Chapter - II

Review of Literature

REVIEW OF LITERATURE

2.1 Seasonal Incidence of Insect-Pests of Tomato and Their Interaction with Crop Phenology

The pest structure and its relative abundance on a given crop vary widely with eco-climatic conditions, crop growing season, time of planting and crop growth stage. In nature tomato plant is attacked by a number of insects and different non-insect-pests, that reduce its yield and also affect the market value of the produce. In general, the major pests of tomato include, gram pod borer, leaf miner, tobacco caterpillar, hadda beetle, mealy bug, aphid and white fly. Most of these pests are polyphagous in nature and thereby have wide host range also. In order to prevent the activity of major pests now-a-days several highly toxic broad-spectrum insecticides are used. As tomato fruits are plucked at close intervals, the maintenance of insecticidal film over plant due to frequent prophylactic application is not only uneconomical but also hazardous. Therefore, the uses of poisonous and hazardous toxicants are not very much desirable. Climatological conditions such as temperature, humidity and day length (photoperiod) directly affect the population of both pests and their host plants. Climate also restrict the dispersal of pests to particular localities or else they would spread far and wide (Srivastava,1993). A significant relationships have been observed in incidence and pest population build up with specific weather situations. The seasonal development of polyphagous insects is closely correlated to the development of their host plants (Srivastava,1993). Atwal (1993) reported that by adjusting time of plantings, infestation by some pests can be prevented, the egg laying period of a particular pest can be avoided, young plants can be established before the attack starts, short duration crops can allow the minimum possible time for pests to multiply or they can mature before the pest appears. Similarly by adjusting the time of harvesting, crop can be saved from attack of the pest which might become abundant late in the season.

2.1.1 Aphid (*Aphis gossypii* Glover)

Among the insect-pests, the plant lice (*Aphis gossypii* Glover, Aphididae: Hemiptera) sucks sap from the leaves and tender shoots and reproduce throughout the year, however, remains more active from October to March. In spring large scale dispersal takes place, but the pest is usually of little significance during the summer and autumn, due to unfavourable climatic conditions. The cloudy, moist and cold weather favours their multiplication while heavy rain reduces its population (Singh,1984). Kandoria *et al.* (1989) studied the seasonal activity and host range of *Aphis gosypii* in Punjab from June to May and reported that the aphid was active throughout the year and found on tomato during February and was very active on melon and tomato in March. It was further reported that the population declined from mid-May to the end of June due to high temperature (40-45^{0}C). Bergman *et al.*(1984) reported that the largest number of *Myzus persicae* were recorded at the end of the tomato season (August) whereas, *Aphis* sp. was more abundant at the beginning of the season (April) in Sau Paulo State. Oliviera (1971) is of the opinion that aphid population was negatively correlated with the amount of rainfall and that too both very high temperature, above 30^{0}C and very low ones under 12^{0}C. According to Mall *et al.*(1992) the average temperature range of 20-25^{0}C and average relative humidity of 50-72% were more favourable for maximum activity of the pest. From field experiment studies Cruz and Bernardo (1971) reported that aphid causing extensive damage during pre-flowering stage of the crop. Contangelo *et al.* (1994) found that the aphid population appeared in peak within the first few weeks after transplanting of tomato.

2.1.2 White fly (*Bemisia tabaci* Gennadius)

Bemisia tabaci Gennadius, Aleyrodidae:Hemiptera, a potent vector of devastating leaf curl virus, commonly known as cotton white fly is found in most of the countries in tropics and sub-tropics. Its main hosts are cotton, tobacco and some winter vegetables including tomato; the infestation on this crops may be sporadically severe. The flies dart about near the plants or crowd in between the veins or ventral surface of leaves, suck sap from the infested parts. As a result leaves became yellowish, wrinkle and curl downwards and ultimately shed off. Their activity is more during the dry season and decreases with the onset of rain and interferes with the photosynthetic activity of the plant by damaging leaves resulting in stunted growth of the plant (Butani and Jotwani, 1984). In Jordon young tomato leaves are generally preferred for oviposition (Ohnesorge *et al.*, 1980). The flies are considered to be the major problem in young plants of tomato during dry season in Costa Rica (Quiros *et al.*,1995). The pest is distributed throughout the northern and western regions of Indian sub-continent and is serious particularly in the dry season (Atwal, 1993).

Abdel *et al.* (1987) have studied the seasonal incidence of white fly in Egypt and found that the population is higher in September-November, *i.e.*

on late summer planted crop, whereas lower in February. In Saudi Arabia, the fly became abundant in summer and early autumn and winter planting showed low infestation of tomato leaf curl viral disease (Mazyad *et al.*, 1979). In Northern India, the highest population (2.97/plant) has been recorded in the 2nd week of October and lowest (1.17/plant) in 1st week of December and higher being from 1st week of October to 2nd week of November. Such fluctuation of population is found positively correlated with the leaf curl virus incidence in the field (Anon 1994-95). Saklani and Mathai (1978) observed that in the plains of India *B. tabaci* population was higher during spring and summer. Verma *et al.*(1989) reported that the incidence of tomato leaf curl virus on tomato is directly related to the population density of the vector *Bemisia tabaci*, the vector developed during January and also transmitting disease. In Italy Gallitelli *et al.*(1991) found heavy infestation of *B. tabaci* during autumn in 1988. Kobatake *et al.*(1981) reported a peak occurrence of the white fly in July, just before the rapid increase in infestation of tomato crops with the virus. Infact the fly occurs in wide range of warm climatic crops in many parts of the world and its population dynamics were affected by multiple crop interactions (Toscano *et al.*,1994). Butter and Rataul (1978) reported that in Ludhiana, Punjab, *B. tabaci* Genn. is known to transmit tomato leaf curl virus more effectively to winter than to summer crops, as the vectors are more active at temperature of 33-39^{0}C. In Assam the minimum disease incidence and white fly population were recorded in the crop planted from October 10 to November 25 (Borah and Bordoloi,1998). Bhardwaj and Kushwaha (1984) reported that white fly population reached peak three times in October, March and November. The population showed negative correlation with relative humidity but positive with temperature in Rajasthan. Venugopala Rao and Reddy (1994) studied the incidence of white fly in relation to different weather parameters and reported that the population build up showed definite negative correlation with temperature, rainfall and relative humidity.

2.1.3 Leaf miner (*Liriomyza trifolii* Burgess)

The serpentine leaf miner, *Liriomyza trifolii* Burgess (Agromyzidae:Diptera) a native of Florida in southern United States and the Caribbean islands (Spencer, 1973) was an accidental introduction to India in 1992 in a wide variety of crops (Lakshminarayana *et al.*, 1992; Pawar, 1992; Shankar *et al.*, 1992; Srinivasan 1992). Adult leaf miner fly damages the leaves to feed or to lay the eggs and the larvae tunneling within the leaf and make characteristic serpentine mine (Natarajan *et al.*,1994;Patil *et* *al.*,1997). Extensive leaf mining activity reduces the photosynthetic capacity of the plants and can result in defoliation and sunscroch which produce unmarketable fruits in tomato, (Johnson *et al.*, 1983). Srinivasan *et al.* (1995) have reported that leaf miner has a wide spread distribution in the southern states of Andhra Pradesh, Karnataka, Maharashtra and TamilNadu. They further reported that in South India leaf miner infests a large number of hosts including vegetables, ornamental plants, fibre crops, pulses, green manuring crops, fodder, narcotics and weeds belonging to 16 families and is prevalent from November to February. The leaves of the top canopy had fewer mines as compared to the leaves in the middle and bottom canopy. The author also added that at Rahod (Pune district), 30-40 days old tomato seedlings were severely affected and the pattern of attack was reverse while in the fields of Karnataka, Andhra Pradesh and rest of Maharashtra, mostly the older plants (70-90 days after planting) had more mined leaves at the middle and bottom canopy. Kapadia (1994) reported that in north Sourashtra agro-climatic zone, the serpentine leaf miner infested 13 field crops, 15 vegetables, 16 weeds, 2 forest trees and 2 ornamental host plants from 18 families. Tomato and marigold were the preferred host for survival of the pest throughout the year and the magnitude of leaf miner infestation is higher in tomato during monsoon and summer than winter. Patil *et al.* (1997) has estimated the loss of vegetative growth due to attack of serpentine leaf miner attack. The per cent infestation at 10 and 20 days after sowing was significantly higher as reveal from the number of maggots. This resulted in lower plant height and lesser biomass production compared to healthy plants. While plants exposed to leaf miner on 30 and 40 days after sowing recorded a plant height and biomass which were at par with uninfested plants. Although leaf miner would feed and oviposit on young lateral foliage (side shoots) of mature plants, they would not do so on young terminal foliage at the apex of the plant (Ledieu and Helyer.1985). Zenhder and Trumble (1984) investigated the spatial and diel activities of *Liriomyza* spp and reported that most adults of *L. sativae* preferred the middle plant height, while *L. trifolii* was most abundant at low plant height. Issa and Marcano (1994) reported that the highest number of leaf miner were found from the end of the dry to the beginning of the rainy season (March to May). In Uttar Pradesh the infestation was higher in January whereas, small population was found in March (Rai and Satpathi,1995). A moderate temperature and high humidity is reported favourable for the development of the fly (Nair,1984). Bagmare *et al.*(1995) reported that the pest appeared at the seedling stages on soybean, kharif tomato and marigold and a high level of incidence has been observed during September-October. They further stated that an average temperature of 27°C, longer sunshine duration of 9 hr/day and average relative humidity 61.50% favoured the multiplication of the pest in Jabalpur. Furthermore, in case of tomato the population was found to be positively correlated with average temperature and sunshine and negatively with relative humidity and rainfall.

2.1.4 Fruit borer (*Helicoverpa armigera* Hubner)

The gram pod-borer or the gram caterpillar, *Helicoverpa armigera* Hubner, Noctuidae : Lepidoptera, has a cosmopolitan distribution. It is a polyphagous pest and its preferred host plants include, pigeon pea, chick pea, berseem, lucerne, tomato, cotton, mung bean, peas, beans and also on flowers and buds of roses and onion. Singh (1984) has reported that the adults of *Helicoverpa armigera* appear in the field in the late February or early March in the northern India and laid eggs preferably on leaves but during flowering, on buds, blooms and flowers. The larvae after hatching feed on leaves and subsequently attack the flower bud that prevents fruit formation. In Punjab the pest passes through one generation on gram during March, two generations on tomato during the period from March to May and one generation on maize and tomato during July-August. In other parts of the country the pest remains active throughout the year. The caterpillar makes a circular hole into the fruit and during feeding they enter the anterior part of the body, keep remaining part outside the fruit (Singh and Singh, 1975) and a single larva can damage several fruits before becoming full-grown. (Ewing and Ivy, 1948). Tiwari and Choudhury (1993) reported that the period of activity commences from October and continue upto March. According to Walker and Cameron (1990) adults of the noctuid *H. armigera* occur in higher number during the period from mid February to early March. Saheen (1979) surveyed the pest on tomato in Egypt and reported that *H. armigera* was present in crop from August to February, reaching peak during September-November. Lal and Lal (1996) found that the borer infestation slowly increased and by the end of March, the tomato fruits were badly damaged by the borer. It was further reported that during the end of March and early April the infestation was 70-80%; in 3rd week of May it was 13-18% and in 4th week of May the value was 3-5%. Sharma *et al.*(1997) reported that seedlings transplanted on 28th March and 12th April yielded lowest due to high infestation by fruit borer, while El-Gendi *et al.*(1997) reported that levels of *H. armigera* were low in all the crops regardless of planting dates. Kalra (1992) reported that in Haryana, its infestation on tomato begins in the 2nd week of April; the number of larva/plant has been 0.9 in 1988 and 0.4 in 1989. By the first week of May the extent of damage of fruits in 1988 has been 18.7% in number and 27.4% in weight. The corresponding values for 1989 have been 12.8% and 13.2% respectively. Thus inter year variation in the quantum of damage is imperative. During the month of June the pest population has declined but the damage of fruits remained still quite high which might be due to the sharp reduction in fruit formation as the crop approaches maturity. Furthermore the relationship between the number of *H. armigera* larvae per plant and per cent fruit damage has been non-significant (r = 0.08). Similarly no clear-cut correlation has been observed between the number of larvae attacking the plants and the prevalent temperature (r = 0.246), average weekly maximum temperature (r =0.298), average weekly relative humidity (r =-0.533). Unusual rains during late winter, high humidity and ambient temperature favoured the pest population build up in Karnal (Sinha and Chakrabarti,1983). Vaishampayan and Veda (1980) reported that minimum temperature and rainfall were positively correlated with the population build up of *H. armigera* at Jabalpur. The influence of temperature on oviposition, larval, pupal periods and adult activity has been discussed by Isshak *et al.*(1981). Harrel *et al.*(1979) have found that temperature, relative humidity and wind speed affect the larval development and pupal periods, whereas a significant negative correlation of pest incidence with rainfall was observed by Rao *et al.* (1990) at Guntur. Pimbert and Srivastava (1991) reported that rainfall deficits promote the growth of population as negative relationship with rainfall was observed with *Helicoverpa armigera.* Adult moth population was found positively correlated with rainfall (Bhat and Virupakshappa, 1990 and Jayaramaiah and Babu, 1990).

2.1.5 Tingid bug (*Urentius hystricellus* Richter)

Moderate infestation of tingid bug, (*Urentius hystricellus* Richter, (Tingidae:Hemiptera) were first time observed damaging egg plant during 1975 at Sabour, Bhagalpur in the Indian State of Bihar. The pest is active mainly during May and June. Nymphs fed on sap on the upper surface of leaves and adults on the lower surface (Yadav, 1978). Singh and Mann (1986) reported that in Punjab, all stages of tingid bug were present from May to September, but only the adult stage were found in October and April. The adults overwintered in the plant debris from November to March. The population of tingid bug had recorded two peaks, the 1st in June and 2nd in August.

2.1.6 Hadda beetle (*Henosepilachna vigintioctopunctata* Fabr.)

The hadda beetles (*Henosepilachna vigintioctopunctata* Fabr., Coccinellidae:Coleoptera) appeared on tomato plant during March-April and remained active from April to October but the highest damage was caused during April-May. The adults hibernate during winter (Singh, 1984).

Veeraval and Bhaskaran (1994) revealed that age of plants has no effect on the multiplication of *Amrasca biguttula biguttula, Coccidohystris insolitus* and *Henosepilachna vigintioctopunctata* whereas, plant age did affect the incidence and build up of *Aphis gossypii, Urentius hystricellus* (Richt.).

The foregoing account reveals that quite a good volume of work has been carried out on the incidence of different pests acting upon tomato in different parts of India and abroad. It is revealed that pest structures varied with region and with so many factors, which influenced the fluctuation of pest population. The incidence of pest varied with season of cultivation and growth stage. Role of important weather factors by which the pattern of pest incidence varied was also worked out by some workers. All these informations helped in formulation of pest management strategy in the respective areas. Till there have some gaps in information with regard to pattern of incidence of major pests and their natural enemies during the entire crop growing season, variation in relative abundance of different pests on crops raised at different time and their correlation with important weather parameters and also crop-pest phenological relationship of different crops raised at different part of the season. It, therefore, needs further investigation to meet the gap of regional specificity.

2.2 Biology of Important Insect - Pests of Tomato

Among the different insect-pests attacking tomato, fruit borer, leaf miner and white fly may be considered major ones not only in India but in other tomato growing countries also. These insects cause direct and indirect damage to the fruits and plants that is reflected in the yield parameters.

2.2.1 Fruit borer (*Helicoverpa armigera* Hubner)

Fruit borer, *Helicoverpa armigera* lays eggs singly (Fletcher, 1914; Srivastava and Saxena, 1958.,Ismail and Swailem, 1976) on the leaves along the mid-vein and sometimes under the calyx of the tomato fruit. Amongst different plant parts namely buds, blooms, flowers and leaves, the leaves are the most preferred one. Rarely the eggs are laid on tomato fruits as well

(Singh and Singh, 1975; Ongoren *et al.*, 1977). The eggs are shining greenish yellow and are round and become yellowish white in colour before hatching. Freshly hatched out larvae are yellowish white in colour but gradually change and acquire greenish tinge. Full-grown caterpillars are apple green in colour with whitish and dark grey broken longitudinal stripes. Pupae are dark brown in colour and have a sharp spine at the posterior end. The moth is stoutly built and is yellowish brown in colour. There can be 5-8 generations in a year depending upon environmental conditions and availability of suitable host.

Under laboratory conditions the incubation period ranges from 2.6 to 3.6 days at 31.1-32.3°C (Singh and Singh, 1975); 3.1 at 27-29°C (Ismail and Swailem, 1976); 4 days at 24°C (Coaker, 1959); 3.4 and 2.5 days at 22°C and 28°C (Ongoren *et al.*, 1977) and 2-12 days (Shavkatsishvilli, 1965). The duration of larval stage was longer under low temperature conditions (Lefroy,1971). The larval period lasted for 8-12 days in Punjab (Singh and Singh, 1975), 21-28 days in Uttar Pradesh (Srivastava and Saxena, 1958). The larval period lasted for 10.8 days (Singh and Singh, 1975), 13.7 days at 27-29°C (Ismail and Swailem, 1976), 14-15 days (Shavkatsishvilli, 1965) on tomato. Pupal period lasts for 5-8 days at 31.1-32.3°C (Singh and Singh, 1975); 8-11 days at 29.4-32.5°C (Sharma, 1978); 10-19 days at 80±2°F (Patel *et al.*,1968) and 19 and 10.5 days at 22°C and 28°C (Ongoren *et al.*, 1977) respectively. Nachiappan and Subramanium (1974) have obtained a mean pupal life of 10.7 days.

When this insect was reared on tomato fruits at 31.1-32.3°C, the preoviposition and oviposition periods varied from 1-4, 2-5 days respectively (Singh and Singh, 1975). At 27-29°C these figures were 2.8 and 4.1 days respectively (Ismail and Swailem, 1976). The corresponding durations were found to be 2.4 and 2-6 days by Atanasov (1964) and 4.25 and 2.66 days by Patel *et al.* (1968) respectively.

The adults have been reported to survive for 1-16 (Singh and Singh, 1975); 6.2-6.6 (Ismail and Swailem, 1976) and 1-29 days (Wilcox *et al.*, 1957). Hsu *et al.* (1960) found that the *Heliothis* (= *Helicoverpa*) moths survived for a mean period of 20 days. Ongoren *et al.* (1977) recorded a total adult life span of 10.6 and 7.2 days in females and 6.9 and 7.6 days in males, at 22° and 28°C respectively. Sharma (1978) also reported a longer life span of females than the males. Nachiappan and Subramanium (1974) reported that total life cycle of *H. armigera* has found to be completed in 35.14 days on tomato. Atwal (1993) stated that the eggs hatch in 2-4 days during April to October and 6 days in February, the larvae become full fed in

13-19 days and the pupal period lasts for 8-15 days but in winter the duration of all stages are prolonged.

According to Sharma and Chaudhury (1988) the average incubation, larval, pupal and the total developmental durations at 20, 25, 30 and 35 ± 1°C were 5,4,3 and 2 days, 31.4, 19.3, 15.3 and 10.3 days, 23.8, 15.5, 9.6 and 8.4 days and 62.2, 38.8, 27.8 and 20.7 days respectively. The authors further stated that there was a negative relation between temperature and duration of different immature stages; the pupal duration was slightly enhanced with the increase of humidity at 20 and 25°C. Goyal and Rathore (1988) reported that during kharif season the duration of larval, pupal, preovipositional, ovipositional period and total life cycle was 14.48, 9.43, 2, 7 and 25.85 days respectively. Kadu *et al.* (1987) observed that the duration of adult female life, male life, pre-reproductive period, incubation, pupal and generation period was shortened with the increase in temperature. The reproductive period, fecundity and hatching percentage of eggs increased with the rise in per degree temperature. Tripathi and Singh (1989) reported that larvae did not survive upto the pupal stage at 12 °Cand 37°C and the most suitable temperature for development was 22°C.

2.2.2 Leaf miner (*Liriomyza trifolii* Burgess)

The adult serpentine leafminer, *Liriomyza trifolii,* have two wings of dark colour with brown spot in it. Each female lay eggs singly inside the puncture made with help of an ovipositor in the leaf. So the eggs are, in direct contact with sap in the host tissues. (Singh, 1984). The larvae tunneling within the leaf and make characteristic serpentine mines (Patil *et al.*, 1997). The larva (maggot) turns dark yellow at the mature stage and came out from the tunnel to pupate (Natarajan *et al,*1994). The pupa became blackish brown at the advent of adult life. Daly *et al.*(1978) found, courtship and mating commonly takes place in the air at least in part and egg hatched quickly. As because it is a new pest in India, sufficient information is not available on the influence of temperature and humidity on its life history.

2.2.3 White fly (*Bemisia tabaci* Genn.)

White fly lays eggs singly on the lower surface of the leaves. Eggs are pear shaped, light yellowish in colour. On hatching the nymphs crawl a little and settle down on a succulent spot on the same leaf and never change the place thereafter. Nymphs are louse like and greenish white in colour. Adults are minute insects, covered completely with a white waxy bloom. They have two pairs of pure white wings and have prominent long hind wings.

The incubation period is 3-5 days in summer but may extend upto 33 days during winter. The nymphal life lasts for 9-14 and 17-81 days in summer and winter respectively and pupal period lasts for 2-8 days and being longer during winter than summer. Adult's longevity is 2-5 days in summer but the time may be as long as 24 days in winter. There are about 12 overlapping generations in a year (Butani and Jotwani, 1984). Khan and Rao (1960) reported that life cycle lasted for 2-3 weeks during April-September but for a longer period during November-February. According to Atwal (1993) the eggs hatch in 3-5 days during April-September, 5-17 days in October-November and 33 days in December-January. Nymphal stage lasts for 9-14 days during April-September and 17-81 days during October-March and pupal stage lasts for 2-8 days. The life cycle is completed in 14-22 days and 11 generations were completed in a year. Bhardwaj and Kushwaha (1984) also reported that in laboratory *B. tabaci* completed 11 generations in a year on tomato seedlings. The duration of the individual stages of life history was measured at temperatures between 8.5 and 34^{0}C during September-October; in Rajasthan. The egg stage lasted for an average range of 5.9 days; the larval stage 10.1 days and pupal stage 6.8 days at mean daily maximum and minimum temperature of 31-31.7^{0}C and 17-21.6^{0}C respectively. Hendi *et al.* (1987) reported that the in Egypt, the pest could successfully be reared on tomato plants in small earthen ware pots at temperature 30±2^{0}C and 60±5% relative humidity. Under these conditions the pre-oviposition period lasted for 1-2 days and the oviposition period 7-36 days. Each female laid up to 304 eggs and these hatched within 5-9 days. There were 3 larval instars, each lasting 2-4 days, and the pupal stage lasted for about 6 days. Adult life span varied from 3-13 day for male and from 8-43 days for female. The development cycle took 17-27 days and a generation took 22-61 days to complete with an average of 34.5±1.4 days. Salas and Mendoze (1995) studied the development and oviposition of *Bemisia* on tomato leaflets in the laboratory at 25^{0}C and 65% relative humidity. The authors observed that the duration in days for the incubation, first, second, third nymphal instars and that of pupal instar were 7.3±0.5, 4.0±1, 2.7±1.1, 2.5±0.7 and 5.8±0.3 respectively. Total life cycle from egg to adult emergence was completed in 22.3 days. The adult longevity was 19.0±3.3 and 19.4±5.8 days for females and males respectively. The pre-oviposition period lasted 1.4±0.7 days and oviposition 16.7±3.2 days. Fecundity was 194.9±59.1 eggs/female while egg viability was 86.5%, sex ratio was 1:2:7 for males: females: virgin females, those were parthenogenetic.

Analysing earlier works conducted at different places by different workers showed that biology and behaviour of important pests of tomato like fruit borer, leaf miner and white fly vary spatially and seasonally. However, duration of different stages of life cycle under prevailing weather conditions in laboratory in different parts of the crop growing season and their correlation with key weather factors need to be worked out. This information is prerequisite for identification of factors influencing the out break of the pest, which is also complementary to the work on seasonal fluctuation of different pest species at field level in an eco-climatic condition.

2.3 Assessment of Crop Loss of Tomato caused by Insect-Pests Complex

The agro-climatic condition of terai region of West Bengal favours round the years cultivation of vegetables which in turn boosts up pest carry over and their abundance. This no doubt makes the production system more remunerative but also influences the degree and magnitude of pest population and subsequent loss caused by them. Among the insect-pests attacking tomato in this region, aphid, white fly, leaf miner, tingid bug and hadda beetle caused damage to the vegetative part *i.e.* on stem and leaf while fruit borer, as the name denotes attacked the cashable part *i.e.* the fruit.

2.3.1 Aphid (*Aphis gosypii* Glover)

Among the insect-pests, aphid *(Aphis gosypii* Gover*)*, is the sap feeder. Due to its heavy aphid infestation the plants remain stunted and the formation of flowers and fruits is adversely affected and resulted in crop loss (Singh, 1984). In Alaska, aphid has been reported to cause 1-6% crop loss in tomato (Stoltz *et al.*, 1997). Therefore, the attack of aphid alone does not capable to cause a severe crop loss.

2.3.2 White fly (*Bemisia tabaci* Genn.)

White fly, *Bemisia Tabaci* Gennadius, is a potent vector of leaf curl viral disease of tomato. Saklani and Mathai (1978) reported that in the plains of India and other hot regions, most of the insecticides were found to be more effective on the summer crops, probably because of the larger populations of *B. tabaci* during the spring and summer. In Egypt *B.tabaci* transmitted both tomato yellow leaf curl virus and tomato leaf curl virus causing complete yield loss of late summer and autumn crop (Saheen, 1977). Saikia and Muniyappa (1989) recorded the incidence of tomato leaf curl viral infection of tomato in Karnataka and reported that, from July to November, about 17-53% and from February to May upto 100% of the crops were infected. Further, in sequential sowings 90-100% of plants was infested in plots sown between the end of January and end of May, while infection in plots sown later was progressively less. The authors further added that the Pusa Ruby variety suffered 50-70% yield losses due to leaf curl disease when sown in February-May. While Kobatake *et al.* (1981) reported that in Japan the disease normally appeared first in mid July; the numbers of affected plants increased rapidly during August.While at Ludhiana *B. tabaci* is known to transmit tomato leaf curl virus more effectively to winter than to summer crops (Butter and Rataul, 1978). Similarly Mustafa *et al.* (1991) also observed that in Egypt, the incidence of tomato leaf curl viral disease was very little in the summer plantation. Singh (1989) recorded 93% yield loss due to devastating leaf curl disease transmitted by white fly. Reddy and Yaraguntaiah (1981) have found that carbofuran application was the most effective in reducing leaf curl disease incidence and increasing yield. Kobatake *et al.*(1981) reported that an application of acephate to the soil or to the foliage in July effectively decreased the incidence and spread the disease.

2.3.3 Leaf miner (*Liriomyza trifolii* Burgess)

The leaf miner (*Liriomyza trifolii* Burgess) caused severe damage to plant by tunneling within the leaf resulting enormous loss in yield of crop. Johnson *et al.* (1983) observed extensive leaf mining badly affect the photosynthetic activity of plants resulting in production of unmarketable fruits. Ledieu and Helyer (1985) opined that yield losses that occurred as a result of leaf miner infestation were not dependent on severity of damage alone as proximity to fruit at an early stage of development was very important. If damage on leaves adjacent to a truss reached 30 mines per leaf at the time when fruit was half swollen a 10% loss in yield resulted in April-May.

Natarajan *et al.* (1994) reported that *Liriomyza trifolii* caused 70-80% leaf infestation on tomato in Coimbatore. In Maharastha during kharif season leaf miner caused 30-40% leaf infestation (Anon, 1995), 20% leaf damage was observed by Han *et.al.*(1996). In Rahuri during kharif season leaf miner caused 50.7% leaf damage in untreated control while on malathion treated plot it was 29.3%, the yield was also 72.5q/ha and

93.1q/ha respectively in untreated and insecticidal treated plots, so leaf miner infestation caused 22.5% reduction of yield (Pawar *et al.* (1996).

2.3.4 Fruit borer (*Helicoverpa armigera* Hubner)

Fruit borer, *Helicoverpa armigera* Hubner, is an important pest in almost all the tomato growing areas in the world. Damage due to fruit borer was recorded to make the fruits unfit for human consumption, causing considerable crop loss (Kashyap, 1983); even the entire loss of 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 (Srinivasan, 1959), where in Punjab it was on an average 30% of the tomato fruits which caused 36% loss in yield of the crop, Singh and Singh (1975). Singh and Narang (1990) reported that in Punjab 51.2% fruit was damaged by fruit borer, while after three sprays of insecticides at fortnightly interval, the damage ranged from 3.4-10.5%. Fruit borer also damaged 50% fruit (Lal, 1985), 40-50% in Bangalore (Khaderkhan *et al.*, 1997). In Haryana it caused 33.8% and 31.3% fruit infestation in number and weight basis respectively that resulted in avoidable loss in 9.3-44.3% in number and 16.1-14.6% in weight (Kaushik,1991). Ganguli and Dubey (1998) assessed 32.52% avoidable losses on Pusa Ruby in Madhya Pradesh. Tewari and Rao (1987) determined the economic damage level for *H. armigera* in tomato as 3.48%. The percentage of fruit damage was consistently higher in the late planted crops (70.4% and 52.4% fruit damage in number and weight respectively) and the yield was declined progressively with late planting (Ogunwolu ,1989). Sharma *et al.* (1997) also reported that late planted crop suffered more from fruit borer infestation and disease in Kulu. Liiotta (1964) for the first time reported that *H. armigera* caused serious damage to late varieties. In the months of April and May damage was 18.2-55.3% as reported by Singh and Chahal (1978). Lal and Lal (1996) further reported that the infestation slowly increased by the end of March.

2.3.5 Tingid bug (*Urentius hystricellus* Richter)

The leaf sucking, tingid bug, (*Urentius hystricellus* Richter) was active during August and September, therefore, summer crops suffer comparatively more than winter crop, Butani and Jotwani (1984). Because of its minor pest status very little information is available on the loss incurred by this pest on tomato.

Assessment of crop loss is an important prerequisite for adopting a strategy for control measures. Avoidable loss and extent of damage of tomato crop varied with region, season, time of planting, variety of crop and pest structure as evaluated by the different workers earlier at different places. Informations available of crop loss, till date were mostly based on a single pest. However, in crop field conditions, pests appear in a complex. An important pest may contribute maximum loss but role of other pests can not be ignored. Therefore, it will be more scientific to assess loss caused by pest complex as a whole considering their conjoint effect on yield and loss therein. Further systematic evaluation on assessment of loss of different varieties of tomato crop raised under different parts of the season need to be evaluated, not only to adjust time of planting to avoid crop loss but also to formulate management programme, both for short and long term for the management of the important pests particularly the key ones.

2.4 Evaluation of Tomato Varieties against Insect-Pests

The strategy for the control of insect-pests on vegetable crops is quite different from that of other field crops because of the nature of utilization or consumption of vegetables. Successful tomato cultivation is mainly depends on the chemical control of the pest. As tomato fruits are plucked at short intervals, the maintenance of insecticidal film is not only uneconomical but also hazardous. Therefore, the use of poisonous toxicants is not very much desirable. Thus cultivation of varieties less susceptible to pests and yielded greater will be the best strategy for pest management programme. The use of low degree of plant resistance has been advocated by many workers (Painter, 1941; Snelling, 1941; Pathak, 1970; Maxwell, 1972; Dahms 1974; Marrewijk and de Ponti, 1975). Now-a-days many cultivars have been developed and recommended by various Research Institutes and State Agricultural Universities. Lal (1991) reported that high yielding varieties and hybrids need more pesticides as they are often susceptible to insect-pests. Banerjee and Kalloo (1989) have reported that HA 101, Pusa Ruby, Red cherry and Manzana were moderately to highly susceptible to leaf curl virus, fusarium wilt and fruit borer attack. In Uttar Pradesh H-24 variety witnessed minimum incidence of leaf curl viral disease 9.4% whereas Pusa Ruby recorded 70% incidence which might be due to the number of vector species as reported by Pandey *et al.*(1995). But according to Borah (1996) 'Arka vikas" variety showed minimum (17.3%) leaf curl viral infection though the white fly population was higher on that variety in Assam. So, the leaf curl virus infection was not found correlated with white fly population but to the number of vectors. The author further added that in spite of higher average pest incidence the variety 'Arka vikas' recorded highest fruit yield. This revealed that though the variety is susceptible to insects but tolerant to other diseases namely wilt etc.

In Uttar Pradesh Rai and Satpathi (1995) have observed that the variety BSS-98 was most susceptible to leaf miner infestation, whereas Pusa Early Dwarf showed least infestation. Kaur *et al.* (1996) found that in Ludhiana, the infestation of fruit borer ranged from 15.5-34.4% in hybrids. It was less than 20% in the hybrids TH 802, TH 2920 and TH 818 as compared to 25.3% and 41.4% in check varieties Punjab Kesari and Punjab Tropic respectively. Besides fruit borer, fungal diseases like late blight and early blight also attack tomato crop. Though the hybrids TH 802 and TH 818 showed considerable tolerance to the fruit borer and early blight disease, had high yield *i.e.* 819.28 and 893.28 q/ha respectively. In Assam, Borah (1996) observed that the variety Akra Abha recorded lowest fruit borer infestation (15.00%) while Pusa Early Dwarf variety recorded highest borer attack (20.2%) but yield was higher on Akra Vikas (66.9t/ha) which observed 16.4% borer attack. This indicated that in these tomato varieties, pest incidence is not related to variety only. The meteorological factors such as temperature, relative humidity and rainfall may have played great role in the pest incidence. In Ethiopia Pusa Early Dwarf, Pusa Ruby was found to be more resistant against fruit borer, *H. armigera*, infestation (Gashawbeza and Tsedeko, 1993). During kharif, in Satpura Plateau zone, among the twelve tomato cultivars, evaluated, Mangla, Karnataka and Art-1 had significant fruit damage due to *H. armigera* (9.9, 8.6 and 8.2% respectively), while Pusa Ruby suffered the least fruit damage (3.2%). Although the Rashmi variety had 2.97 t/ha yield loss, produced highest total yield (20.92 t/ha) and the highest healthy fruit yield (17.95 t/ha) (Shukla *et al.*, 1993). Kashyap and Verma (1986) recorded 42.55% damage of tomato fruits in susceptible varieties while it was only 1.7-2.9% in resistant cultivars. In Chamba district of Himachal Pradesh, S-12 was the most resistant (0.66% of fruits infested), while HS-110 was the most susceptible (14% of fruits infested) (Thakur *et al.*, 1998). The cultiver BL-410 was found most suitable terms of good yield, attractive fruit shape and size as well as comparatively free from insect-pest and disease damage (Jaiswal *et al.*,1997). Similarly, PT-4225 was also found appropriate on the basis of fruit yield and post-harvest shelf life. Lal and Lal (1996) reported that in Delhi and adjoining areas of Meerut and Hapur in western Uttar Pradesh, and in Sonepat and Panipat in

Haryana, most of the farmers grow two Indo-American hybrids like Rashmi and Rupali in March-April.

Canerday *et al.*(1969) reported that small fruited processing cultivars were less susceptible than the fresh market cultivars and thus suggested that the differences between cultivars may be caused by a simple dilution factor than by true resistance. However, in contrary to these findings, Fery *et al.*(1979) observed that genotypes with many small fruits per plant often appeared to be more susceptible to insect pest attack than leading commercial cultivars when rated on a number basis but proved more resistant when rated on a percentage basis.

Resistant varieties are the most effective, economical, practical and easiest means of IPM. 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 possess resistance to at least one insect-pest or disease. The development of insect biotypes capable of surviving on resistant plants appears to be the major threat to the extensive use of resistant varieties. Therefore, high level of resistance is not always necessary. Use of moderately resistant varieties in combination with need based insecticidal applications produce economic yield.

From a critical look to the earlier work it can be said that in most of the cases varieties were evaluated against single key pest of tomato which was either against white fly or leaf miner or fruit borer. Although these three pests can be considered as key pests in India also and any one of the pests mentioned above became endemic to different localities. However, in nature one pest may appear in abundance and cause severe damage but role of other pests can not be ignored. It is, therefore, better to evaluate varieties against pest complex rather than against a single species. Under constantly changing dynamic agricultural situation pest structure is also changed continuously. Selection of variety, tolerant /resistant to pest is not everlasting. Time and pace is, therefore, to be considered before formulating a programme in varietal evaluation. It is, therefore, necessary to evaluate the varieties commonly grown in any area against the pest in complex since the variety/varieties grown in a locality for long is difficult to replace or introduce, more particularly to those varieties having higher productivity.

2.5 Management of Insect-Pests of Tomato through Pesticides

2.5.1 Synthetic insecticides

Since most of all the pests attacking tomato are polyphagous in nature, their occurrence and subsequent damage are very common in almost all the regions. So, synthetic insecticides are now-a-days indispensable to agriculture for achieving higher production and ensuring protection of crop plants from pest enemies. Malathion at the recommended dosages (0.05% ai) can be applied to most edible crops 2 to 3 days before the harvest of crop without danger of excess harmful residues. For this reason malathion is usually recommended for vegetable growing tracts as in terai region of West Bengal (Anon, 2000). Malathion is a contact and stomach poison used for the control of a wide variety of pests of crops such as aphids, hoppers, psyllids, plant bugs, aleyrodids, flea beetles, grey weevils, caterpillars, rice hispa, mealy bugs, scales, thrips etc. and red mites on arecanut (Srivastava, 1993). The other contact and stomach poison, DDVP, used against sucking pests, caterpillars and mainly against miners (Srivastava, 1993). Several workers reported activity of several insecticides for controlling pests of tomato. Singh and Chahal (1978) obtained best results by alternate sprays of malathion and carbaryl at 10 days interval starting from leaf perforation against *H. armigera*. Tiwari and Choudhury (1993) recorded that spraying of 0.05% endosulfan is effective to control *H. armigera*. Whereas, endosulfan 0.07% was the most effective resulting in 97.8-100% larval reduction after 10 days of first spray (Kaushik, 1991). In Gujarat, during rabi season endosulfan spray @ 0.07% gave highest cost-benefit ratio (1:52.6) against *H. armigera* on tomato (Patel *et al.,* 1991). In western north Carolina, endosulfan, fenvalerate and methomyl have found to be more profitable when applied against *H. zea* (Walgenbach and Estes,1992). While in Jabalpur as reported by Sharma and Patel (1994) fenvalerate monocrotophos, carbaryl dust are found to be most effective followed by alphamethrin and endosulfan against gram pod borer and after 10 days of these treatment all the insecticides are at par and significantly superior to control. Gashawbeza and Tsedeko (1993) stated that in Ethiopia against potato tuber moth and *H. armigera* cypermethrin gàve significantly better control than Bt, an average of 19% damaged fruit as compared to 27%, while application of cypermethrin @ 75 gm ai/ha once at early flowering and once at early fruiting stage of the crop would result in minimal damage from these pests. Singh and Narang (1990) reported that in Punjab application of fenvalerate, permethrin and cypermethrin @ 50 gm ai/ha or deltamethrin @ 20 gm ai/ha gave equal or better control of the fruit borer than carbaryl or endosulfan applied at 1000 and 700 gm ai/ha respectively. Yields are higher when synthetic pyrethroids are used. According to Pokharkar and Chaudhury (1997) the synthetic pyrethroids *viz,* cypermethrin 0.0075%, fenvalerate 0.01% and deltamethrin 0.002% were superior to conventional insecticides on controlling *H. armigera.* Creighton *et al.* (1971) reported that DDT spray and mixture of 44% carbaryl and 11% methylparathion was highly effective to control tomato while NPV failed to protect the tomato fruits effectively from *H. zea.*

Chirinos and Geraud (1996) reported that with the application of methomyl and cypermethrin @ 0.122% ai, 100% mined leaflets were observed from the 5th week with 20-40% parasitism. Poe *et al.* (1978) reported that in Florida, untreated control plots had significantly higher mean numbers of active and total mines of *Liriomyza sativae* in foliage samples than plots treated weekly with sulprofos, chlorpyrifos, methamidophos, oxamyl and acephate alone and combinations of methomyl and oxamyl, leptophos and oxamyl, leptophos and endosulfan and methamidophos and acephate. They further opined that there were no significant differences among treatments in the total number of fruit, although there were significant differences among treatments in total weight of fruits, as none of the treatments was significantly different from the control. Rushtapakornchai *et al.* (1996) reported that two applications of bifenthrin, fipronil, fenpropathrin and acephate gave significant *L. trifolii* control in Thailand. Richter and Tsegaye (1988) reported that methamidophos, dimethoate and deltamethrin were highly toxic to larvae of *L. trifolii.* While, Geraud *et al.* (1996) observed the percentage infestation and the number of mines caused by *Liriomyza* were significantly lower ($P<=0.05$) on the untreated control, whereas the percentage parasitism was significantly higher on the untreated control and for the methomyl 0.1% ai. v/v + *Bacillus thuringiensis* (0.0032% ai w/v:16UIP/mg) mixture. Jeyakumar and Uthamaswamy (1997) stated that among the synthetic insecticides phosalone, chlorpyriphos recorded high larval mortality at 24 hrs. Rasool *et al.* (1986) found that in Pakistan, Sumithion (fenitrothion), Perfekthion (dimethoate) and Rogor (dimethoate) afforded effective control of *Urentius sentis* (*U. hystricellus*) in cotton. According to Patel and Kulkarni (1955) application of contact and systemic insecticides was found most effective against tingid bug population in Brinjal. Singh *et al.* (1975) reported that DDVP and monocrotophos are 15.3 and 816.67 time as toxic as compared to pp′-DDT when used against tingid bug on brinjal crop, while application of mecarbam and two formulations of tetradifon were less toxic.

Among the pests attacking tomato, fruit borer (*Helicoverpa armigera*) is the most important causing direct yield losses as the attack of this pest is confined to the fruits mainly. The farmers mostly use toxic chemicals for the control of this pest. These persistent chemicals make a thin film over foliage and fruiting bodies to kill early larval instars before they bore into the fruits. As tomatoes are plucked at short intervals and even consumed raw, the application of insecticides leaves toxic residues in fruits, which become hazardous to human health. Continuous use of chemicals also creates resistance in insects against these insecticides. Lal and Lal (1996) reported that in Delhi heavy application of pesticides has changed the entire scenario of insect-pests on tomato. Even after 20 insecticidal sprayings, the damage due to borer was 60-70% or even more. *H. armigera* has been found to became resistant to DDT and carbaryl (Collins, 1986), endosulfan (Wilson, 1974;Basson *et al.*, 1979) monocrotophos (Witten and Bull, 1970) and recently to synthetic pyrethroids also (Collins, 1986). Walker (1988) also reported that the borer developed resistance against carbaryl and synthetic pyrethroids and against cypermethrin, fenvalerate and endosulfan (Mc Caffery *et al.*, 1989). Resistance to DDT and synthetic pyrethroids and to a lesser extent to endosulfan and monocrotophos has been detected by King and Sawicki (1990). Aldicarb, carbaryl and dimethoate caused resurgence causing insecticides of *H. armigera* (Eveleens, 1983). Recent reports revealed and that this pest can not be managed by using of available insecticides as they do not give satisfactory control of this pest (Dhingra *et al.*, 1988 and Patil, 1993). Toscano *et al.* (1994) observed high levels of resistance to both organophosphate and pyrethroid insecticides in *Bemisia* population in USA and elsewhere in the World. Prophylactic control measure mostly with the use of chemical pesticides, particularly in intensively cropped areas apart from resistance and resurgence problem lead to the destruction of not only the insect-pests but also their natural enemies and allow the development of secondary pests, persistence of pesticide residues in food chain, environmental pollution and pesticide associated health hazards. Therefore, the ultimate solution to manage this pest lies in developing integrated management strategy involving the minimum use of chemicals and more reliance on other methods.

2.5.2 Neem derivatives

Now a day some environment friendly pesticides (Biopesticides) are used to overcome toxic residual hazards. Among the biopesticides neem derivatives are applied against lepidopteran larvae. These disrupt the growth of these larvae and also act as antifeedent agents (Mustafee, 1997). Therefore, the biological control of insect-pests should be coupled with the judicious use of pesticides based on threshold values that had to be determined through survey and surveillance (Acharya Chowdhury, 1997).

Neem (Azadirachtin), a botanical obtained from *Azadirachta indica* is a safe pesticide and active against insect-pests of tomato indirectly and directly. Pawar *et al.* (1996) have found that during kharif season in Rahuri treatment with 5% neem seed kernel extract was the most effective and was at par with cypermethrin at 0.01%, endosulfan at 0.07% and dimethoate at 0.03% for leaf miner control. Neem oil 50 EC (0.3%) has found to be most effective at 24 hrs after treatment in TamilNadu (Jeyakumar and Uthamaswamy, 1997) and neem seed kernel extract (4%) has been reported as effective (Jagannatha, 1994) against *L. trifolii* on tomato in Coimbatore and Bangalore respectively. The effectiveness of neem seed kernel extract to *Liriomyza* had been reported by Larew (1986), Meisner *et al.*(1986) and Parkman and Pienkowski (1990) on different crops.

Sabillon and Bustamante (1995) is on the opinion that neem products reduced the number of *B. tabaci,* and protected the crop from attack by fruit boring larvae of *Spodoptera* sp. and *Helicoverpa zea* and diseases (particularly *Phytophthora infestans*) in Honduras. Sridhar and Sunderbabu (1997) have found that Neem Azal-F-1% and Neem Azal F-5% alone as well as with different combination of insecticide treatment were effective against aphid and white fly. Azadirachtin act as an antifeedant to the noctuid, *Spodoptera frugiperda* and as a moulting inhibitor in *H. virescens*, Klocke *et.al* (1989). While Sharma and Patel (1994) observed that neem oil were least effective against gram pod borer in Jablapur. In Delhi, application of neem oil or neem product available in the market did not provide any effective control against *H. armigera* on tomato and the experience of farmers regarding neem oil was not promising as suggested by Lal and Lal (1996). The author further stated that the use of neem product on other vegetable crops in large areas did not control insect pests.

In order to overcome all these difficulties alternatives to the chemical pesticides are to be introduced in the management programmes of insect-pests of tomato. The integration and exploitation of all the compatible methods have been emerged out (Geier, 1966, Smith and Von den Bosch, 1967). Biological control of pests is an ideal alternative to use of chemical pesticides. In its modern definition biological control is essentially the use of one living organism to control another living organism (Rao, 1970).

One of the important components and function of biological control is the biological suppression of insect-pests by employing pathogens like bacteria, viruses, fungi, protozoa and nematodes as biological control agents (Dutky, 1959) which was designated as 'Microbial Control' by (Steinhaus, 1949). In West Bengal lepidopteran pests harbour more on crops during monsoon months and caused severe damage, resulting in the lower yield and production. Microbial agents represents an ideal form of pest control particularly for use in IPM system as it can provide long and short term pest suppression with less disruption in ecology (Pramanik, 1996). The potential use of insect pathogens like Bacteria *(Bacillus thuringiensis)*, fungi *(Metarrhizium anisoptiae, Beauveria bassiana)* and nuclear polyhedrosis viruses (NPV) in pest control has been recorded by various workers (Tanada, 1956; Steinhaus, 1957; Aizawa, 1963 ; Ignoffo, 1965 and Hemipel,1967). *Bacillus thuringiensis* sub-species *kurstaki* (Tanada, 1956; Hemipel, 1967), NPV (Rabindra and Jayraj, 1986) and entomogenous fungus *Beauveria bassiana* (Sharma *et al.*, 1994) are been widely used against the lepidopteran pest *H. armigera.*

2.5.3 Entomopathogenic bacteria : *Bacillus thuringiensis* (Bt.)

A spore forming aerobic bacterium was isolated in Japan (Ishiwata, 1901) and a similar organism was isolated from the diseased larvae of flour moth and named as *Bacillus thuringiensis* in Thuringa, Germany by Berliner (1915). Old well sporulated cultures of *B thuringiensis* were used to induce in silkworm by oral feeding whereas vegetative cultures of the bacteria were ineffective (Akoi and Chigasaki, 1915).

The bacteria *Bacillus thuringiensis* (Bt.) produces several insecticidal toxin which are responsible for the control of the pests by providing mortality of the insects soon after their entry into the body. Lepidopteran pests are highly susceptible to Bt. having widest spectrum of activity and can be used in a manner similar to that of chemical insecticides for short term or temporary suppression of insect-pests. *B. thuringiensis* sub-species *kurstaki* is widely used against lepidopteran pests of various crops such as *Pieris* and *Trichoplusia* on crucifers, *Manduca* on tomato and tobacco and *Heliothis* (= *Helicoverpa*) on cotton and tomato (Tanada, 1956; Hemipel, 1967). A preparation of HD-1 strain of Bt. at 12.0×10^{9} IU/ha and 16×10^{9} IU/ha gave 100% mortality of 3rd and 5th instar larvae of *H. armigera* respectively at 96 hrs after application (Dabi *et al.*, 1979). The Bt was effective against *Spodoptera litura* (Boised) causing more than 80% mortality, both in the laboratory and in the field when applied in combination with endosulfan (Zaz and Kushwaha, 1983). It was further reported that *B. thuringiensis* var. *kurstaki* when applied, infected larvae become sluggish and fed less and reduced the population and adult emergence rates as well as survivors which reached the adult stage failed to lay eggs. Lutwama and Matanmi (1988) studied the efficacy of *B. thuringinesis* and *Baculovirus heliothis* against larvae of *H. armigera* on tomato and found that these larvae were susceptible to both pathogens. When *Bacillus* (Dipel) was combined with virus there is no significant effectiveness but when applied separately and combination of bacteria and virus with carbaryl were not significantly more effective than pathogen applied alone. Shankar and Mallikarjunappa (1992) evaluated the efficacy of BIOBIT WP (a commercial product of Bt. var. *kurstaki*) and found it as the most effective in relation to other conventional synthetic pesticides. Three sprays (I-20 days old crop, II-flowering time, III-20 days after II) of Dipel 8L a commercially available formulation of Bt. (2ml/l of water) gave 47.2% reduction of tomato fruit borer larvae and yielded 199 q/ha in Udaipur, Rajasthan (Gupta *et al.*, 1997).

Bacillus thuringiensis var. *kurstaki* (Tested as Delfin) at 1 and 1.5 kg formulated material/ha was effective by reducing the larval survival to about 87% over the pretreatment count after 96 hrs of the spray (Gupta and RajaRammohan, 1997). They further stated that combined use of egg parasitoid and Bt. was effective in suppression of fruit borer infestation on tomato in Solan.

Bacillus thuringiensis can be used shortly before harvest without any restriction, as it has no ill residual effect. It is a selective agent that proves efficiency against larvae without harmful effects on human beings, domestic animals, beneficial organism and agro-ecosystem. Little informations are available on the toxic effect of *B. thuringiensis* on non-target pests. Smirnoff and Macleod (1961) mentioned that Bt. var. *thuringiensis* has no effect on birds and mice. Besides this, no ill effects were recorded in honeybee colonies after feeding with large quantities of Bt. (Wilson, 1962). A similar opinion on birds, animals and useful insects was also recorded by Nedkova *et al.* (1980). Following the same trend the normal and 100 times more than normal dose of Dipel and Bactospine (Spore suspension of Bt.) had no adverse effects on the populations of earthworm as reported by Benz and Altwegg (1975).

2.5.4 Entomopathogenic fungus : *Beauveria bassiana*

Laboratory studies showed that toxins of the entomogenous fungus *Beauveria bassiana* destroy the natural physiological balance of *Helicoverpa armigera*. Reduction in respiratory efficacy may lead to the accumulation of carbohydrates in the noctuid. Toxic metabolities of the pathogen appear to play an important role in the decrease of total proteins, amino acids and nucleic acids (Sharma *et al.*, 1994). However, Bassi(1835) established pathogenic nature of the fungus *Beauveria bassiana* (Bals.) in silkworm *Bombyx mori* Linn. and other insects. Taking from his findings, Le conte (1874) first advocated the diseases as a means of insect control. In field cage studies, damage to soybean and corn by *Helicoverpa zea* has been reduced by application of this fungus with mortality reaching 76% (Ignoffo *et al.*, 1978; Mahammed *et al.*, 1978). The larvae of three species of lepidopteran pests of cole crops namely, *Artogeria rapae* Linn., *Pieris rapae* Linn., *Plutella xylostella* Linn., *Trichoplusia ni* Hb. were susceptible to Boverin (a microinsecticidal preparation of *B bassiana* produced in USSR) and LC_{50} for the three species were 0.25, 0.025 and 0.27% respectively (Ignoffo *et al.*, 1979). Sandhu *et.al* (1993) reported that conidia of *B. bassiana* survived longer at lower temperature (0-20^{0}C) and lower r. h. levels (0-53%) where as conidia did not survive at higher temperature (30-40^{0}C). The authors further reported that when the temperature decreased from 30^{0}C to 0^{0}C at nearly all relative humidity levels the longevity of conidia increased and remained virulent for third instar larvae of *H. armigera* under favourable condition for 24 months. Meneses *et al.*(1980) reported that in a field application *B. bassiana* strain 32 (isolated originally from *Leptinotarsa decemlineata* in France) killed 66.3-95.8% of the adult rice pest *Lissorhoptrus brevirostris* (Suffr.) within 4 days of application. Srivastava and Tandon (1980) is in opinion that the *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 6 days when they were sprayed.

2.5.5 Entomopathogenic virus : Nuclear polyhedrosis virus (NPV)

A wilt disease in the gypsy moth (*Lymantria dispar*) was observed by Chapman and Glaser (1915) under field conditions which was later diagnosed as nuclear polyhedrosis virus (NPV). Young and Yearian (1974) reported that persistence of Ha NPV on foliage of tomato was significantly better than on cotton and soybean and little viral activity remained after 96 hrs. Among the several entomopathogens tested against *H. armigera* the NPV has been found to be quite effective on chickpea (Rabindra *et al.*, 1989). Mc Garr (1968) reported the control of *H. zea* and *H. virescens* in cotton crop by

NPV at the rate of 100 LE per acre, which was at par with insecticidal control. NPV 100LE (1ml/L of water) gave 38.9% reduction in larval population under field condions on tomato in Rajasthan and yielded 182 q/ha (Gupta *et al.*, 1997). Kinzer *et al.* (1976) found that 3 sprays of Ha NPV at weekly interval were as effective as monocrotophos applied as foliar spray at 5-7 days interval. Narayanan (1979) obtained 81.3 and 71.6% reduction in larval population of *H. armigera* on chickpea with NPV @ 250 and 125 LE per hectare respectively. It was further stated that endosulfan 0.07% was comparable to NPV 250 LE alone during evening hours and virus at 250 LE +Sandoz liquid adjuvant applied during morning hours. There was high reduction in larval population after 3 sprays of NPV at 7 days interval, which was due to synchronization of first application with appearance of 1st and 2nd instar larvae of the pest. Mistry *et al.* (1984) reported the effectiveness of NPV against *H. armigera* infesting chickpea and tomato where 5-6 application of NPV at 100 LE/acre caused 75-85% mortality (ave. 80.6%) as against 0 to 5.1% (mean 1.1%) in untreated plots of tomato. The fruit damage was 4% in treated as against 15% in control plots. Pawar *et al.*(1987) evaluated NPV of *H. armigera* on chickpea and reported that two sprays of NPV at 500 LE/ha were as effective as two sprays of endosulfan 0.05% in reducing the infestation of larvae and pod damage and thereby increased the yield. Field trials in chickpea fields in Bihar and U.P. during 1987 showed that a single spray of 250 LE of HaNPV in 500 Litres of water/ha resulted in 97.2% mortality of the noctuid in 1987 and 25.4-78.8% larval mortality during 1988 (Misra *et al.*, 1991). Pokharkar and Chaudhary (1997) reported that combined applications of Ha NPV 250 LE/ha with half the dose of the pyrethroids *viz*, cypermethrin 0.0075%, fenvalerate 0.01% and deltamethrin 0.002% were comparable with their normal dose in reducing the larval population and fruit damage and increasing the yield. However, carbaryl 0.15% and endosulfan 0.07% alone and their sub-normal dose combined with Ha NPV 250 LE/ha were far better than monocrotophos and quinalphos at 0.05% and their combination with Ha NPV. Ganguli *et al.* (1997) found that spraying with NPV (250 LE/ha) at the appearance of the pest, followed 7 days later by endosulfan at 0.035 and 0.07% will protect the tomato crop from *H. armigera* and yielded significantly greater. Srivastava (1993) reported that nuclear polyhedrosis is primarily a lepidopteran disease, occurring also in some Diptera and Hymenoptera. NPV of *H. armigera* was found safe to silkworm *(Bombyx mori* L., *Samia cyuthia ricini* B.*)*, honey bees *(Apis cerana indica* F*)* and an entomogenous nematode *(Steinernema feltiae* Filipjev) (Sanjay *et al.*, 1991).

2.5.6 Entomotoxin soil actinomycetes : Avermectin

The avermectin is 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 actinomycete micro-organism (*Streptomyces avermitilis*). This process results in the production of four homologous pairs of highly related compounds; avermectins A_1, A_2, B_1 and B_2. Avermectin B_1 (avamectin, MK-936) is the major component isolated from the fermentation broth and is a mixture of homologous avermectin, containing a minimum of 80% avermectin B_{1a} and a maximum of 20% avermectin B_{1b} (Fisher and Mrozik, 1989). *S. avermitilis* was first isolated from a soil sample collected from Japan. Burg *et al.* (1979) have described the characteristics of *S. avermitilis* culture and the avermectins and invermectins produced by this fermentation process. The toxicity of abamectin varies considerably between species and method of application. Abamectin is moderately toxic to mammals in cases of acute oral exposure, but it is much less toxic in instances of dermal exposure because it does not readily penetrate the skin (Lankas and Gordon, 1989). Abamectin is highly toxic to many insects such as leaf miners, mites, ants, cockroaches (Lasota and Dybas, 1991), house flies (Scott and Georghion, 1986) and Colorado potato beetles (Argentine and Clark, 1990). However, so called second generation avermectin (*eg.* MK-244) have shown the greatest toxicity to several important lepidopteran pests such as southern army worm (*Spodoptera eridamia*), tobacco bud worm (*Heliothis virescens*), and cotton boll worm (*Helicoverpa zea*) (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).

The most important commercial use of abamectin (avermectin B_1) is an acaricide. They are known to be effective against a wide range of mite pests such as eriophyids, tetranychids, tarsonemids and tenuipalpids. It provided excellent initial and residual control of immature and adult mites on a number of crops (Muraleedharan, 1993). Several workers reported the excellent efficacy of abamectin in mite control. Abamectin was widely used in the control of *Polyphagotarsonemus latus, Tetranychus cinnabarinus, Acephylla theae, Calacrus carinatus, Eriophyes discoridis, Aculops lycopersici* on castor, cotton, chilli, tea, tomato and cucumber respectively in different parts of the World (Huengens and Degheele, 1986; Donatoni *et al.*, 1988; Rangel *et al.*, 1990; Zie *et al.*, 1992; Muraleeddharan, 1993; Szwejda, 1994). Rodriguez *et al.*(1997) reported that in Canary islands, there was a large infestation of *Frankliniella occidentalis* early in the growing period of the tomato crop, which was controlled with twice abamectin applications. It is worthwhile to mention here that abamectin neither persists nor accumulates in the environment. It rapidly degrades both in water and soil and it does not bioaccumulate; because it is used in such small concentrations, the use of abamectin in tomato is not likely to have adverse impact on health and the environment.

A critical analysis of earlier works reveals clear and rapid change in management strategy from synthetic pesticide towards those biological origin in view of developing awareness to health and environment. However, use of biologically originated pesticides is yet to establish in field level. Considering the present status of pest management of tomato more and more research are required to be conducted on non-synthetic, biologically originated pesticides to incorporate in integrated pest management programme of tomato at a low cost for minimum disruption of environment and also to avoid health hazard.