Chapter - V

Discussion

DISCUSSION

5.1 Seasonal Incidence of Insect-Pests and Their Natural Enemies of Tomato and Their Interaction with Crop-Phenology.

Weather plays a major role on crop production and also influences greatly in pest population dynamics. Besides weather, pest population dynamics also varies with crop growth stages *i.e.* phenology even in the same crop growing season, although it is also influenced greatly by prevailing weather conditions. IPM is a multitactical ecological approach wherein roles of weather and crop phenology are prominent. Appropriate understanding of the weather factors influencing the pest population fluctuation at different stages of crop growth can help in formulating control strategy. It is rather difficult to find a direct cause and effect relationship between any single climatic factor and pest activity, because the impact of weather elements on pest is confounded (Parker, 1946 and Banerjee, 1972). However, studies on abiotic and biotic factors of environment and interaction between crop phenology and insect phenology are of immense help in pest management programme through formulation of pest models by quantifying relationship between pest incidence and influencing weather parameters and by asynchronisation of peak attack at critical stage of crop growth by optimizing sowing dates, crop varieties, cropping system etc. Therefore, the present investigation was undertaken with an objective to study the effect of various weather factors and crop phenology on the population build up of various insect-pests of tomato in complex, so that the findings may be utilized in pest avoidance programme while formulating IPM in future. A detailed studies on causative relationship between important weather parameters, crop phenology and pest population build up was worked out in view to asynchronise the vulnerable stages of tomato crop from peak period of incidence of pest species through adjustment of planting times and other cultural practices, which is being discussed as follows.

Relative abundance and fluctuation of pest population on different crops planted at different time as influenced by weather

Relative abundance of insect-pest species on tomato, namely aphid *(Aphis gossypii)*, white fly *(Bemisia tabaci)*, leaf miner *(Liriomyza trifolii)*, fruit borer *(Helicoverpa armigera)*, tingid bug *(Urentius hystricellus)*, hadda beetle *(Henosepilachna vigintioctopunctata)* and some dominant predators namely

Coccinella septempunctata., *Menochilus sexmaculata* and several species of spiders varied widely with different time of planting.

Aphid (*Aphis gossypii* Glover) : Among the four planted crops aphid population was always lower in P_1 and P_4, maximum being 0.49 and 0.30 per leaf respectively. Aphid population was relatively higher on P_2 and P_3 crops with the highest being 5.76 and 5.16 per leaf respectively. Higher population was maintained from 3rd to 10th standard week *i.e.* from middle of January to 2nd week of March. The present findings is in conformity with Kandoria *et al.*(1989) where aphid was observed active on tomato during February and very active in March in Punjab. Singh (1984) had also added similar report where dispersal of aphid was observed with the advent of spring when there was a rise of temperature. During the prevalence of aphid attack in terai region average temperature, r.h. and sunshine hr/day ranged from 15.43 to 22.13^{0}C, 69.11 to 73.96%, 5.70 to 8.94 hr/day respectively and the total rainfall was 5 mm. Keeping aside the difference in level of aphid population, almost, similar information was also obtained by Mall *et al.*, (1992), that a average temperature range of 20-25^{0}C and average r.h. of 50-72% were more favourable for the maximum activity of aphid population, confirms the results of the present investigation. Correlation between temperature and rainfall with aphid population revealed that the aphid population had negative correlation with maximum, minimum and average temperature and with total rainfall supports the results obtained by Oliviera (1971), Singh (1984) and Kandoria *et al* (1989). Although aphid population in general had negative correlation with r.h. but during higher period on incidence *i.e.* on P_2 and P_3 planted crop, r.h. maximum, average and r.h. gradient was significantly positive and minimum r.h. was significantly but negatively correlated with aphid population which is in conformity with Mall *et al.*(1992).

White fly (*Bemisia tabaci* Genn.) : Like aphid, the population of white fly was always at a low level on P_1 and P_4 crop and was relatively higher on P_2 and P_3 crop ; maximum being 1.68 and 1.19 per plant respectively. Higher population of white fly was maintained from 5th to 11th standard week *i.e.* during February-March. Naresh and Nene (1980) reported that in Nainital (Terai region of U.P.) white fly remained active from October to May on tomato, which confirms the result under present investigation. Saklani and Mathai (1978) reported that in the plains of India population of *Bemisia tabaci* was higher during spring, which is also in support of the present findings. However, Borah and Bordoloi (1998) recorded higher fly population from the 10th-25th October planted crop and Kobatake *et.al.*(1981) observed peak occurrence of white fly during July on tomato in Japan. However, these observations are not in conformity with the present findings, which might be due to regional climatic variation as influenced by agroclimatic conditions which determine largely the activity and fluctuation of white fly population. In Ludhiana, Punjab white fly was the most active at temperature ranged 33-39^{0}C, Butter and Rataul, (1978) but in terai region of West Bengal temperature never raised too high during the entire crop growing season, therefore, higher population was observed at 17.07-22.13^{0}C temperature, 65.29-72.78% average r.h.. Moreover, the temperature is not the only factor determining the fly population. Rather all the weather parameters combined with the availability of host plants largely determine the size and fluctuation of population of any species. From correlation studies it is observed that temperature, r.h. and rainfall was negatively correlated with white fly population, which is in conformity with the findings of Venugopala Rao and Reddy (1994) where building up of white fly population showed a negative relationship with temperature, rainfall and r.h.. The observation of Butani and Jotwani (1984) also supports the present findings that activity of white fly decreased with the onset of rains. During the period of higher white fly incidence *i.e.* during February-March, r.h. maximum and gradient was significant and positively correlated and minimum and average r.h. was significant and negatively correlated with white fly population. The present results are not in conformity with that of Bharadwaj and Kushwaha (1984) who recorded that the white fly population had negative correlation with r.h. and positive correlation with temperature in Rajasthan. The differences are obviously due to wide variation in temperature and r.h. level in two far distantly located and radically different agro-ecological situations.

Leaf miner (*Liriomyza trifolii* Burgess) : Unlike aphid and white fly, the level of leaf miner infestation gradually increased with the progress of crop growing season. Therefore, the leaf damage was the lowest on P_1 crop and with advancement of season the extent of damage became progressively higher. Although the highest level of infestation (91.92%) was recorded on P_2 crop but infestation was restricted for last few weeks of crop growth stage only, whereas, the percentage of leaf infestation was consistently in higher proportion in last two plantings from very early fruiting stages. On the whole higher level of leaf miner infestation was recorded during the period from 11th to 19th standard week *i.e.* from later part of March to later part of May when average temperature and r.h. ranged from 21.60-27.23^{0}C and 65.39-80.25% respectively, confirms Bagmare *et al.* (1995). Issa and Marcano (1994) observed highest leaf miner infestation during March to May *i.e.*

towards the end of dry season to beginning of the rainy season, which strengthens present observation. In terai region of West Bengal premonsoon rain starts between the later part of March and early part of April which favoured leaf miner infestation. A similar observation was also made by Kapadia (1994) where in North Sourashtra agro-climatic zone leaf miner infestation in tomato was higher during monsoon and summer and also found positive correlation with temperature and rainfall with leaf miner infestation, which is in support to the result of present findings. Rai and Satpathi (1995), however, observed higher leaf miner incidence during January in Uttar Pradesh and Bagmare *et al.* (1995) found a high incidence of the miner during September –October in Jabalpur. These region specific differences are reasonably expected because of quite a significant difference in the climatic conditions influencing leaf miner incidence. From correlation studies between leaf miner incidence and important weather parameters it is observed that the maximum, minimum and average temperature had significantly positive correlation but temperature gradient had significantly negative correlation with leaf miner incidence. Maximum r.h. and its gradient have significantly negative but r.h. minimum and average had significantly positive correlation with leaf miner incidence under present investigation. Although these parameters were significantly but negatively correlated with r.h. during this period of crop growth which might be due to fluctuation of r.h. during the early part of the season as well as crop growth, resulting lower infestation of leaf miner during this part of the season. Bagmare *et al.*(1995) also reported that leaf miner incidence on tomato was found positively correlated with average temperature and negatively correlated with r.h. which supports the results of the present findings.

Tingid bug (*Urentius hystricellus* Richter) : Tingid bug is mainly recognized as a pest of brinjal. However, this pest was also recorded on tomato during later part of growing season from 11th to 17th standard week *i.e.* from March-April. Singh and Mann (1986) reported that the pest was advanced to adult stage during April in Punjab confirms the findings under present investigation. The pest is also active mainly during May and June in Bihar (Yadav, 1978). Although this information is not in conformity with the present record but it is quite possible that the pest can attack tomato during May-June provided the crop is available during the period. Since the crop period in terai region vis-à-vis in the present investigation completed almost before May there is no scope to study further.

Haddaa beetle (*Henosepilachna vigintioctopunctata* Fabr.) : Hadda beetle is a well recognized polyphagous pest having wide diversity of host range and recorded in tomato only during April-May, might be due to non-availability of other suitable host during the period. Singh (1984) reported that the hadda beetle appeared on the plants during March-April and remained active up to October but the highest level of damage is caused during April-May, supports the findings of present studies. An early onset of monsoon rain in terai region limits tomato crop cultivation upto May and, therefore, the pest switch over their attack to other alternate host plants like cucurbits, brinjal etc. which are grown during summer-monsoon months.

Fruit borer (*Helicoverpa armigera* Hubner) : Fruit borer, a cosmopolitan species, is highly polyphagous pest of various economic crops. Although it feeds on foliage at its early stage of development of other host crop but in tomato its attack was very much confined only to the cashable part of the plant *i.e.* fruits. The very soft skin of the young fruits favours boring even by the first instar larvae. Therefore, its incidence was always restricted to the fruiting stage *i.e.* later stage of crop growth irrespective of times of planting. In the area of present investigation the infestation of fruit borer was confined to 7th to 20th standard week *i.e.* from later part of February to May on all the four different crops, the higher number of infestation covered the period from 11th to 20th standard week *i.e.* from March to May when average temperature and r.h. ranged from 20.68 to 28.13^{0}C and 65.39 to 80.25% respectively. In Northern India also the fruit borer appears in the tomato field in late February or early March (Singh, 1984). Sharma *et.al.*(1997) recorded fruit borer incidence in crops planted during the period from 28th March to 12th April in Kulu Valley. In the present study last planting was made on 24th February and borer was recorded till last date of harvest. This indicates that in case of for further delay in crop raising borer incidence could be noted beyond the month of May. Till, the findings under present investigation are in conformity with Sharma *et al.* (1997). Highest fruit borer incidence was observed in mid February and early March (Walker and Cameron, 1990) and initiation of fruit borer incidence on tomato began in 2nd week of April in Harayana as reported by Kalra (1992) quite different from with the present result. The correlation between important weather parameters and borer infestation reveals that maximum, minimum and average temperature and r.h., sunshine hr/day and total rainfall were positively correlated and temperature and r.h. gradient was negatively correlated with borer infestation. Vaishampayan and Veda (1980) also suggested such a relation. According to Sinha and Chakrabarti (1983) the unusual rain during late winter leads to high humidity and ambient temperature that favours the pest population build up. This is also revealed in the present investigation. In case of P_3 and P_4 crops when level of infestation was higher, maximum, minimum and average r.h. had significant and positive correlation but r.h. gradient had significant and negative correlation with borer infestation. Rainfall was found positively correlated with borer infestation supports the findings of Bhat and Virupakshappa (1999) and Jayaramaiah and Babu (1990) but not in conformity with that of Rao *et al.* (1990) and Pimbert and Srivastava (1991) where rainfall deficit promoted growth of borer population.

Natural enemies : The population of natural enemies of different pests studied was always very low. Only two predator species namely *Coccinella septempunctata* and *Menochilus sexmaculata* and a few species of spider were recorded. It has already been discussed that the population of natural enemies not only depends on the prevalent weather conditions but also on the availability and level of pest population. The population of two most important pest-prey (aphid and white fly) never reached in higher level. However, relatively higher activity of these natural enemies was observed during February to April when the climate was moderate and population of pests-prey was relatively high. *Menochilus sexmaculata* population was observed mainly during relatively colder period of the season whereas *Coccinella septempunctata* on warmer period. Spider population, although recorded very low in number throughout the crop growing season, it increased with the increase of ambient temperature.

From the foregoing discussion on incidence of different pest species and their natural enemies it can be said that fruit borer, leaf miner, white fly and aphid are the important pests of tomato in this region. Early crop *i.e.* first planted crop is more or less escaped maximum attack of both the major pests, the leaf miner and fruit borer. The population of hadda beetle and tingid bugs were also negligible at the earlier part of the season. Moreover, this part of the season can be considered as the principal season for tomato, where natural environment also favoured production of the crop. The population of aphid and white fly although appeared in relatively higher proportion but the level of population was not too high to make a devastating situation. This is why productivity of tomato was the highest (77.12 t/ha) in case of P_1 crop. With the advancement of planting season activity of major pests like fruit borer and leaf miner were increased which ultimately resulted in progressively low production of tomato. Therefore, the productivity was lowered gradually, 49.00 t/ha in P_2 crop, 47.05 t/ha in P_3 crop and 38.21 t/ha in P_4 crops respectively. From overall observations it can, therefore, be concluded that raising of tomato in early season produces more yield due to relatively lower incidence of the major pests. However, considering profitability of late crop due to high market value during off-season exploiting natural agro-ecological condition of the region, cultural manipulation is required to keep the incidence of major pests low during later part of season.

Phenological relation with relative incidence of pest population

It has been observed under present investigation that relative incidence of different insect pest species and their natural enemy population on tomato varied widely with different time of planting. Apart from weather the pest structure and their relative infestation were largely determined by the crop growth stage or crop phenology. Relative preference of plant parts by a pest also influenced by crop growth stage. Therefore, stage vulnerability is depends greatly on crop- insect -phenological relationship.

Among the four planted crops the infestation by the two sucking pests, aphid and white fly was always lower on P_1 and P_4 crops and was relatively higher on P_2 and P_3 planted crops. The population of these two pest species was found more abundant during early growth stage of crop.

Aphid (*Aphis gossypii* Glover) : Before appearance of fruits mean aphid population of all the four crops was higher (1.59/leaf) as against later stage of crop growth *i.e.* fruiting stage (0.51/leaf). The finding is in support of Cruz and Bernardo (1971), where the aphid population was reported to cause extensive damage during early growth stage (before-flowering) stage. Contangelo *et al.* (1994) also observed that aphid population reached into peak within few weeks after transplanting supports the results under present studies.

White fly (*Bemisia tabaci* Genn.) : Population of white fly was found active during February-March *i.e.* on the crops of P_2 and P_3 crops in this region. It was also higher at early stage of crop growth (0.51/plant) as compared to fruiting stage (0.22/plant). Butani and Jotwani (1984) also made similar observation that the pest attacks the crop at early stage of crop growth resulted yellowing, wrinkled leaf curl and ultimately shed off leaves. Quiros *et al.* (1995) reported that in Costa Rica leaf curl disease was recorded more on young plants due to the presence of more vector population, white fly, which is in support of the present findings.

Interaction between crop growth stage *i.e.* phenology and pest population was quite remarkable. Variations in pest population over different time of planting in both the stages was significant which might be due to influence of prevailing weather factors at different stages of crop growth, which has already been discussed earlier. However, the variation of pest population at different growth stages in particular may be attributed to the physico-chemical variations in the plants at differences stages of their growth. At early stage, plants remained succulent, cuticular layer was thin and softer, favoured easy penetration of stylet and better nourishment resulting higher population growth of the sucking pests namely aphid and white fly. On the contrary, with the advancement of crop growth, plant parts particularly the leaves and stem, which are also niche of aphid and white fly, became hardy, less succulent, thicker and tough cuticular layer provided resistance in penetration of stylet for sucking and ultimately resulted lower population growth.

Tingid bug (*Urentius hystricellus* Richter) : The tingid bug another sucking pest of tomato, appeared only in the last two planted crop and the population was recorded relatively higher in P_4 crop (1.00/leaf) *i.e.* during mid March to mid May, which is in conformity with the findings of Yadav (1977), where the population was active mainly during May-June. In the present study the population build up depends more on the climatic conditions and the plant age has no impact on the incidence and build up of tingid bug population which contradicts the observation of Veeraval and Bhaskaran (1994) where plant age affects the incidence and build up of *Urentius hystricellus* Richt.

Hadda beetle (*Henosepilachna vigintioctopunctata* Fabr.) : Hadda beetle another minor pest of tomato in this region was found to infest the P_1 and P_4 crop and its population was recorded higher in P_4 crop (0.77/plant), which might be due to influence of climatic conditions, rather than the influence of plant age. Veeraval and Bhaskaran (1994) observed that in Tamilnadu the age of plants did not affect the multiplication of *Henosepilachna vigintioctopunctata* confirms the present results.

Leaf miner (*Liriomyza trifolii* Burgess) : The leaf miner, is one of the most damaging pests of tomato and is very difficult to control through chemical means because of its unique nature of feeding and incidence with relation to plant growth stage. The relative incidence of the pest was maximum during later stage of crop growth *i.e.* during fruiting stage. Average leaf damage of four different planted crops were higher (50.30%) at fruiting stage as against early stage (12.41%). The results are in conformity with Johnson *et al.* (1983) where extensive leaf mining activity reported to reduce photosynthetic capacity of plants and resulted in defoliation and sunscroch, which ultimately resulted lower yield and produced unmarketable fruits in tomato. The interaction between crop growth stage and leaf miner infestation was significantly correlated. A similar result was also obtained by Bagmare *et al.* (1995), where the positive correlation was observed between leaf miner infestation and crop growth. Here also the significant variation over different time of planting was due to prevailing weather conditions that influenced population growth. The leaf miner is an internal feeder, feed within the leaf, with the advancement of plant growth, leaves became thick hence provided better food and shelter to the larva within the leaf favoured higher incidence in later stage of crop growth. Patil *et al.*,(1997) claimed that leaf miner favours and infests more at early stage of plant growth contradicts the present findings. Although at higher level of infestation preference of leaf could not become a factor for plant part selectivity where the question of survivability comes in force that ultimately results to accommodate the highly populated larvae to mine the young leaf for feeding. However, Zenhder and Trumble (1984); Ledieu and Helyer (1985) and Srinivasan *et al.* (1995) recorded leaf miner infestation on middle and bottom canopy. It was further observed that though the eggs are laid on young terminal foliage of side branches but leaf mining occurred on the mature leaves at the low plant height, which is in conformity with the present findings.

Fruit borer (*Helicoverpa armigera* Hubner) : Since fruit borer is very much specific to the food *i.e.* fruits of tomato and, therefore, its incidence is always confined only to the fruiting stage of the crop irrespective of time of planting. Fruit damage was the lowest (8.34%) in P_1 crop, with gradual increase reached highest level (13.19%) in P_4 crop, *i.e.* during late February to May. However, significant variation in level of infestation over crops at different times was observed which might be due to prevailing weather conditions influencing relative abundance of larval population attacking fruits. A similar observation was also made by Singh (1984) where fruit borer was found to prefer egg laying on buds, blooms and flowers and subsequently attack on fruits.

Natural enemies : Natural enemy populations were found to vary with prevailing climatic conditions of different plantings as well as with the host or prey population. The population of all the natural enemies became higher on P_3 crop when the population of sucking pests also recorded relatively higher.

During the P_1 crop the pest attack was minimum which resulted higher yield 77.12 t/ha. With gradual increase of pest population particularly the internal feeders, the yield of tomato crop in subsequent planting started to decline. Significantly the lowest yield was obtained from

P_4 crop which might be due to more abundance of leaf miner during early stages of crop growth as compared to other plantings and higher borer infestation. This findings is at par with that of Johnson *et al.* (1983) and Ledieu and Helyer (1985) who reported that yield loss occurred as a result of leafminer infestation which were not dependent on severity of damage alone but infestation proximity to fruit at an early stage of development was very important.

In the present investigation population build up of the major insect-pest of tomato namely aphid, white fly, leaf miner and fruit borer was influenced by the important weather parameters as well as crop phenology. All the insect-pests as mentioned above are polyphagous in nature. Seasonal development of polyphagous insects is closely correlated to the development of the host plant (Srivastava, 1993). Among the four insect-pests studied, the sucking ones were most active at the early stage of crop growth and the internal feeders were most active at fruiting stage. Again with the advancement of season, population of sucking pests namely, aphid and white fly declined and damage due to internal feeder, namely leaf miner and fruit borer increased gradually. Atwal (1993) reported that by adjusting time of planting, infestation by some pests can be prevented, the egg laying period of a particular pest can be avoided, young plant can be established before the attack start, short duration crop can allow the minimum possible time for pests to multiply or they can mature before the pest appearance. However, activity of all the insect-pests in a complex was at a low level during normal growing season (P_1 crop). Thus by growing tomato in normal season, pressure from pest complex can be avoided to a greater extent but it is very difficult to avoid incidence of insect-pests in complex completely at late season because of the unique pest structure of tomato in the region. Late stage of tomato is the most vulnerable stage of crop growth because the cashable part of the plant *i.e.* fruit is produced at this time. Moreover, value of tomato grown out of normal season is higher. Atwal (1993) suggested pest avoidance by adjusting time of harvesting crop can be saved from the attack of the pest which might become abundant rather late in season. In view of problem in management of internal borer at late stage *i.e.* fruit bearing stage through synthetic insecticides considering toxic residual hazard strategy of pest avoidance through early harvest of mature fruits may be a good proposition to minimize crop loss at this stage. Other pests like aphid, white fly and leaf miner at initial stage of infestation can be controlled by applying any relatively safe insecticide.

5.2 Biology of Important Insect-Pests of Tomato.

The duration of different stages of lifecycle varies significantly among the different seasons studied. The duration of all the stages of leaf cycle of different pests differed significantly with temperature but non-significantly with r.h. This is why, the temperature played an important role in the process of development of different pests. So the activity of the pests was more during warmer part of the year.

Fruit Borer (*Helicoverpa armigera* Hubner) : The duration of different development stages of fruit borer namely the incubation, larval and pupal stages, adult male and female life span and duration of total life cycle varied negatively with temperature and r.h. With the increase of temperature these periods were shortened. But the reproductive stages like preoviposition and oviposition periods showed a positive correlation with temperature as well as r.h. *i.e.* with the increase of temperature and r.h., the activity of reproduction also increased leading into higher population of pest at field level. This findings is in support of Kadu *et al.*(1987), where adult female life, male life, pre reproductive period and incubation period were shortened with the increase in temperature, while reproductive period increased with the rise of every per degree of temperature.

Incubation period was a minimum of 3.1 days at 27-29^{0}C temperature (Ismail and Swailem, 1976), 2.6-3.6 days at 31.1-32.3^{0}C (Singh and Singh, 1975), 3.4 and 2.5 days at 22^{0}C and 28^{0}C (Ongoren *et al.* 1977) were at par with the observations of present investigation. It is noteworthy to mention here that incubation period was shorter, 3.75 days at 28.58^{0}C while longer 5.10 days at 22.71^{0}C temperature. The larval period under present studies was longer during February-March at a temperature range of 23.27-26.54^{0}C and shorter during April-May when the temperature range was 26.67-30.23^{0}C. The effectiveness of these temperature ranges conforms to that of Lefroy (1971), where the duration of larval stage was longer under low temperature conditions. The average larval period in the region under studies was recorded 18.94 days, where in Punjab it was 8-12 days (Singh and Singh, 1975) in Uttar Pradesh 21-28 days (Srivastava and Saxena, 1958).

Average pupal period was 13.66 days in this region. Nachiappan and Subramanium, (1974), observed that the mean pupal duration was 10.7 days. In the present investigation it was also observed that mean pupal period was 10 days at 28.5-31.5^{0}C which is in conformity to that of Sharma (1978) where the pupal period was 8-11 days at 29.4-32.5^{0}C.

The preoviposition and oviposition period were 2-4 and 6 days as reported by Atanasov (1964) which is in conformity with the present studies where the corresponding values were found 1.90 and 5.52 days respectively. Patel *et al.*(1968) recorded preoviposition and oviposition period were 4.25 and 2.66 days contradicts the findings of present investigation. The total life span of male and female under present investigation were 5.00 days and 9.03 days which were at par with Sharma (1978) where females were observed generally lived longer than the males. The duration of total life cycle was about 38.52 days which is almost similar to that of Nachiappan and Subramanium (1974) where total life cycle of *H. armigera* was completed in 35.14 days on tomato.

Leaf miner (*Liriomyza trifolii* Burgess) : In leaf miner, mating and courtship under present investigation was taken place in air which was at par with Daly *et al.*(1978). The maggot started mining from the oviposit side and after attaining maturity came out of the tunnel to pupate supports Natarajan *et al.*(1994) which makes characteristic serpentine mines supports Patil *et al.* (1997). All the developmental stages showed a negative correlation with temperature and r.h. Therefore, at high temperature life cycle is completed at faster rate, which might be the reason of higher level of leaf miner infestation during warmer part of the season. Moreover, average duration of life cycle for four generations were 19.95 days and longer being during February-March.

White fly (*Bemisia tabaci* Genn.) : In case of white fly, the duration of different development stages were increased with the decrease of temperature and r.h. The present results revealed that the duration of all the developmental stages were longer during December-January, while these were shorter during October-November, which is in conformity to the findings of Butani and Jotwani (1984) where the duration of different developmental stages were recorded longer in winter than in summer. Bhardwaj and Kushwaha (1987) reported that the incubation, nymphal, pupal stages lasted on an average 5.9 days, 10.1 days and 6.8 days in Rajasthan but the corresponding values in present studies were 9.87 days, 13.29 days and 5.57 days respectively during October-March, which can be attributed to variation in regional climatic conditions.

In a study by Hendi *et al.*(1987) reported that preoviposition and oviposition periods were 1-2 days and 7-36 days respectively at 30±2^{0}C temperature and 60±5% r.h. while at 25^{0}C temperature and 65% r.h. the preoviposition and oviposition periods were 1-4±0.7 days and 16.7±3.2 days respectively as reported by Salas and Mendoze (1995). The present findings revealed that preoviposition and oviposition period was 1.12 and 2.32 days at 27°C temperature and 77% relatives humidity; and 3.00 and 5.00 days at 21.5°C temperature and 63% r.h. The average duration of the entire life cycle was 30.87 days, which supports the earlier records of Hendi *et al.* (1987) who obtained an average developmental cycle of 34.5±1.4 days.

Thus it can be sum up that the biological activity of the pests is became more during warmer part of the season leading into higher population infestation during the period which ultimately resulted in lower yield as compared to that of winter season. Thus the results from the studies on biological activity of different pests supplement to justify the relative incidence of pest population under field conditions in different times of the crop-growing season.

5.3 Assessment of Crop Loss of Tomato Caused by Important Insect-Pests

Assessment of loss due to pests is the basic prerequisite for decision making in pest management. In the field of agriculture pest problem is complex, dynamic and ever changing in nature, varies with regional climatic conditions, agronomic practices, crop growing season, variety etc. which also influence degree and the magnitude of pest population and subsequent loss caused by them. Considering the subject mentioned above the experiment was conducted in two dominant crop growing season in terai zone with two commonly grown varieties having diverse genetic make up – open pollinated (Pusa Ruby) and hybrid (Abinash-II). In addition to seasonal crop loss of two different varieties, insect-pests population of different species and dominant natural enemies were also recorded to have an idea on relationship between level of pest population and crop loss caused by them.

A critical analysis of the results on assessment of loss showed that the composition of insect-pests species in both the seasons and varieties followed almost similar pattern but variation in their population at different seasons and varieties were much spectacular. A relatively low level of population of all the pest species was observed during winter as compared to that of spring-summer season. The pest-structure was also differed with seasons but not with varieties. This might be due to low temperature and r.h. prevailing in winter season and resulted in natural suppression of pest population due to ecological pressure. Lower incidence of pest during winter season also resulted in better yield (62.33-84.91 t/ha) of crop in all the three years studied.

Table 5.3.1a Comparative account on relative abundance of aphid (*Aphis gossypii* Glov.) between open pollinated and hybrid varieties and interaction with variety and treatment on winter crop.

Treatments	Aphid/leaf											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	0.31	0.21	0.29	**0.27**	0.26	0.21	0.25	**0.24**	0.28	0.21	0.27	**0.26**
	(0.90)	(0.84)	(0.89)	**(0.88)**	(0.87)	(0.84)	(0.87)	**(0.86)**	(0.89)	(0.84)	(0.88)	**(0.87)**
Insecticidal Control	0.11	0.07	0.09	**0.09**	0.07	0.05	0.08	**0.07**	0.09	0.06	0.09	**0.08**
	(0.78)	(0.75)	(0.77)	**(0.77)**	(0.75)	(0.74)	(0.76)	**(0.75)**	(0.77)	(0.75)	(0.77)	**(0.76)**
Fungicidal Control	0.29	0.19	0.27	**0.25**	0.24	0.19	0.23	**0.22**	0.27	0.19	0.25	**0.23**
	(0.89)	(0.83)	(0.88)	**(0.87)**	(0.86)	(0.83)	(0.85)	**(0.85)**	(0.87)	(0.83)	(0.87)	**(0.86)**
Insecticidal and	0.10	0.05	0.08	**0.08**	0.06	0.04	0.06	**0.05**	0.08	0.05	0.07	**0.06**
Fungicidal Control	(0.77)	(0.74)	(0.76)	**(0.76)**	(0.75)	(0.73)	(0.75)	**(0.74)**	(0.76)	(0.74)	(0.75)	**(0.75)**
Mean	**0.20**	**0.13**	**0.18**	**0.17**	**0.16**	**0.12**	**0.16**	**0.14**	-	-	-	-
	(0.84)	**(0.79)**	**(0.83)**	**(0.82)**	**(0.81)**	**(0.79)**	**(0.81)**	**(0.80)**				

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.006	0.008	0.012	0.002	0.006	0.007	0.003	0.005	0.007	0.003	0.004	0.005
CD at 5%	0.017	0.023	N.S.	0.006	0.017	N.S.	0.009	0.014	N.S.	0.009	0.011	N.S.

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

Table 5.3.1b Comparative account on relative abundance of white fly (*Bemisia tabaci* Genn.) between open pollinated and hybrid varieties and interaction with variety and treatment on winter crop.

Treatments	White fly/plant											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	0.78	0.36	0.38	**0.52**	0.60	0.18	0.23	**0.34**	0.89	0.27	0.30	**0.43**
	(1.13)	(0.94)	(0.94)	**(1.04)**	(1.05)	(0.82)	(0.85)	**(0.92)**	(1.09)	(0.88)	(0.90)	**(0.96)**
Insecticidal Control	0.40	0.16	0.12	**0.23**	0.23	0.05	0.07	**0.12**	0.32	0.10	0.09	**0.17**
	(0.95)	(0.82)	(0.79)	**(0.87)**	(0.85)	(0.74)	(0.75)	**(0.79)**	(0.90)	(0.77)	(0.77)	**(0.82)**
Fungicidal Control	0.75	0.33	0.35	**0.49**	0.58	0.17	0.21	**0.32**	0.67	0.25	0.28	**0.40**
	(1.12)	(0.93)	(0.92)	**(1.02)**	(1.04)	(0.82)	(0.84)	**(0.91)**	(1.08)	(0.87)	(0.88)	**(0.95)**
Insecticidal and	0.35	0.14	0.10	**0.20**	0.20	0.04	0.06	**0.10**	0.27	0.09	0.08	**0.15**
Fungicidal Control	(0.92)	(0.81)	(0.77)	**(0.85)**	(0.84)	(0.73)	(0.75)	**(0.77)**	(0.88)	(0.77)	(0.76)	**(0.81)**
Mean	**0.57**	**0.25**	**0.24**	**0.36**	**0.40**	**0.11**	**0.14**	**0.22**	-	-	-	-
	(1.03)	**(0.86)**	**(0.86)**	**(0.93)**	**(0.95)**	**(0.78)**	**(0.80)**	**(0.85)**				

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.008	0.012	0.018	0.004	0.005	0.008	0.004	0.005	0.007	0.004	0.006	0.008
CD at 5%	0.023	0.034	N.S.	0.011	0.014	0.023	0.011	0.014	0.020	0.011	0.017	N.S.

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

Table 5.3.1c Comparative account on relative abundance of leaf miner (*Liriomyza trifolii* Burgess) as mined leaf % between open pollinated and hybrid varieties and interaction with variety and treatment on winter crop.

Treatments	Mined leaf %											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	2.35	1.20	1.35	**1.63**	6.56	4.23	5.21	**5.33**	4.46	2.71	3.28	**3.48**
	(1.68)	(1.30)	(1.36)	**(1.46)**	(2.66)	(2.17)	(2.39)	**(2.41)**	(2.23)	(1.79)	(1.94)	**(1.99)**
Insecticidal Control	1.50	1.03	0.85	**1.13**	4.23	3.58	3.26	**3.69**	2.87	2.30	2.05	**2.41**
	(1.41)	(1.24)	(1.16)	**(1.28)**	(2.17)	(2.02)	(1.94)	**(2.05)**	(1.83)	(1.67)	(1.60)	**(1.70)**
Fungicidal Control	2.30	1.11	1.29	**1.57**	6.45	4.10	5.12	**5.22**	4.38	2.60	3.20	**3.40**
	(1.67)	(1.27)	(1.34)	**(1.44)**	(2.64)	(2.14)	(2.37)	**(2.39)**	(2.21)	(1.76)	(1.92)	**(1.97)**
Insecticidal and	1.35	0.92	0.83	**1.03**	4.08	3.30	3.10	**3.50**	2.71	2.11	4.30	**2.26**
Fungicidal Control	(1.36)	(1.19)	(1.15)	**(1.24)**	(2.14)	(1.95)	(1.90)	**(2.00)**	(1.79)	(1.62)	(6.60)	**(1.66)**
Mean	**1.88**	**1.06**	**1.08**	1.34	**5.33**	**3.80**	**4.17**	**4.43**	-	-	-	-
	(1.54)	**(1.25)**	**(1.26)**	(1.35)	**(2.41)**	**(2.07)**	**(2.16)**	**(2.22)**				

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.015	0.022	0.031	0.011	0.016	0.023	0.010	0.014	0.020	0.008	0.011	0.016
CD at 5%	0.044	0.063	0.089	0.032	0.046	0.067	0.029	0.040	0.058	0.023	0.029	0.046

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

Among the various insect-pests that feed upon tomato four species namely, aphid, white fly, leaf miner and fruit borer occurred in all the three years studied. But the population size of a particular pest species exhibited inter-year and inter-seasonal variations. Of the four pest species the fruit borer is undoubtedly the key one and damages due to this borer can be assessed from the number and weight of the damaged fruits. The damage due to miner, aphid and white fly can be visualized from symptoms caused by them, but the extent of damage is very difficult to quantify directly. However, their cumulative effects were manifested on crop yield. Aphid and white fly were recorded only during winter *i.e.* on normal crop growing season, whereas, tingid bug appeared only during spring-summer *i.e.* out of normal crop growing season or off season. The two key pests, the fruit borer and leaf miner, appeared in both winter and spring-summer seasons. Level of infestation of different pests varied with the season and variety which ultimately manifested in yield and there by gain in yield of tomato. With regard to varieties, level of white fly and aphid population was significantly higher on open pollinated variety (Pusa Ruby) than hybrid (Abinash-II) and interaction between the varieties was significant (Table 5.3.1a-5.3.1b). On the contrary leaf miner infestation was significantly higher on hybrid than on open pollinated variety and interaction between the two varieties was significant (Table 5.3.1c and 5.3.2a). This might be due to thick leaf character of hybrid. Moreover, hybrid was more susceptible to leaf miner attack than open pollinated one and percentage of leaf damage was 3-4 times higher than open pollinated variety in different seasons, 1.63% and 5.33% during winter and 20.04% and 60.36% during spring-summer season on open pollinated and hybrid respectively. Fruit borer infestation was also more on hybrid than on open pollinated variety and was more in spring-summer than in winter season, 7.05% and 7.62% (in number) during winter and 11.02% and 12.96% (in number) during spring-summer on open pollinated and hybrid respectively. The interactions between the borer infestation in number and weight was significant (Table 5.3.1d-5.3.1e and 5.3.2b-5.3.2c).

Tingid bug, a minor pest of tomato, appeared only in spring-summer season and its population was recorded higher in open pollinated variety (1.22/leaf) than hybrid (0.94/leaf) and interaction between two varieties was significant (Table 5.3.2d).

The leaf miner and fruit borer damage the crop both in winter and summer season. The magnitude of damage was higher in summer and hybrid was found more susceptible to these pests. The high level of pest

Table 5.3.1d Comparative account on relative abundance of fruit borer (*Helicoverpa armigera* Hubner) as bored fruit % in number between open pollinated and hybrid varieties and interaction with variety and treatment on winter crop.

Treatments	Bored fruit % in number											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	8.68	5.50	6.96	**7.05**	9.00	6.01	7.85	**7.62**	8.84	5.76	7.40	**7.34**
	(3.03)	(2.45)	(2.73)	**(2.75)**	(3.08)	(2.55)	(2.89)	**(2.85)**	(3.05)	(2.50)	(2.81)	**(2.80)**
Insecticidal Control	5.02	3.39	3.89	**4.10**	5.10	2.78	4.39	**4.09**	5.06	3.08	4.14	**4.09**
	(2.35)	(1.97)	(2.10)	**(2.14)**	(2.37)	(1.81)	(2.21)	**(2.14)**	(2.36)	(1.89)	(2.15)	**(2.14)**
Fungicidal Control	8.73	5.30	6.84	**6.96**	8.98	5.80	7.80	**7.53**	8.86	5.55	7.32	7.24
	(3.04)	(2.41)	(2.71)	**(2.73)**	(3.08)	(2.51)	(2.88)	**(2.83)**	(3.06)	(2.46)	(2.80)	**(2.78)**
Insecticidal and	4.98	3.21	3.69	**3.96**	5.00	2.62	4.00	**3.87**	4.99	2.92	3.84	**3.92**
Fungicidal Control	(2.34)	(1.93)	(2.11)	**(2.11)**	(2.35)	(1.76)	(2.12)	**(2.09)**	(2.34)	(1.85)	(2.08)	**(2.10)**
Mean	**6.85**	**4.35**	**5.52**	5.52	**7.02**	**4.30**	**6.01**	5.78	-	-	-	-
	(2.71)	**(2.20)**	**(2.45)**	(2.45)	**(2.74)**	**(2.19)**	**(2.55)**	(2.50)				

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.012	0.017	0.024	0.015	0.021	0.031	0.025	0.033	0.047	0.009	0.013	0.019
CD at 5%	0.035	0.049	0.069	0.044	0.060	0.090	0.073	0.095	0.136	0.026	0.037	0.055

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

Table 5.3.1e Comparative account on relative abundance of fruit borer (*Helicoverpa armigera* Hubner) as bored fruit % in weight between open pollinated and hybrid varieties and interaction with variety and treatment on winter crop.

Treatments	Bored fruit % in weight											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	7.80	5.00	6.32	**6.37**	8.69	5.89	7.69	**7.42**	8.24	5.44	7.00	**6.89**
	(2.88)	(2.35)	(2.61)	**(2.62)**	(3.03)	(2.53)	(2.86)	**(2.81)**	(2.96)	(2.44)	(2.74)	**(2.72)**
Insecticidal Control	4.52	3.00	3.53	**3.68**	4.92	2.72	4.17	**3.94**	4.72	2.86	3.85	**3.81**
	(2.24)	(1.87)	(2.01)	**(2.04)**	(2.33)	(1.79)	(2.16)	**(2.11)**	(2.28)	(1.83)	(2.09)	**(2.08)**
Fungicidal Control	7.74	4.75	6.21	**6.24**	8.65	5.82	7.64	**7.37**	8.20	5.28	6.93	**6.80**
	(2.87)	(2.29)	(2.59)	**(2.60)**	(3.02)	(2.51)	(2.85)	**(2.81)**	(2.95)	(2.40)	(2.72)	**(2.70)**
Insecticidal and Fungicidal Control	4.38	2.85	3.35	**3.53**	4.82	2.57	3.92	**3.77**	4.60	2.71	3.64	**3.65**
	(2.21)	(1.83)	(1.96)	**(2.01)**	(2.31)	(1.75)	(2.10)	**(2.07)**	(2.26)	(1.79)	(2.03)	**(2.04)**
Mean	**6.11**	**3.90**	**4.85**	**4.96**	**6.77**	**4.25**	**5.86**	**5.63**	-	-	-	-
	(2.57)	**(2.10)**	**(2.31)**	**(2.34)**	**(6.69)**	**(2.18)**	**(2.52)**	**(2.47)**				

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.010	0.019	0.022	0.013	0.019	0.029	0.022	0.030	0.045	0.006	0.010	0.015
CD at 5%	0.029	0.055	0.064	0.038	0.055	0.083	0.064	0.086	0.131	0.017	0.029	0.044

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

Tables 5.3.1f Comparative account of yield between open pollinated and hybrid varieties and interaction with variety and treatment on winter crop.

Treatments	Yield t/ha											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	42.26	33.3	54.85	**43.48**	74.00	62.33	84.91	**73.75**	58.13	47.83	69.88	**58.62**
Insecticidal Control	48.47	36.79	60.67	**48.65**	85.36	69.25	94.25	**82.95**	66.91	53.02	77.46	**65.80**
Fungicidal Control	46.36	38.62	56.87	**47.28**	82.32	72.74	89.27	**81.01**	64.34	55.54	73.07	**64.14**
Insecticidal and Fungicidal Control	53.17	42.00	62.61	**52.59**	92.87	80.66	98.20	**90.53**	73.02	61.33	80.41	**71.56**
Mean	**47.57**	**37.69**	**58.75**	**48.00**	**83.64**	**71.17**	**91.66**	**82.06**	-	-	-	-

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.530	0.750	1.067	0.588	0.831	1.176	0.512	0.724	1.024	0.305	0.431	0.610
CD at 5%	1.542	2.153	3.094	1.711	2.385	3.410	1.490	2.078	2.969	0.887	1.237	1.769

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

population during summer resulted much lower yield even less than half in summer crop (27.15 t/ha in control) than winter crop (58.62 t/ha in control) (Table 5.3.1f and 5.3.2e), although climate influences on crop growth and yield can not be ignored. Since pest infestation was higher on spring-summer crop and again more on hybrid, gain in yield was also higher from hybrid in all season in general and further more in summer in particular.

In light of present investigation a look into the earlier works showed that tomato fruit borer is the key pest of tomato all over the world although extent of damage and loss in yield of tomato varied with region and crop growing season. Damage due to fruit borer was recorded to make the fruit unfit for human consumption, hence causes considerable crop loss (Kashyap, 1983), even the entire crop in many tomato growing areas of United States (Fery and Cuthbert, 1974). In India extent of damage due to fruit borer varied with region. Loss of tomato fruit due to borer extended upto 40-50% in Tamilnadu (Srinivasam, 1959), 36% and 51.2% (Singh and Singh, 1975 and Singh and Narang, 1990 respectively) in Punjab, 40-50% in Bangalore by KhaderKhan *et al.*(1997) and 50% (Lal, 1985). However, avoidable loss was assessed 32.52% in M.P. (Ganguli and Dubey, 1998) and 9.3-44.3% in number and 16.1-41.6% in weight in Harayana (Kaushik, 1991). Whereas economic damage level for *H. armigera* in tomato was recorded 3.48% (Tewari and Rao, 1987). In terai region of West Bengal fruit damage in wt. was extended upto 6.37% in open pollinated and 7.42% in hybrid during winter season and it become 9.99% and 11.80% to open pollinated and hybrid respectively during spring-summer crop indicates always higher than economic damage level. However, the variation in loss in yield of tomato was might be due to regional climate variation in different season, which influenced relative abundance of insect-pests population. A critical review from earlier work shows that percentage of fruit damages is consistently higher in late planting crop (70.4% and 52.4% fruit damage in number and weight) and yield was observed declining progressively in late season (Ogunwolu, 1989). In present investigation damage due to borer was higher on late planted crop (Spring-summer crop) than normal growing season in winter, confirms the Ogunwolu (1989). The present investigation also confirms Singh and Chahal (1978) where *H. armigera* was recorded to damage 18.2-55.3% to the fruits in the month of April-May *i.e.* late tomato growing season, however, magnitude of damage is quite higher than in the present investigation.

White fly, a potent vector of leaf curl viral disease of tomato was recorded to cause complete yield loss of tomato during late summer and

Table 5.3.2a Comparative account on relative abundance of leaf miner (*Liriomyza trifolii* Burges) as % mined leaf between open pollinated and hybrid varieties and interaction with variety and treatment on spring-summer crop.

Treatments	Mined leaf %											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	20.37	22.87	16.87	**20.04**	61.97	63.11	56.01	**60.36**	41.17	42.99	36.44	**40.20**
	(4.51)	(4.83)	(4.17)	**(4.53)**	(7.91)	(7.90)	(7.52)	**(7.80)**	(6.46)	(6.59)	(6.08)	**(6.38)**
Insecticidal Control	13.00	15.10	7.20	**11.77**	40.90	42.78	23.91	**35.86**	26.95	28.94	15.55	**23.81**
	(3.67)	(3.95)	(2.77)	**(3.50)**	(6.43)	(6.58)	(4.94)	**(6.02)**	(5.24)	(5.43)	(4.01)	**(4.93)**
Fungicidal Control	20.00	21.37	16.67	**19.35**	61.10	61.12	55.85	**59.36**	40.55	41.24	36.26	**39.36**
	(4.53)	(4.68)	(4.14)	**(4.46)**	(7.85)	(7.84)	(7.50)	**(7.36)**	(6.41)	(6.46)	(6.06)	**(6.31)**
Insecticidal and	12.87	15.00	7.00	**11.62**	40.12	43.12	23.32	**35.52**	26.49	29.06	15.16	**23.57**
Fungicidal Control	(3.66)	(3.95)	(2.74)	**(3.48)**	(6.37)	(6.60)	(4.88)	**(6.00)**	(5.19)	(5.44)	(3.96)	**(4.91)**
Mean	**16.56**	**18.58**	**11.93**	**16.70**	**51.02**	**52.53**	**39.77**	**47.77**	-	-	-	-
	(4.13)	**(4.37)**	**(3.53)**	**(4.02)**	**(7.18)**	**(7.82)**	**(6.34)**	**(6.94)**				

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.187	0.070	0.375	0.623	0.881	1.246	0.265	0.374	0.529	0.141	0.200	0.283
CD at 5%	0.544	0.201	1.091	1.813	2.528	3.613	0.771	1.073	1.534	0.410	0.574	0.821

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

Table 5.3.2a Comparative account on relative abundance of leaf miner (*Liriomyza trifolii* Burges) as % mined leaf between open pollinated and hybrid varieties and interaction with variety and treatment on spring-summer crop.

Treatments	Mined leaf %											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	20.37	22.87	16.87	**20.04**	61.97	63.11	56.01	**60.36**	41.17	42.99	36.44	**40.20**
	(4.51)	(4.83)	(4.17)	**(4.53)**	(7.91)	(7.90)	(7.52)	**(7.80)**	(6.46)	(6.59)	(6.08)	**(6.38)**
Insecticidal Control	13.00	15.10	7.20	**11.77**	40.90	42.78	23.91	**35.86**	26.95	28.94	15.55	**23.81**
	(3.67)	(3.95)	(2.77)	**(3.50)**	(6.43)	(6.58)	(4.94)	**(6.02)**	(5.24)	(5.43)	(4.01)	**(4.93)**
Fungicidal Control	20.00	21.37	16.67	**19.35**	61.10	61.12	55.85	**59.36**	40.55	41.24	36.26	**39.36**
	(4.53)	(4.68)	(4.14)	**(4.46)**	(7.85)	(7.84)	(7.50)	**(7.36)**	(6.41)	(6.46)	(6.06)	**(6.31)**
Insecticidal and	12.87	15.00	7.00	**11.62**	40.12	43.12	23.32	**35.52**	26.49	29.06	15.16	**23.57**
Fungicidal Control	(3.66)	(3.95)	(2.74)	**(3.48)**	(6.37)	(6.60)	(4.88)	**(6.00)**	(5.19)	(5.44)	(3.96)	**(4.91)**
Mean	**16.56**	**18.58**	**11.93**	**16.70**	**51.02**	**52.53**	**39.77**	**47.77**	-	-	-	-
	(4.13)	**(4.37)**	**(3.53)**	**(4.02)**	**(7.18)**	**(7.82)**	**(6.34)**	**(6.94)**				

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.187	0.070	0.375	0.623	0.881	1.246	0.265	0.374	0.529	0.141	0.200	0.283
CD at 5%	0.544	0.201	1.091	1.813	2.528	3.613	0.771	1.073	1.534	0.410	0.574	0.821

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

Table 5.3.2c Comparative account on relative abundance of fruit borer (*Helicoverpa armigera* Hubner) as bored fruit % in weight between open pollinated and hybrid varieties and interaction with variety and treatment on spring-summer crop.

Treatments	Bored fruit % in weight											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	12.52	10.00	7.45	**9.99**	13.91	11.72	9.76	**11.80**	13.21	10.86	8.61	**10.89**
	(3.61)	(3.24)	(2.82)	**(3.24)**	(3.80)	(3.49)	(3.20)	**(3.51)**	(3.70)	(3.37)	(3.02)	**(3.38)**
Insecticidal Control	7.90	6.50	4.45	**6.28**	8.17	7.95	5.95	**7.35**	8.04	7.22	5.20	**6.82**
	(2.90)	(2.65)	(2.22)	**(2.60)**	(2.94)	(2.91)	(2.54)	**(2.80)**	(2.92)	(2.78)	(2.39)	**(2.70)**
Fungicidal Control	11.90	9.75	7.25	**9.63**	13.75	11.60	9.72	**11.69**	12.82	10.67	8.49	**10.66**
	(3.52)	(3.20)	(2.78)	**(3.18)**	(3.77)	(3.48)	(3.20)	**(3.49)**	(3.65)	(3.34)	(3.00)	**(3.34)**
Insecticidal and	7.71	6.32	4.25	**6.09**	8.00	7.65	5.65	**7.10**	7.86	6.98	4.95	**6.59**
Fungicidal Control	(2.87)	(2.61)	(2.18)	**(2.57)**	(2.92)	(2.85)	(2.48)	**(2.76)**	(2.89)	(2.74)	(2.33)	**(2.66)**
Mean	**10.01**	**8.14**	**5.85**	**7.99**	**10.96**	**9.73**	**7.77**	**9.48**	-	-	-	-
	(3.24)	**(2.94)**	**(2.52)**	**(2.92)**	**(3.36)**	**(3.20)**	**(2.88)**	**(3.16)**				

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.022	0.030	0.048	0.012	0.020	0.030	0.020	0.029	0.040	0.015	0.022	0.028
CD at 5%	0.064	0.086	0.139	0.035	0.057	0.086	0.057	0.083	0.116	0.044	0.064	0.080

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

Table 5.3.2d Comparative account on relative abundance of tingid bug (*Urentius hystricellus* Richt.) between open pollinated and hybrid varieties and interaction with variety and treatment on spring-summer crop.

Treatments	Tingid bug/leaf											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	1.16	1.64	0.86	**1.22**	1.02	1.14	0.65	**0.94**	1.09	1.39	0.76	**1.08**
	(1.29)	(1.46)	(1.16)	**(1.31)**	(1.23)	(1.28)	(1.07)	**(1.20)**	(1.26)	(1.37)	(1.12)	**(1.25)**
Insecticidal Control	0.53	0.84	0.29	**0.55**	0.48	0.53	0.21	**0.41**	0.50	0.68	0.25	**0.48**
	(1.01)	(1.16)	(0.89)	**(1.02)**	(0.99)	(1.01)	(0.84)	**(0.95)**	(1.00)	(1.09)	(0.87)	**(0.99)**
Fungicidal Control	1.10	1.56	0.83	**1.16**	0.98	1.06	0.63	**0.89**	1.04	1.31	0.73	**1.02**
	(1.26)	(1.03)	(1.15)	**(1.29)**	(1.22)	(1.25)	(1.06)	**(1.18)**	(1.24)	(1.34)	(1.11)	**(1.23)**
Insecticidal and	0.50	0.76	0.27	**0.51**	0.45	0.50	0.20	**0.38**	0.47	0.63	0.23	**0.44**
Fungicidal Control	(1.00)	(1.12)	(0.88)	**(1.00)**	(0.97)	(1.00)	(0.84)	**(0.94)**	(0.98)	(1.06)	(0.86)	**(0.97)**
Mean	**0.82**	**1.20**	**0.56**	**0.86**	**0.73**	**0.81**	**0.42**	**0.66**	-	-	-	-
	(1.15)	**(1.30)**	**(1.03)**	**(1.17)**	**(1.11)**	**(1.14)**	**(0.96)**	**(1.07)**				

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.005	0.007	0.010	0.009	0.013	0.018	0.005	0.008	0.012	0.002	0.003	0.004
CD at 5%	0.015	0.020	N.S.	0.026	0.037	N.S.	0.015	0.023	0.035	0.006	0.009	0.012

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

Table 5.3.2e Comparative account of yield between open pollinated and hybrid varieties and interaction with variety and treatment on spring-summer crop.

Treatments	Yield t/ha											
	Open pollinated				Hybrid				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Untreated	17.22	10.00	18.68	**15.30**	41.00	30.56	45.43	**39.00**	29.11	20.28	32.05	**27.15**
Insecticidal Control	22.93	13.23	24.00	**20.05**	56.00	42.00	59.67	**53.18**	39.46	27.61	41.84	**36.61**
Fungicidal Control	20.37	12.17	20.65	**17.73**	45.78	37.87	50.85	**44.83**	30.08	25.02	35.75	**.31.28**
Insecticidal and Fungicidal Control	25.11	14.60	26.55	**22.09**	61.70	47.78	65.00	**58.16**	43.40	29.69	45.77	**40.12**
Mean	**21.41**	**11.75**	**22.47**	**18.79**	**51.12**	**39.55**	**55.24**	**48.79**	-	-	-	-

Figure in parenthesis indicate square root transformed value

	96-97			97-98			98-99			Mean		
	T	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**	**T**	**V**	**T x V**
SEM ±	0.394	0.558	0.789	0.424	0.599	0.847	0.355	0.502	0.711	0.225	0.318	0.451
CD at 5%	1.146	1.601	2.288	1.234	1.719	2.464	1.033	1.441	2.062	0.655	0.913	1.308

T= Treatments, V= Varieties, T x V= Interaction between treatments and varieties

autumn in Egypt (Shaheen, 1979). Similar report was also made by Kobatake *et al.*(1981) from Japan where it was normally attacked during mid July and rapidly reached at highest level during August. However, these informations are contradictory with the present findings where white fly was only recorded during normal growing season in winter although population was never reached at threshold level. The present finding is in conformity with Butter and Rataul (1978) and Mustafa *et.al.*(1991) where transmission of tomato leaf curl virus by white fly was more effective to winter than summer crop at Ludhiana and TYLCV disease was very little on summer crop in Egypt respectively.

In Karnataka, it was higher during February-May and caused upto 100% loss of crop and in July-November the incidence ranged from 17-53%. Tomato cv. Pusa Ruby was observed to suffer from 50-70% yield loss when sown in February-May. This might be due to more or less equitable climate that favoured year found activity of white fly transmitting leaf curl disease. Singh (1989) recorded 93% yield loss due to devastating leaf curl disease transmitted by white fly. However, in terai region population of white fly was always far below than threshold level and thereby little or no leaf curl disease was witnessed during the period of investigation. aphid was reported to cause 1-6% crop loss in tomato (Stoltz *et al.*1997) but in terai region its population was at a lower level.

Leaf miner caused severe damage to tomato plant resulting enormous loss in crop yield. However, loss due to leaf miner is not dependent only on severity of damage alone but proximity to fruit at early development stage is most important. Ledieu and Helyer (1985) observed 10% loss during April-May at fruit development stage when 30 mines were recorded per leaf. Jhonson *et al.*(1983) observed that leaf mining badly affect photosynthesis. Pawar *et al.*(1995) reported 50.7% leaf damage by leaf resulting 22.5% reduction of yield during kharif season.

From critical review of earlier work it is observed that extend of damage and crop loss due to insect-pests have been assessed on the basis on individual pest species. But in the practical field of agriculture it is very difficult to assess loss by any individual pest because the different pests have different feeding habit and also feed at different stage of crop growth. Therefore, reduction in yield is the cumulative effect by all pest species involve in damage in a complex. It has already been mentioned that among the different pests feed upon tomato plant, damage due to fruit borer can be quantified only through percentage of fruit damage or bored, till loss in yield by a simple pest species is difficult to quantity.

It can be possible only if the crop is grown under condition out of natural crop eco-system. Therefore, crop loss assessed by the pest complex under present investigation is more comprehensive and practical. Thus it can be summerised that tomato crop in terai zone suffer more in spring-summer season than winter and open pollinated varieties suffered less than hybrid which ultimately resulted higher gain in yield during spring-summer season and also from hybrid crops. The conventional recommended pesticide measures could not protect the crop fully from the attack of insect-pests. However, loss of fruit yield of tomato can be saved 10.63% and 11.00% in winter and 23.69% and 26.66% in spring-summer from open pollinated (cv.Pusa Ruby) and hybrid (Abinash-II) respectively, by using insecticide (malathion @ 0.05%) and carbofuran @ 2gm/plant).

5.4 Evaluation of Tomato Varieties against Insect-Pest, Natural Enemies and Yield.

The results from the insect-pest interaction on different tomato varieties and as a consequence the incidence and abundance of natural enemies and their total effect on tomato yield revealed that out of the seven varieties evaluated neither was completely resistant to the pest complex nor to an individual pest. A variety found tolerant/less susceptible to one pest, showed more susceptibility to another. Pusa Ruby, the representative of open pollinated variety under present investigation was found more susceptible to both the sucking pests while showed less susceptibility to the internal feeders. Among the hybrids Abinash-II recorded the highest leaf miner infestation but was tolerant to white fly. The hybrid Rasika was also more susceptible to leaf miner and fruit borer than to the sucking pests. The hybrid Arjuna and Rupali, however, were moderately tolerant to all the pest. The hybrids in general yielded higher than the open pollinated ones because of their inherent genetic capacity which influenced yield attributing characters like larger size and weight of fruit leading into higher yield of tomato. Among the hybrids Arjuna was out yielder followed by Abinash –II and Rupali.

An attempt has been made to rank the varieties and hybrids against individual pest species which is summerised below :

Aphid : Pusa Ruby > Divya > Rupali > Abinash-II > Arjuna > Rasika > Kubergeeta

Whitefly : Pusa Ruby > Rupali > Rasika > Arjuna > Kubergeeta > Divya > Abinash-II
Leaf miner : Abinash –II > Rasika > Kubergeeta > Rupali > Divya > Arjuna > Pusa Ruby
Fruit borer (%) : Rasika > Arjuna > Rupali > Divya > Abinash –II > Kubergeeta > Pusa Ruby.

Lal (1991) reported that high yielding varieties and hybrids required more pesticidal treatments as they are often susceptible to insect pests. In present investigation also hybrids in general showed more susceptibility to insect-pests than the high yielding open pollinated one. Pusa Ruby showed moderate susceptibility to fruit borer and more to white fly vector of leaf curl virus, this was at par with the findings of Banerjee and Kalloo (1989) who reported that HA-101, Pusa Ruby, Red Chery and Manzana were moderately to highly susceptible to leaf curl virus, fusarium wilt and fruit borer. The F_1 hybrid BSS – 98 was noted to be the most susceptible to leaf miner infestation in Uttar Pradesh (Rai and Satpathi, 1995). In the present investigation too hybrids in general and Abinash-II in particular suffered more from leaf damage due to miner than Pusa Ruby. Pandey *et al.*(1995) reported that H-24 witnessed minimum incidence of leaf curl virus (9.4%) whereas, Pusa Ruby recorded (70%) higher incidence which might be due to the higher number of white fly vector acting upon the variety. In present investigation Pusa Ruby although recorded highest white fly population but the leaf curl disease was not so much severe. The result under present investigation supports Borah (1996).

More borer infestation (in term of percentage) was recorded on the hybrids than on the open pollinated variety Pusa Ruby. The hybrid Rasika recorded the highest bored fruit percentage in number and weight (10.36% and 8.29%) and Pusa Ruby recorded the lowest bored fruit (7.06% and 5.61%) in number and weight. This is in conformity with Shukla *et al.* (1993) where in Satpura Plateau, Pusa Ruby suffered least fruit damage (3.20%) among the twelve tomato cultivars, but the difference in level of infestation was might be due to variation in regional climatic conditions. In Assam open pollinated variety Pusa early dwarf witnessed more (20.20%) borer attack as compared to hybrids namely Akra abha (15.00%) and Akra vikas (16.40%) (Borah, 1996) contradicts present findings. The hybrids Arjuna in the present investigation although recorded higher average pest incidence but also produced the highest fruit yield that differed significantly from rest of the varieties studied. The result is in conformity with that of Borah (1996) where Akra vikas yielded higher (66.90t/ha) though had 16.40% fruit borer attack. It can, therefore, be said that fruit borer though caused damage substantially but could not able to affect the inherent character of the variety. Moreover, hybrids because of their unique genetical make up can produce higher yield even at higher level of borer incidence. In the present investigation it has been observed that the fruit borer infestation was the lowest in Pusa Ruby in number (7.00%) and weight (5.61%) when rated in percentage and thus it was designated as least susceptible among the varieties studied. On the contrary when bored fruit was rated in number per plant, it was remarkably the highest in case of Pusa Ruby (10.05/plant). This might be due to higher number of fruits produced by a single plant (127.66) and this number when converted into percentage the value was lowered. This finding is in conformity with Fery *et al.* (1979) who observed that genotypes with many small fruits per plant often appeared to be more susceptible than the leading commercial cultivars when rated on a number basis but proved more resistant when rated on a percentage basis. This might be due to the smaller size and weight of fruit in the open pollinated variety Pusa Ruby (38.19 gm) as compared to the hybrid (81.21-112.19 gm). The hybrid Arjuna though produced the lowest number (71.40/plant) of fruits among the varieties studied but yield was significantly higher (84.34 t/ha) due to larger size and better weight of single fruit. Moreover, the open pollinated varieties are indeterminate type having longer fruiting period. Therefore, it can produce more number of tomato for a prolonged period as compared to hybrids suffering higher number of fruit damage by borer, but when converted into percentage, the value of fruit damage became lowered and such variety seems to be less susceptible. Gashawbeza and Tsedeko (1993) found Pusa Ruby more resistant against fruit borer contradicts to that of the present investigation. The present result further contradicts Canerday *et al.* (1969) who reported that small-fruited processing cultivars were less susceptible than the fresh-marketed cultivars and thus suggested that the differences between cultivars may be caused by a simple dilution factor than by true resistance. The degree of fruit boring was not too much different among the varieties studied. However, Kashyap and Verma (1986) recorded 42.55% damage of tomato fruits on susceptible varieties while it was only 1.7-2.9% in resistant cultivars. It could not be possible by a simple dilution factor as stated by Canerday *et al.*(1969).

Arjuna among all the varieties and hybrids studied showed moderate tolerance to all the pests and was out yielder followed by Abinash-II and Rupali.

It is imperative to discuss here that the resistant varieties are the most effective, economical, practical and easiest means of integrated pest management. Moreover, it is safe and compatible with all other methods of pest control. Most of the modern varieties released and grown widely in insect-pest prone areas provides resistance to at least one insect-pests or disease. However, with the introduction of national seed policy under present global economic and commercial scenario seeds of different varieties from various sources are being introduced in the country without following classical methods of evaluation of varieties. Since the farmers are more concerned about the yield and keeping quality of tomato fruits for long distance transport mostly ignore pest-disease problem because they are managed by usual chemical means without considering health and environmental hazard. The development of insect biotypes capable of surviving on resistant plant further appears to be major threat to the extensive use of resistant varieties. Therefore, high level of resistance is not always necessary.

In perspective of present socio-techno-economic situation of the terai region commonly grown tomato varieties and hybrids were evaluated. From the observation of three years studies of these variety and hybrids it was found that the hybrid Arjuna was moderately tolerant or less susceptible to pest complex of tomato and also have higher productivity. Thus use of moderately tolerant Arjuna hybrid in combination with need based applications of safer pesticides would produce economic yield through further suppression of the pest.

5.5 Management of Insect-Pests Complex of Tomato Through Pesticides

The present experiment has been carried out for two fold of objectives-firstly, for comparison of the usual recommended synthetic pesticides with those of biologically origin and secondly, for effectiveness of biologically origin pesticides at field level in view of serious health and environmental hazard posed by the excessive use of toxic synthetic pesticides in order to develop a sustainable agricultural production system vis-à-vis to meet the export demand for pesticides free commodities in changing agricultural scenario under global perspective. It is quite apparent that tomato fruit borer and leaf miner are the key pests of tomato in this zone and these pests are more dangerous at the fruit bearing stage of crop growth. The larvae of fruit borer or leaf miner that once enter in the fruit or leaf are difficult to control by any conventional pesticidal measures. Moreover, the fruits of tomato are plucked at frequent intervals and consumed raw as salad or after little cooking or processing. As a result there is very possibility to retain toxic pesticidal residue within the fruits which may cause health hazard. Growers are mostly concerned about the loss caused by fruit borer because the larvae once enter into the fruits make them unfit for human consumption and such fruits have no market value, hence cause huge economic loss. Again the leaf miner affects the photosynthetic activity of the plant resulting poor yield of tomato. Such problems compel the growers to be over-dependent on synthetic hazardous insecticides to save their crop where health and environment paid least or no attention.

Keeping parity with the objectives delineated above only seven pesticides each representing distinct source of origin were evaluated. Among them, malathion and DDVP are synthetic ones widely recommended for combating pests of tomato considering its shorter persistency and lower mammalian toxicity to avoid toxic hazard from the fruits plucked at frequent interval. Rest of the pesticides were of biological origin and safer to health and environment. Among them, azadirachtin, a botanical pesticide, *Bacillus thuringiensis* var. *kurstaki*, a bacterium, pathogenic to insects, *Beauveria bassiana* an entomofungus and avermectin a microbial toxin produced by a soil borne actinomycetes (*Streptomyces avermitilis*). A critical analysis of the overall performance of the pesticides revealed that avermectin and DDVP were found superior over others with regard to suppression of pest complex which was reflected in yield of tomato too.

Malathion : Malathion, a stomach and contact poison insecticide, provided good control at 3 days after spraying against leaf miner (42.33%) and tingid bug (75.91%). After 8 days of treatment, the level of suppression was although reduced but it provided moderate control of leaf miner (32.49%) and tingid bug (64.43%). Pawar *et al.* (1996) reported that malathion @ 0.05% suppressed 57.79% mined leaf of tomato after 8 days of spraying in Rahuri, which contradicts the findings from the present investigation. After 14 days of spraying it was not much effective, against tomato fruit borer, due to its peculiar feeding behaviour. Till it suppressed to an extent of 35.79% of fruit boring. Singh and Chahal (1978) found best results by alternative sprays with malathion and carbaryl at 10 days interval starting from leaf perforation against *H. armigera.* However, malathion was recorded more harmful to spiders, since, it killed spider fauna resulted in suppression on spider population to a level of 45.12% which was at par with Ghosh (1999) where the suppression level was 46.08% in Brinjal.

DDVP : DDVP is also a synthetic organic insecticide having stomach and contact action but it is relatively safer to health and environment because of its low persistency. DDVP @ 0.05% provided good control in different days after treatment over all other pesticides evaluated. It was found that DDVP lowered down the pest population of different species particularly the leaf miner and tingid bug significantly after 3 days of spraying. DDVP in present investigation suppressed 51.58%, 44.63% and 36.96% leaf miner attack at 3, 8 and 14 days after spraying respectively and 87.56%, 73.53% and 61.94% tingid bug population at 3, 8 and 14 days after spraying respectively. Pawar *et al.* (1996) reported that DDVP @ 0.076% resulted 54.04% suppression against leaf miner infestation after 8 days of treatment which is not in conformity with present findings and might be due to variation in regional climatic condition and concentration level used. DDVP was not much effective against fruit borer, since it remain concealed inside the fruit. Till it suppressed to a level of 46.81% of fruit in number and 49.64% of fruit in weight. DDVP has adverse effect on spider fauna. It is found that it significantly suppressed spider population to a level of 45.12%. In present investigation DDVP was found to be most effective against all the pests found during the course of investigation which was at par with Srivastava (1993) where DDVP was found most efficacious against sucking pests, miners and borers. However, it was reported comparatively more effective than malathion and other insecticides studied in the experiment except avermectin and NPV against the fruit borer. This might be due to its added fumigation action.

Azadirachtin : Azadirachtin is a well-known botanical pesticide, obtained from *Azadirachta indica,* which is a safer pesticide. It provided better control at 3 days after spraying and suppressed the infestation of different pest to an extent of 27.85% leaf miner, 72.70% of tingid bug. After 8 days of spraying it provided moderate to low control of these two pests. It was rather not effective after 14 days after spraying. However, azadirachtin suppressed 31.89% and 31.85% fruit borer in number and weight. The level of suppression of pest infestation were significantly lower among the pesticides studied. In present studies azadirachtin @ 1500 ppm *i.e.* @ 2.5 ml/1 was least effective against leaf miner. Pawar *et al.*(1996) and Jagannatha (1994), used neem seed kernel extract 5% and 4% and obtained effective results against *Liriomyza trifolii* in Rahuri and Bangalore respectively. This might be due to difference in source and concentration level that influenced efficiency of azadirachtin against the same pest. However, it gives clear indication that better result could be achieved at higher concentration level.

Therefore, the usual recommended concentration that has been followed against different pests in present investigation was too low to achieve better results. Mustafee (1997) reported that lepidopteran larvae were particularly sensitive to neem derivatives as it disrupted growth and acted as antifeedant agents. The present results showed that azadirachtin was least effective against fruit borer larvae, as the larvae feed inside the fruit and, therefore, escape contamination of neem products resulting lower efficacy against fruit borer larvae. Sharma and Patel (1994) and Lal and Lal (1996) also observed that neem oils were found least effective against the larvae of *Helicoverpa armigera*. Azadirachtin was also found moderate to highly harmful to spider fauna.

In order to overcome the undesirable and adverse effect of the wide spread, broad spectrum synthetic insecticides, now-a-days a large number of microorganisms comprising of bacteria, fungi, protozoa, viruses, nematodes etc. are used as disease causing organisms of crop pest for their suppression with least disruption of human health and environment (Dutky, 1959).

Bacillus thuringiensis **:** Among the different micro-organisms or bio-insecticides used against crop pests *Bacillus thuringiensis* (Bt.) derived from the common soil bacterium *Bacillus* are increasingly important for pest management. Insecticidal crystal proteins (also known as δ-endotoxins) from Bt are extremely toxic to certain pests yet cause little or no harm to human, to most beneficial insects, and to other non-target organisms (Croft, 1990 and Flexner *et al.*1986). After proteolytic activation in the insect midgut, Bt. toxins bind to the brush border membrane of the mid gut epithelium and create pores that cause cells to swell and lyse (Gill *et al.*1992). Technical innovations including expression of Bt. toxin genes in transgenic crop plants and transgenic bacteria should increase the usefulness of Bt. (Boulter *et al.*1990; Brunke and Meeusen, 1991; Feitelson *et al.*1992; Gasser and Fraley, 1989; Meeusen and Warren, 1989; Peferoen, 1992; Lambert and Peferoen, 1992 and Lereclus *et al.*1992). At the same time, mounting concerns about environmental hazards and widespread resistance in pest population are reducing the value of conventional synthetic insecticides.

Bacillus thuringiensis var *kurstaki* (Bt.) in present investigation, was found moderate to highly effective to all the pest on tomato after 3 days of spraying. It was found more effective against tingid bug, suppressed the pest to an extent of 72.19% at 3 days after spraying than leaf miner (32.66%). The effectiveness was decreased gradually as observed at 8 and 14 days after spraying. Bt was effectively suppressed fruit boring percentage (48.21%

and 48.85% in number and weight respectively). The finding is in conformity with that of Gupta *et al.*(1997), where the sprays with Dipel 8L a commercially available formulation of Bt. (2ml/l of water) reduced fruit borer larvae upto 47.2% in Udaypur. Tanada (1956) and Hemipel (1967) reported that it is widely used against lepidopteran pest of various crops, such as, *Pieris* and *Trichoplusia* on cruciferous, *Manduca* on tomato and tobacco, *Heliothis* on cotton and tomato, which is also supported of present investigation. Bt was found less harmful to spider fauna. The unique feature of Bt. is that it has no harmful effect on birds and mice (Smirnoff and Macleod, 1961) on honeybee colonies (Wilson, 1962); on birds, animals and useful insects (Nedkova *et al.*1980); on earthworm (Benz and Altwegg, 1975). It can therefore be said that lepidopteran pests are highly susceptible to Bt. having widest spectrum of activity.

Beauveria bassiana **:** The entomogenous fungus *Beauveria bassiana* although was not much effective against pest complex of tomato in present investigation, but suppressed significantly more pest population after 3 days of treatment than 8 and 14 days. It was found moderately effective against fruit borer and its population could be suppressed to an extent of 43.44% and 45.34% bored fruit in number and weight respectively. Although *B. bassiana* has been reported to suppress a wide variety of caterpillars, however, in present studies its effectiveness was observed lower, which might be due to internal feeding habit of both the dipteran and lepidopteran pests of tomato, namely leaf miner and fruit borer. Therefore, level of suppression of important pests of tomato was not satisfactory. On surface feeding caterpillars, Srivastava and Tandon (1980) observed that *B. bassiana* caused 100% mortality in 4 days when the larvae of the mango pest, *Orthaga euadrusalis* (Walk.), were allowed to crawl over the fungus and in six days when they were sprayed. It can, therefore, be said that *B. bassiana* is much effective against the surface feeding caterpillars than internal feeder. Till its effect on internal feeder of tomato can not be ignored.

Nuclear Polyhedrosis Virus : Rabindra *et al.* (1989) found NPV most effective against *H. armigera* among the several entomopathogen tested. Nuclear Polyhedrosis Virus (NPV), an entomopathogenic virus used against lepidopteran pests at larval stage again effectively suppressed the pest of tomato within 3 days of spraying under present investigation, however, its effectivity was decreased thereafter. It suppressed the fruit boring percentage in number and weight significantly (49.39% and 50.99% respectively). Gupta *et al.* (1997) reported that in Rajasthan NPV 100 LE gave 38.9% reduction in larval population of *Helicoverpa armigera* under field conditions on tomato which is almost in conformity with the findings under present investigation. However, the results under present investigation is not in conformity with Mistry *et al.*(1984) who found 80% mortality of larvae of *H. armigera* and 75% suppression of borer infestation at 3 days after spraying. This might be due to more frequent use of NPV (5-6 times) in field. Although NPV is primarily a lepidopteran disease, but occurring also on diptera and hymenoptera (Srivastava, 1993). This again supports the present findings that NPV gave 36.60% suppression of leaf mining caused by a dipteran leaf miner (*L. trifolii*) as compared to avermectin (44.18%) and DDVP (44.39%). Moreover, it was quite safer to natural enemies of the pest complex of tomato.

Avermectin : The avermectins are a group of closely related 16 membered macrocyclic lactones with potent acaricidal, insecticidal and nematicidal activities. They are natural products of fermentation by a soil actinomycetes micro-organism (*Streptomyces avermitilis*). Abamectin is reported highly toxic to various species of leafminer (Lasota and Dybas, 1991) and borer of *Helicoverpa* species (Dybas, 1989). The selectivity of abamectin toxicity between target and non target arthropods appears to be favourable, as relatively low toxicity has been reported for many non target arthropods (Lasota and Dybas, 1991). Among the seven insecticides, avermectin in the present investigation showed excellent performance against the pest complex of tomato and gave significantly highest control against all the pests at 3,8 and 14 days after spraying over other pesticides. It is also observed that avermectin was much active at 3 DAS than 8 and 14 DAS. Like other internal borer species of *Heliothis* and *Helicoverpa* (Dybas, 1989) and leaf miner (Lasota and Dybas, 1991) avermectin was also much effective against *Helicoverpa armigera* involved in fruit boring on tomato and suppressed to an extent of 49.95% and 52.03% fruit boring in number and weight respectively, which was also significantly superior over all other pesticides studied under present investigation. Moreover, abamectin neither persists nor accumulates in the environment. It rapidly degrade both in water and on soil and does not bioaccumulate. Because it is used in much small concentration, the use of avermectin in tomato is not likely to have an adverse impact on human health, non target biota and environment. Therefore, considering their natural biological origin, safer to health and environment as well as most effectiveness amongst the available pesticides, avermectin can be safely used in tomato.

In the present investigation, two groups of pesticides based on their origin were evaluated against pest complex of tomato considering health and environment. It is observed that none of the pesticides can fully control the pest complex nor any major pest. Most interesting feature of the present investigation is that all the biologically originated pesticides showed effectiveness equally and even better than synthetic insecticides. It is evidenced from the foregoing discussion that avermectin and HaNPV were the most effective ones against the pest complex of tomato in this region. Higher level of pest suppression by these aforementioned pesticides also led into elevated yield of tomato. Considering overall performances of pest suppression and its impact on health and environment avermectin and HaNPV can be accepted for management of key pests of tomato. Since these pesticides are biologically originated and safer to health and environment they will be compatible to other components of pest management under IPM programme. Therefore, recommendation so far made by malathion and DDVP because of their shorter persistently and low mammalian toxicity but harmful to the activity of natural enemies of crop pests needs to be reviewed and modified. It is worthwhile to mention here that pest management strategy once developed can not be everlasting. With rapid advancement of Science and technology and constantly changing dynamic nature of agriculture pest management strategy is go on changing from time to time.

Under present investigation it has been observed that none of the pesticides could provide full control of the key pests. It was only avermectin from among the pesticides tried, which suppressed about 50% of fruit boring. Therefore, IPM is the only way to combat insect-pests problem of tomato in better manner. Under this IPM strategy, avermectin and HaNPV are the most compatible and best-suited pesticides because of their non-persistency, rapid degradability and non-bioaccumulation characteristics. Thus use of avermectin in tomato is not likely to have an adverse impact on health, non-target organism and environment and may, therefore, be recommended for tomato.