992) have reported that the fruit diameter or circumference do not show significant correlation with the yield but in the present study fruit diameter has been found to be positively correlated with total yield of the crop. Further the study reveals that the relationship between yield and number of fruit is positive which does not agree with the findings of Singh (1984) and Khurana *et al.* (1988). This discrepancy between the results of different workers may be attributed to the different germplasm used and the environmental conditions under which the studies were carried out.

Tables 30 and 31 show that the fruit length, fruit circumference, fruit number and fruit weight have positive influence/effect on the total yield in brinjal. Thus, it appears that increase in any one of the above mentioned characters will increase the yield. Therefore, for selection of plant type, these characters may also be important traits along with others.

Genotypic path analysis for some reproductive character :

Partitioning of genotypic correlation coefficient (Tables 32 and 33) into direct and indirect effects reveals that only number of fruits/pl has a high positive direct effect (0.686 and 0.772 respectively for 1991-92 and 1992-93) on total yield in brinjal followed by fruit weight (0.399 and 0.495 for 1991-92 and 1992-93 respectively). Besides these, fruit length and circumference have also moderate positive effect.

Thus, it can be concluded that in the improvement of fruit yield in egg plant, emphasis should be given to the selection of plants with high value of fruit number, coupled with weight, length, and circumference.

Phenotypic path analysis for some reproductive characters :

Tables 34 and 35 show that significant positive association of characters exists specially in respect of fruit number, fruit weight, followed by fruit circumference and length for both the years of study. Thus, it can be suggested that for improvement of yield, due consideration should be given on these reproductive parameters along with other characters.

Variations in the characters between the observations of two years might be due to environmental fluctuations.

Environmental path coefficients for some reproductive characters

Environmental path coefficient for both the years are presented in the Tables 36 and 37. Variation from positive direct effect to negative one might be due to abiotic factors during experimentation. But the high residual effects in both the years indicate that the environmental impact is minimum.

Correlation with some susceptibility components and percent yield loss :

Correlation matrix presented in Tables 38 and 39 reveals that all the susceptibility components studied viz. larvae/pl, larvae/ft, holes/ft, holes/pl, infested branches/pl and infested fruit/pl have significant positive correlation with the percent yield loss in brinjal at genotypic level for both the years of study. So, while selecting plant type, these characters have to be considered for resistant genotype identification.

Varying results have been obtained for different susceptibility components among themselves with respect to percent yield loss. Larvae/pl indicates very significant positive correlation with larvae/ft, holes/pl, holes/ft, infested branches/pl and infested fruit/pl and also with loss in yield for the observations in both the years. This positive relation may be implicated to more number of pest population and consumption of fruits by them through the breeding of more and more cycles of pests for infestation. Yield loss is greater due to higher number of larvae/ft which causes maximum infestation to the edible fruit leading to production of unmarketable fruit. While selecting resistant plant type these susceptibility components will have to be considered.

Genotypic path analysis for some susceptibility components towards *L. orbonalis* attack in brinjal with yield loss

Table 40 on partitioning of different susceptible components into direct and indirect effect reveals that excepting the days taken to borer attack on fruit and infested fruit/pl all the characters like larvae/pl, larvae/ft, holes/pl, holes/ft, days to borer attack on branches and infested branches/pl have positive direct effect with the loss in production of edible fruit during 1991-92. Although all the characters studied have positively related to yield loss but days taken to borer attack on branches as well as on fruit is negatively correlated at genotypic level. Although direct effect of days to borer attack on branches is positive but the genotypic correlation with loss of yield is negative due to negative indirect effect via larvae/pl, larvae/ft, holes/pl, holes/ft, days to borer attack on fruit, and infested branches/pl, which suggested that genotypes with lower value of the days taken for borer attack on branches i.e. the attack at early stage of the crop growth phase, plays an important role for increasing the number of fruits/pl and thereby yield in brinjal.

Direct and indirect effects of the susceptible components during 1992-93 (Table 41) reveals that almost all the characters are positively related to the loss in yield. Negative direct effect on yield loss has been recorded against larvae/pl, holes/pl, and infested branches/pl which has enhanced marketable yield in brinjal. This might be due to reduction of apical growth and enhancement of secondary branches leading to better yield.

Residual effect was 0.54 for both the years of study, suggesting that the other susceptibility components have to be included before drawing a conclusion.

Phenotypic path analysis of some susceptibility components of *L. orbonalis* attack with yield loss in brinjal :

The Table 42 indicates that larvae/pl, holes/pl, and days to borer attack on fruit, infested branches/pl, infested fruit/pl had negative direct effect on yield loss while larvae/ft, holes/ft and days to borer attack on branches had some amount of positive direct effect. Although negative phenotypic correlation exhibited by holes/pl, holes/ft, days to borer attack on fruit, infested branches/pl and infested fruit/pl positive correlation exists simultaneously for the larvae/pl and larvae/ft along with the parameters days to borer attack on branches during 1991-92.

On the contrary, during 1992-93 (Table 43) significant positive phenotypic correlations have been recorded for all the characters having direct positive effect on yield loss excepting the days to borer attack on fruit where direct effect is negative (-0.011).

Variations in the observation of different seasons might be related to environmental fluctuations.

Residual effect during 1991-92 has been 0.964 while in 1992-93 it has been 0.623, suggesting very a low contribution of phenotypic effect.

Path analysis at environmental level for some susceptibility components of *L. orbonalis* with loss in yield :

Direct and indirect environmental paths indicate that for both the years of observations (Tables 44 and 45) positive effect is exhibited for the components larvae/pl and days to borer attack on branches. On the other hand, both negative and positive effects are expressed for other characters at insignificant level. Such variations, again, may be attributed to the environmental factors.

Residual effect is very high 0.974 (1991-92) and 0.888 (1992-93) indicating a very low level of influence by the environmental fluctuations, if any.

5.4. Genetic divergence :

Present study reveals that during 1991-92 (Fig. 36) marketable yield, primary branches and fruit weight have contributed largely towards the divergence. But during 1992-93 (Fig. 37), primary branches/pl, fruit weight, larvae/ft and days taken to flowering have contributed to the maximum for the total divergence among the 41 genotypes of brinjal screened. The degree of contribution has been marketable yield (70.6%) followed by fruit weight (28.1%) during 1991-92 while of primary branches/pl (52.5%) followed by fruit weight (28.2%) and number of larvae/ft (17.9%) during 1992-93. Contribution of fruit weight towards total divergence has also been reported by Abdul Vahab *et al.* (1994) in okra.

Hence, for selecting genetically divergent parents for hybridization, these characters demand for due consideration. From the study, it is apparent that choice of parents for any breeding programme need not necessarily be based on source of origin. Factors other than geographical origin such as genetic drift, and selection intensity could be responsible for genetic diversity. However, geographical isolation can alter genetic set up of the population (Wallace, 1963).

The 41 genotypes have been grouped into 4 clusters (Tables 46 and 49) on the basis of D^2 values, such that varieties belonging to one cluster have on an average smaller D^2 values than those belonging to the other clusters.

Interestingly, the lines collected from different sources and hybrid parents have also been included in the same cluster which reveals that geographic distance need not necessarily be related to genetic divergence (Murty *et al.*, 1966; Singh and Gupta, 1979; and Hazra *et al.*, 1993; Abdul Vahab *et al.*, 1994). Consequently it is suggested that selection of parents for hybridization or in other crop improvement need not necessarily be based on geographical diversity alone but genetic diversity must form the sound base for selection. The relationship between genetic diversity as measured by D^2 statistics and geographic diversity warrants a discussion. Geographic diversity may result from the interaction of agroclimatic conditions and natural selection. Rapid ecotype differentiation may occur in out breeding species even in the absence of reproductive isolation. Murty *et al.* (1965) expressed the view that human selection would help to intensify ecotype formation while Somayujulu *et al.* (1970) stated that it would result in erosion of genetic diversity. However, it may be possible that by hybridizing materials from different sources, the correlation between genetic and geographic diversity can be broken.

A comparision of inter and intra cluster distances (Tables 47 and 50) for each population reveals that many of the intercluster distances are quite wide, indicating that considerable variability exist amongs these varieties. The high values for intra cluster distance suggest that relatively greater number of intermating cycles might have been involved for developing these varieties / strains / lines.

Lastly, it is not easy to comprehend genetic divergence between genotypes because of large number of dimensions involved. Relationship among genotypes can be better visualized, if their dimensionality is reduced without losing essential information.

On the contrary of the general rules, parents selected from among the cluster-I could produced top hybrid with respect to the primary branches/ pl (Navkiran × KD), number of secondary branches/pl (BLP × Navkiran), days to flowering (BLP × KD), marketable yield/pl (BLP × Navkiran), length of fruit (BLP × Krishna) and total yield/pl (BLP × Navkiran). This justifies the highest genetic distances among the genotypes included in the cluster-I.

Top hybrids have also been resulted from the cross between cluster I and II for the characters plant height (Navkiran × BGW), weight of fruit (BGW × KD), larvae/pl and fruit (BGW × BLP) and holes/pl (BGW × KD). This result proves a moderate genetic distances between two clusters.

In the present investigation divergent groups (IV × I) have shown a better response towards the inheritance of pest resistance characters like days to borer attack on branches, days to borer on fruit, infested branches/pl, infested fruit/pl and loss of yield and also for the characters days taken from transplanting to first picking indicating importance of grouping and genetic divergence study.

Results of the cluster mean values during 1991-92 and 1992-93, (Tables 48 and 51 respectively) indicate that for most of the clusters the genotypes included average values for almost all the quantitative traits studied.

5.5. Screening of 12 agrochemicals using *L. orbonalis* as a shoot borer and as a fruit borer.

5.5.1. Efficacy of 12 agrochemicals on the suppression of *L. orbonalis* infesting a local cultivar

Shoot borer :

The present observation of the superiority of endosulfan, methyl parathion and pyrethoids (Table 52) is in agreement with the findings of Bothera and Dethe (1991) for endosulfan, and also Jagan Mohan and Prasad (1984) for synthetic pyrethroids. Several other recent reports also corroborate the effectiveness of synthetic pyrethroides against the shoot borer (Agnihotri *et al.,* 1990; Acharya, 1991; Thanki and Patel, 1991).

Fruit borer :

The best efficacy at the final stage with respect to cypermethrin 0.006% (Table 53) may be due to higher accumulation of the compound after 3 successive sprays as well as due to differences in the activity of meristem of the cultivar with the progress of age and interaction of meristem with azadirachtin in this exclusive climate of North Bengal terai zone. However, a conclusive explanation can be drawn only after a thorough exploration of the underlying mechanism. The efficacy of all the agrochemicals declined 15 days after spray as compared to that of 7 days after the treatment. This decline after 7 days leads to higher percent damage in yield which might be due to slow decay of the treated chemicals with the lapse of time.

5.5.2. Impact of 12 agrochemicals on growth, yield and economics of *S. melongena*

The spraying of agrochemicals has been induced vegetative growth of the plants (Table 54). Similar results of promoting vegetative growth with the use of agrochemicals have also been obtained by Uthamasamy *et al.* (1973), who found an increased growth of brinjal after disulfotan and aldicarb treatment. Singh and Kavadia (1988) have also reported an increase in plant height and number of leaves/pl in this crop. No satisfactory interpretation is available for such agrochemical-promoted growth and yield of brinjal. One simple explanation may be that the agochemicals by way of reducing the attack of insects less damage has been caused as compared with the control plants.

Results on the effect of some agrochemicals on fruit weight, yield and cost : benefit ratio reveals that generally, the marketable fruit weight has been higher than that of unmarketable fruit except in cases of quinalphos and phosphomidan treatments where a reverse situation has been recorded (Table 55). Singh and Kavadia (1988) have also reported an increased fruit weight due to endosulfan in combination with aldicarb and disulfotan, whereas aldicarb followed by aldicarb produce some adverse effects on fruit weight.

Several workers reported increased yield with insecticidal schedules (Satpathy, 1973; Joshi and Sharma; 1973, 1991). Worked in Agra climate, Rajdhar and Singh (1989) obtained a good result with aldrin and BHC in terms of yield and quality while malathion and parathion in terms of phosphorus content in soil and crude protein content in fruits. Reddy and Joshi (1990) reported from Madhya Pradesh that all the treatments with pesticides in combination with planofix (NAA-100 ppm) increased growth and fruit set in brinjal. Carbaryl or endosulfan combined with plant growth regulator gave the best yield. The endosulfan combination was the most economical. All treatments except planofix alone rersulted in significant reduction of infestation by the *L. orbonalis*. All these views agree with the present findings.

Reddy and Joshi (1990) and Dhamdhere and Sharma (1991) reported endosulfan to be the most effective and economical in terms of reducing infestation and thereby increased yield and additional income over control. The data presented in Table 55 clearly indicate that cypermethrin 10EC followed by dimethoate appear to be the economically viable pesticide for control of this fruit borer.

5.5.3. Screening of pesticides using six promising brinjal cultivars under modern concept of IPM :

An examination of the performance of 6 cultivars under unprotected, semiprotected and protected conditions (Tables 56 to 60) provides a comparative picture. Summarily, the performance of different cultivars in reference to the damage by the major insect pests under semiprotected and unprotected conditions brings to the light the following points :

1. KD, BLP, and Navkiran are relatively resistant to shoot and fruit borer whereas R-14 being most susceptible.
2. Navkiran shows relatively resistant towards all the major pests in question whereas R-14 is relatively susceptible to all the insect pests.
3. Mean yield of healthy fruit of KD is the best (5.54 kg/pl) followed by Navkiran (4.81 kg/pl).
4. Ratio of infested to healthy fruit yield on weight basis shows KD (1 : 5.08) as the most resistant followed by Navkiran (1 : 5.01) and BLP (1 : 4.86) whereas R-14 as most susceptible (1 : 0.76).

Superiority of synthetic pyrethroid over endosulfan in efficacy of insecticide combinations was reported by Umapathy and Baskaran (1991) against the borer causing its 79.7% mortality. Brar *et al.* (1992) also recorded very good result with the combination of carbofuran and cypermethrin. Islam and Quiniones (1990) reported superiority of endosulfan over methyl parathion. Further, endosulfan residues was less (0.0023 mg/kg) 6 days after the spray compared to that of parathion (0.015 mg/kg). According to Raha *et al.* (1993) residues of endosulfan in and on brinjal fruits immediately after application was below the tolerance level of 2 ppm as specified by FAO/WHO. Reddy and Joshi (1990) reported the endosulfan when applied in combination with plant growth regulators gave the best yield. The endosulfan combination was the most economic. Singh (1993) also recommended a spraying with endosulfan (0.07%) under IPM for controlling tomato borer as safe pesticide. Hence, considering the safe pesticide treatment combinations of carbofuran @ 750 g a.i./ha at 3 weeks after transplanting applied at the root zone combined with a single spray of endosulfan @ 525 g a.i./ha at 70 days after transplanting may be recommended following IPM in combination with cultivar KD. This view did agree with the findings of Mandal *et al.* (1996).

The relative differences of infestation of shoot and fruit borer and jassid in different brinjal varieties has been reported by Subbaratnam and Butani (1981), Mote (1981a) and Bajaj *et al.* (1989). However, the varieties have not been tested for their performance towards other pests and to their yield. Further, none of the varieties considered in this experimentation has been tested previously. A large number of insecticides have also been tested by several workers such as Mehto and Lal (1981), Mote (1981b), Nimbalkar and Ajri (1981), Agnihotri *et al.* (1990), Acharya (1991) and Bothera and Dethe (1991). But the information on the choice of varieties under specific chemical treatments is lacking. In fine, no brinjal cultivar has been reported to be completely resistant to the pest attack. The present approach of integrating the chemical pesticide application with the partially resistant varieties of different pest can go a long way in the economic management of the brinjal pests. On the basis of the present result the combination of carbofuran and endosulfan appear to be suitable along with the consideration of resistance. Because the residue of endosulfan is below the permissible tolerance level and this pesticide is much cheaper than the synthetic pyrethroids. Again, with the combination of carbofuran and endosulfan the selected six varieties can be ranked in the reducing order of superiority as KD > Navkiran > BLP > BGW > Krishna > R-14.

5.6. Performance of six selected parents and their 30 F_1 hybrids

Leaf characters, flower colour, fruit colour and fruit shape of the selected six parents and their 30 F_1 hybrids along with two check varieties such as Tal and Nababganj are discussed summarily with the help of Table 61.

Heterosis for some vegetative characters :

Analysis of variance (Table 62) clearly indicated variable performance among different vegetative traits.

Plant height at first flowering :

Perusal of Table 65, regarding this character reveals that the extent of heterosis over better parent ranged from - 33.33% for Krishna × R-14 hybrid to 7.14% for Navkiran × BGW. Positive heterosis for this character has also been reported by Venkataramani (1946) and Singh *et al.* (1974, 1978). But Patil and Shinde (1984) is of the opinion that plant height is negatively associated with heterosis for yield.

Heterosis defined as the manifestation of greater vigour in leaf area, growth, dry matter accumulation and higher yield of F_1 hybrid in comparison with its inbred parents (Sonone *et al.*, 1984). This has been reported for various characters in brinjal (Vishwanathan, 1973; Singh *et al.*, 1985).

Plant height at first harvesting :

An examination of the results in Table 66 for this character, among the parents and hybrids, shows a positive heterosis over better parent by the Navkiran × BGW hybrid, which is statistically significant even at 1% level of significance. This might be due to the plant height achieved at the time of flowering through heterotic effect. The heterosis for plant height at first harvesting in brinjal had also been reported by Dharmegowda *et al.* (1979), Patil and Shinde (1984), Mandal *et al.* (1994) and other workers.

Shankaraiah and Rao (1990) also reported that seedling height and vigour are to be associated with yield and thus can be used as reliable indices for yield.

Number of primary branches :

Regarding this character, only 8 out of 30 F_1 hybrids have shown a significant positive heterosis over the better parent while the other hybrids have expressed significant negative heterosis (Table 67). Besides this, two crosses, Krishna × BGW and BGW × Krishna show 0.00% heterosis over BP, suggesting no dominance. This result is in conformity with Singh *et al.* (1978), Singh (1980), Balamohan *et al.* (1983) and Patil and Shinde (1984) and Mandal *et al.* (1994).

Number of secondary branches :

Regarding this trait, the extent of heterobeltiosis ranged from -80.00% for BLP × BGW to 66.67% for BLP × Navkiran (Table 68). This observation agrees with the earlier findings of Patil and Shinde (1984) and Mandal *et al.* (1994). Superiority of the hybrids might be due to heterosis controlled by dominant parental genes.

Number of days to flowering :

Values (Table 69) for the range of heterosis or hybrid vigour over better parent varies from - 53.00% in BLP × KD to 38.46% in BLP × Navkiran. Hence, crosses with negative values have been considered to be desirable which in turn has given an early yield from the crosses. This negative heterosis might be due to non-additive gene action corroborating the views of Dharmegowda *et al.* (1979), Patil and Shinde (1984) and Mandal *et al.* (1994).

Number of days taken from transplanting to first picking :

The magnitude of heterobeltiosis for this character has been from - 50.00% in the cross KD × R-14 to 15.79% in BLP × Navkiran (Table 70). This variation in days taken from transplanting to picking is only due to variation in days to flowering - there was no earliness of ripening of brinjal fruits (Venkataramani, 1946). Negative heterosis has also been mentioned by Chadha *et al.*, 1990 regarding this character.

Heterosis for some reproductive characters

Analysis of variance clearly indicates variable performance of the five reproductive components studied (Table 63).

Length of fruit :

The performance of parents and hybrids shows a variation for this trait in the magnitude of significant heterosis ranging from - 28.57% (KD × R-14) to 32.98% (BLP × KD). The significant positive heterosis over better parent has been recorded for BLP × KD as 8.70% (Table 72). This might be due to overdominance and it supports the results obtained by Singh (1980), Balamohan *et al.* (1983), Patil and Shinde (1984), Dahiya *et al.* (1994) and Mandal *et al.* (1994).

Maximum circumference of fruit :

Results show that in almost all the crosses there has been a depression of this trait. Range of heterobeltiosis observed has been - 60.00% (BLP × BGW) to 25.00% (BLP × Krishna) as evident from the data presented in Table 73.

Heterosis with respect to equatorial diameter was reported by Concilio and Sanguinate (1982). Significant negative heterosis over better parent indicates the presence of incomplete dominance and it contradicts the inference of Patil and Shinde (1984) who described that the phenomenon was due to over-dominance.

Number of fruits/plant :

Significant positive heterosis for the character number of fruits/pl has been recorded in 11 hybrids out of 30. The magnitude of positive heterosis over better parent ranges between 2.74% (KD × BGW) and 217.23% (R-14 × Navkiran).

It is clear from the result (Table 74) that inspite of heavy bearing in BLP (37.77) and Krishna (21.66) R-14 and Navkiran yield maximum heterotic effects which might be due to synergistic effects of dominance of both the parents in the hybrid. Although R-14 × BLP gives the highest number of fruits (55.00) which might be due to heavy bearing traits possessed by BLP in cluster. Randhawa and Sukhija (1973) also observed heterosis over better parents for this character in crosses. Thakur *et al.* (1968) reported heterosis for this character upto 34.06%. These views were also in agreement with the findings of several other workers and most of them opined that the heterobeltiosis occurred for the character number of fruits/pl due to over dominance corroborating the observation of Mandal *et al.* (1994) and the present finding.

Weight of fruits :

In general, majority of the crosses show a negative heterosis for this trait. Range of heterobeltiosis is from - 5.00% (BLP × BGW) to 108.33%

(BLP × Krishna). The result (Table 75) is not so enthusiastic as compared to the findings of Singh (1980) who has recorded comparatively a good amount of heterosis for this character.

Yield/plant :

Significant heterobeltiosis has been expressed in different F_1's ranging from - 43.48% (Navkiran × BLP) to 52.53% (BLP × Krishna) with respect to total yield/pl (Table 76). The hybrid, BLP × Navkiran shows the highest yield of 9.80 kg/pl which might be due to a good combination of the bearing habit of BLP and the weight of fruit of Navkiran variety. Results obtained in the present study clearly indicates that high yields of the hybrids have been due to higher number of fruits/pl, increased length of fruits and fruit weight. Heterosis with respect to yield/pl had also been reported by several workers who reported that positive heterosis over better parent was mainly due to over-dominance (Mishra, 1961; Thakur *et al.*, 1968; Lal *et al.*, 1974; Dharmegowda *et al.*, 1979; Dhankhar *et al.*, 1980 and Singh, 1980)

Heterosis in brinjal for yield was attributed to increase in number of branches/pl, fruit length, and number of fruits and heavy bearing habit of the hybrid induced through parental contribution (Ram *et al.*, 1981; Concilio *et al.*, 1983; Nualsri *et al.*, 1986; Gopinath *et al.*, 1986 and Mandal *et al.*, 1994).

The heterosis expressed in the hybrids of the crosses employed for the above characters can be utilized in combination with earliness of marketable fruitings for evolving high yielding and early maturing hybrid in brinjal.

Heterosis for susceptibility components :

Analysis of variance (Table 64) shows significant treatment differences among different components studied.

Very few hybrids has exhibited relative insect resistance, which might be through less number of larvae/ft, holes/ft and percent loss in yield, suggesting a probable relation between the loss in yield and all these susceptibility traits.

There are very few literature in support of this insect resistance evolved through breeding specially against the shoot and fruit borer.

Dhankhar *et al.* (1983) reported borer resistance in BR-103 × White Long and BR-112 × Aushey. Besides this Srivastava and Lal (1995) also reported that SM-202 × PPL hybrid showed moderate resistance on both number and weight basis against this pest.

In the present investigation BGW × BLP hybrid appears to be the best among all with respect to larvae/pl and larvae/ft and BLP × Navkiran shows the most desirable characters against number of holes/pl by the shoot and fruit borer. This multiple resistance could have been transmitted by the top line BLP variety, being one of the parents for these hybrid. Least number of infested branches in the hybrid of R-14 × Navkiran and the least number of infested fruit/pl in case of KD × R-14. This have resulted possibly due to insect resistance quality of the parents Navkiran and KD. Considering yield loss simply KD variety can be recommended to the farmers of Darjeeling terai region (Table 88).

Variability among the parents and hybrids :

Wide range of variation has been observed for all the vegetative characters supporting the observation of Singh *et al.* (1974) and Kabir and Som (1993). Higher values of PV as compared to GV have been expressed by all the tested characters (Table 89). Similarly, PCV has been obtained in higher value than the GCV. This has been a general trend of expression as evident from the Table 89 and agrees with the similar observation of Mandal and Dana (1992) in brinjal and Chattopadhyay (1995) in cowpea. Excepting the character days to flowering (76.06%) all the estimates of heritability (in a broad sense) are higher (above 95%). Similar observation has also recorded by Chattopadhyay (1995) in cowpea. Number of primary and secondary branches is to be given due consideration while selecting the varieties. Results suggest that genotypic variation in the present cultivars for these characters is probably due to high additive genetic effects. Therefore, the selection on phenotypic basis for these characters, backed by high heritability and genetic advance would be more effective in achieving desired results by employing suitable plant breeding methods.

Analysis of variance suggests a wide range of variability for all the reproductive characters. The results indicate considerable genetic variability for fruit number and yield. Estimates of components of variance reveals higher genotypic variance than environmental variance, supporting the views of Ahmed *et al.* (1990) in chilli. Higher genetic advance and genetic gain have been reflected for number of fruits/pl coupled with higher heritability (Table 90) indicating a large scope for the improvement of the character through selection. Higher GA and heritability for the character may be due to predominance of additive gene action as suggested by Kumar *et al.*

(1993) in chilli, Anuradha and Gowda (1994) in gladiolus, Singh *et al.* (1974) and Kabir (1981) in brinjal.

A significant amount of variability has been obtained among the tested susceptibility components of 38 strains of brinjal. Estimates of components of variance indicate a maximum genetic variation for percent yield loss followed by infested fruit/pl, while GCV shows a maximum value along with heritability and GA for the trait larvae/ft (Table 91). Therefore, selection of phenotype on the basis of these characters could be more useful for relative susceptibility to the shoot and fruit borer.

The high value of heritability suggests that all the characters are under genotypic control (Singh *et al.,* 1974). Heritability value alone provides no indication of the amount of genetic progress that would result from selecting the best individuals. Ramanujan and Tirumalechar (1967) in red pepper (*Capsicum annum* L.) discussed the limitation of estimating heritability and suggested that the heritability estimates in broad sense would be reliable if accompanied by the high genetic advance (GA) probably due to additive gene effects (Panse, 1957). Selection is thus, likely to be beneficial in improving those traits having low GA but high heritability is not always an indication of high genetic gain (Johnson *et al.,* 1955; Swarup and Chaugale, 1952). Thus, it appears that the afforesaid characters are influenced by non additive gene effects.

Correlation and path analysis for the parents and hybrids

The marketable yield/pl is highly associated with the secondary branches/pl in both genotypic and phenotypic correlations and path analysis (Tables 92-95). It suggests that this vegetative character is an important yield component for selection of genotypes. This finding corroborates that of Mandal and Dana (1992).

Number of fruits/pl had negative correlation with maximum circumference of the fruit but a high positive correlation with the fruit weight (Table 96). The results provided in the Tables 97-99 indicate that fruit weight and number of fruits had positive direct correlation on the total yield in brinjal. This view does agree with the findings of Salehuzzaman *et al.* (1979) and Singh and Singh (1980) in brinjal and also for cowpea (Chattopadhyay, 1995). It has been reported that there is a strong association between number of fruits and yield/pl (Srivastava and Sachan, 1973; Singh and Nandpuri, 1974; Hiremath and Roa, 1974). Salehuzzaman and Alam (1983) registered that the yield in egg plant is a complex character which is the product of its components. Whether one should select only for the components or for the yield itself will depend upon their heritabilities and genetic inter relationships among the yield and its components. Analysis of all the reproductive components reveals the fact that all the characters are inter-dependent and influence one another by highly positive direct and indirect effects.

Results of correlation (Table 100) and path analysis (Tables 101-103) for the susceptibility components indicate that percent infested fruit/pl has a high positive direct effect on yield loss. Again, the total yield is correlated with the percent yield loss of brinjal. By applying selection pressure on these characters, it is possible to increase the marketable yield but the total yield will be adversely affected. So the emphasis must be on the combined effect of heterosis with yield and resistance to shoot and fruit borer. This inference agrees with the conclusion of Dhankhar *et al.* (1983) and Srivastava and Lal (1995) for exploitation of hybrid vigour with respect to yield and insect pest resistance.