"PEST ABUNDANCE AND SCREENING OF GENOTYPES AGAINST MAJOR INSECT PESTS OF TOMATO."

A

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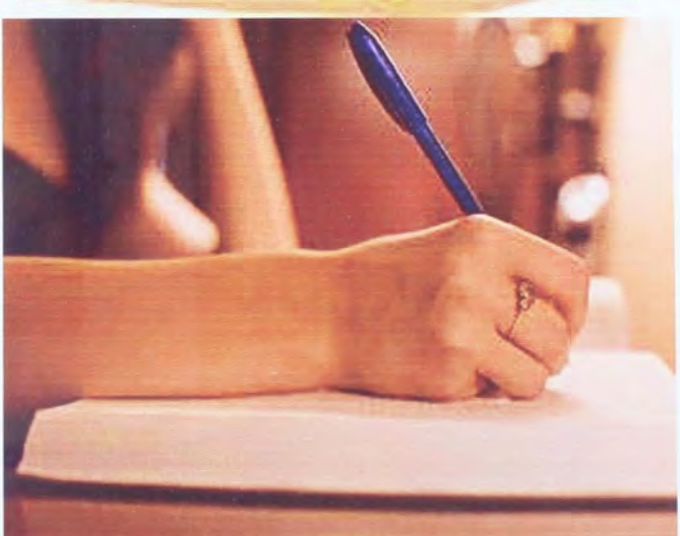
Abstract



"Pest Abundance and Screening of Genotypes against Major Insect Pests of Tomato"

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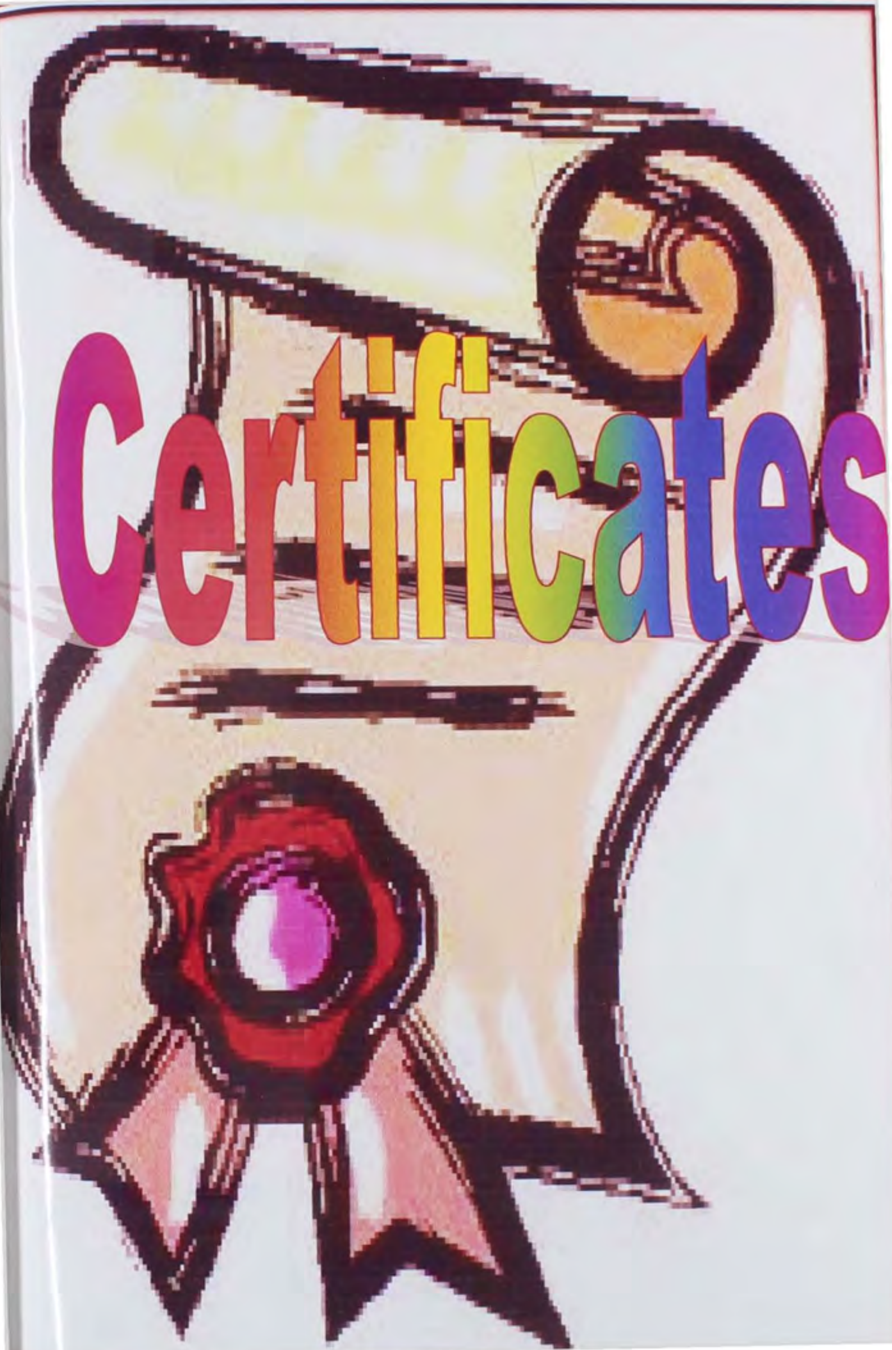
ABSTRACT

Studies on pest abundance, population dynamics of *Helicoverpa armigera* (Hubner) through pheromone trap and screening of tomato genotypes against major insect pest of tomato were carried out at Regional Horticultural Research Station Farm, NAU, Navsari during 2011-12. Results revealed that the incidence of sucking pests *viz.*, whitefly (*Bemisia tabaci* Gennadius) started from fourth week of November with a peak during third week of December. The incidence of leaf miner (*Liriomyza trifolii* Burgess) started from fourth week of November and reached peak during second week of February. The incidence of fruit borer (*Helicoverpa armigera* Hubner) started from fourth week of December and reached peak during third week of January. The incidence of leaf eating caterpillar (*Spodoptera litura* Fab.) started from third week of December and reached peak at the end of the crop season. Among various weather parameters, maximum, minimum and average temperature showed significantly negative correlation with fruit borer and positive

correlation with evening and average relative humidity. Leaf eating caterpillar and leaf miner were significantly positively influenced by wind velocity. Maximum temperature had significant negative correlation on the population of whitefly. Number of moth catches in pheromone trap showed the highly significant negative correlation with maximum, minimum and average temperature.

Out of five genotypes and two varieties of tomato, JT-3 recorded the lowest population of fruit borer, 2011/TOINDVAR-5 recorded lowest population of whitefly while, 2011/TOINDVAR-1 and 2011/TOINDVAR-2 recorded the lowest per cent damaged leaves by leaf miner and leaf eating caterpillar, respectively. Whereas minimum per cent damaged fruits by fruit borer were recorded in JT-3 (4.33%). Among all the genotypes screened, 2011/TOINDVAR-1 showed resistance against fruit borer, whitefly, leaf miner and leaf eating caterpillar. Hence, it can be utilized for developing the genotype/variety with multiple resistant against fruit borer, whitefly, leaf miner and leaf eating caterpillar.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CERTIFICATE

This is to certify that the thesis entitled **"Pest Abundance and Screening of Genotypes against Major Insect Pests of Tomato."** submitted by Shri **PATEL SHAILESHKUMAR DAHYABHAI** in partial fulfillment of the requirements for the award of the degree of **Master of Science (Horticulture)** in the subject of **Horticultural Entomology** of the Navsari Agricultural University, Navsari is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously framed the basis for the award of any degree, diploma or other similar title.

Place : Navsari

Date : April 16 2013

(H. V. Pandya)
Major Advisor

DECLARATION

This is to declare that the whole of the research work reported in this thesis in partial fulfillment of the requirements for the degree of **Master of Science (Horticulture)** in **Horticultural Entomology** by the undersigned is the results of investigation carried out by him under the direct guidance and supervision of **Dr. H. V. Pandya**, Head and Associate Professor, Department of Entomology, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari and that no part of the work has been submitted for any other degree so far.

Place : Navsari

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Shailesh
(Patel S. D.)

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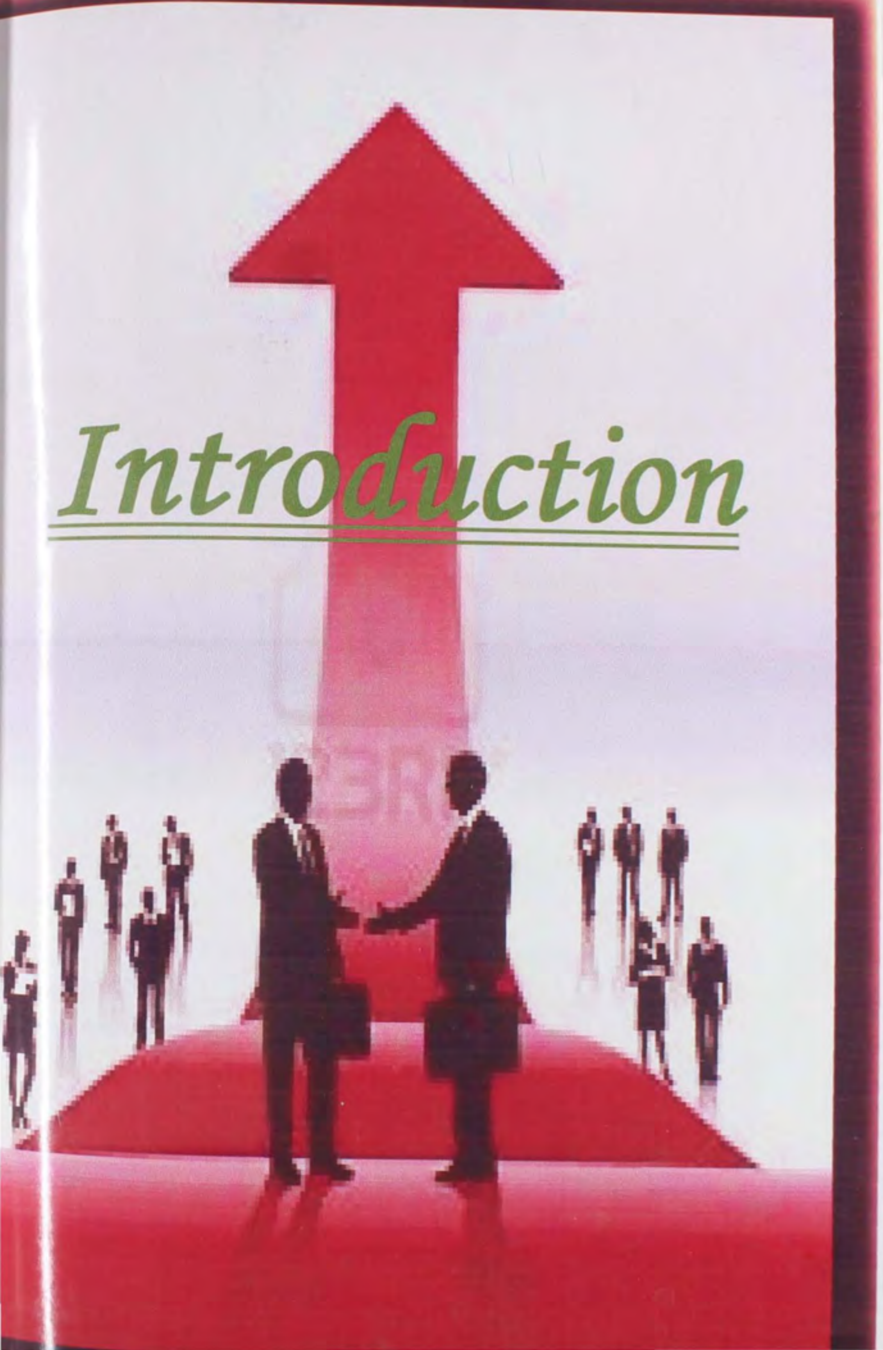


1. INTRODUCTION

Tomato *(Lycopersiconesculentum* Miller) is a solanaceous fruit vegetable, its origin is in Tropical America (Thompson and Kelly, 1957). Tomato plays an important role in our daily diet; it is a good source of vitamin 'A', 'B' and excellent source of vitamin 'C'. According to Rai *et al.* (2002), it contains 94.5 per cent water, 3.9 per cent carbohydrate, 1 per cent protein, 0.1 per cent fat and 0.5 per cent mineral matter. It can be eaten as a fresh fruit and is one of the most popular salad vegetables. It is used for culinary purpose or is also used in preparation of soups, salad, pickles, ketchup, sauces, pureesand many products.

Tomatois one of the most popular vegetables around the world. It ranks third largest vegetable crop after potato and sweet potato, but it tops in the list of canned vegetables. Vegetables are grown approximately in 38.92 per cent area of the total cultivated land in India. Tomato iscultivated as cashcropas well as vegetable crop oncommercial scale in almost all parts of India. In India, tomato hasbeen popular since last five decades and it is grown under an area of 8.65 lakh hectares with a total production of 165.26 lakh tonnes (Anon., 2011).

In Gujarat,the area under tomato is38.800 hectares with total production of 9,78,400 M.T. with productivity of 25.2 Tonnes per hectare. Gujarat share about 6 per cent tomato production in total tomato production in India. Ahmedabad, Banaskantha. Bhavnagar, Mehsana, Rajkot, Vadodara, Valsad and Navsari are the major tomato growing districts of Gujarat (Anon., 2011).

Among the constraints responsible for low yield of important vegetable crops, the losses due to insect pests are considered to be an important one. The crop is damaged extensively by a number of insect pests. Insects act either as vectors of disease or as defoliators, damage to leaves and fruits. As many as 16 pests of different groups have been recorded on tomato in India right from germination to harvesting which reduced not only its yield but also spoiled its quality (Butani, 1977). According to Reddy and Kumar (2004a), efforts are being made to realize its potential yield, attack by insects attributed to losses in yield up to 50 to 80 per cent. Few of them are considered to be major pests of tomato. The important insect pests of tomato are as under.

List of Important insect pests of tomato

Common name	**Scientific name**	**Family : Order**
Aphid	*Aphis gossypii* Glover *Myzuspersicae (*Sulzer*)*	Aphididae : Hemiptera
Jassid	*Amrasca biguttula biguttula* (Ishida)	Cicadellidae : Hemiptera
Whitefly	*Bemisia tabaci*	Aleyrodidae : Hemiptera
Thrips	*Thripstabaci*(Lind.) *Scirtothripsdorsalis*(Hood) *Thripspalmi*(Karny)	Thripidae : Thysenoptera
Leaf miner	*Liriomyza trifolii* (Burgess)	Agromyzidae : Diptera
Fruit borer	*Helicoverpa armigera* (Hubner)	Noctuidae : Lepidoptera
Tobacco leaf eating caterpillar	*Spodoptera litura* (Fab.)	Noctuidae : Lepidoptera
Fruit sucking moth	*Othreis fulonica* (Linnaeus) *Othreis materna* (Linnaeus)	Noctuidae : Lepidoptera
Mealy bug	*Ferrisia virgata* (Cockerell)	Pseudococcidae : Hemiptera
Fruit and shoot borer	*Leucinodesorbonalis*(Guen.)	Pyraustidae : Lepidoptera
Stem borer	*Euzophera perticella* (Raj.)	Phycitidae : Lepidoptera
Tomato moth	*Lacanobia oleracea*	Noctuidae : Lepidoptera
Epilachna beetle	*Henosepilachna vigintioctopunctata* (Fab.)	Coccinellidae : Coleoptera

Among various insect pests, *H. armigera*, *L. trifolii* and *S. litura* are potential pests causing considerable damage to tomato by attacking on various plant parts *viz.*, buds, flowers, fruits and leaves of tomato. About 21.50 per cent fruit damage was estimated due to *H. armigera* (Om Prakash *et al.*, 1979). Tiwari and Moorthy (1984) reported yield loss ranging from 22.39 to 37.79 per cent due to incidence of *H. armigera*.

The leaf miner larvae mines the tender leaves and feeds on inner tissues and thus give rise to transparent zigzag galleries, while leaf eating caterpillar, *S. litura* larvae feeds on chlorophyll content and skelotonize the entire leaf (Reddy and Kumar, 2004a).

Sucking pests *viz.*, aphid, jassid and whitefly are also the important pests limiting profitable cultivation of tomato in India. Among them, A. *gossypii* and *M. persicae* caused significant reduction in yield up to 25 to 80 per cent, while nymphs and adultsof *A. biguttula biguttula* sucked sap from plant tissues (Reddy and Kumar, 2004a).

Whitefly, *B. tabaci* is of considerable importance, because not only it feeds upon the plants but it also transmits tomato leaf curl virus; the development of the bud is hindered, bud shedding percentage increased and fruit formation was unsatisfactory and caused significant reduction in yield (Reddy and Kumar, 2004a).

Study on pest complex is the essential component for entomological aspect to start with any crop. Information regarding population dynamics, screening of genotypes in a sort duration crop like tomato is helpful to the farmers for managing the pest population. Above work on tomato in Gujarat is scanty, hence attempts have been made to have comprehensive information on the aspects cited below.

The following aspects were studied during the course of present investigation.

1. Pest abundance of major insect pests and their natural enemies in tomato in relation to major abiotic factors.

2. Population dynamics of *Helicoverpa armigera* through pheromone trap and working out correlation coefficients and regression equations between moth catches with weather parameters.

3. Screening of tomato genotypes against major insect pests.

   The result obtained through these investigations will form the subject matter for this dissertation.

Review of literature

2. REVIEW OF LITERATURE

Tomato *(Lycopersicon esculentum* Millet) is seriously threatened by attack of many insect pests at different stages of plant growth. Among the insect pests of tomato, fruit borer *(Helicoverpa armigera* Hubner), tobacco leaf eating caterpillar *(Spodoptera litura* Fab.), whitefly (*Bemisia tabaci* Gennadius) and leaf miner *(Liriomyza trifolii* Burgess) are major ones causing considerable damage to the crop. Hence, the research works done on the above insect pests are reviewed here under the following headlines.

2.1 Pest abundance of major insect pests of tomato

2.2 Population dynamics of *Helicoverpa armigera* through pheromone trap

2.3 Screening of tomato genotypes against major insect pests of tomato

2.1 Pest abundance of major insect pests of tomatoin relation to weather parameters

2.1.1 Fruit borer (*H. armigera*)

Datar and Pawar (1998) reported that tomato fruits of Pusa Ruby, Marglobe and Sioux varieties harvested during 15th July to 1st November had heavy infestation of fruit borer and from December onwards, the percentage infestation reduced considerably due to reduction in relative humidity, from 15th March to 15th June, the infestation was very low and no infestation was observed in tomatoes harvested in June. They further reported that rainfall, number of rainy days and relative humidity exhibited positive and significant correlation while maximum temperature had negative and significant correlation with fruit borer infestation level.

Tiwari and Moorthy (1984) reported that infestation of fruit borer was more in the first 4 pickings. In March-April harvesting, the infestation at the first picking was 49.70 % but it reduced to 4.25 % at the 7^{th} picking. The trend was similar in all the season.

Seasonal abundance of *H. armigera* was studied at Anand, Gujarat for 3 seasons on different corps by Yadav *etal.* (1986). They observed that the activity of *H. armigera* commenced with the onset of the monsoon on lucerne and then moved over to tomato, chickpea and then back to lucerne by April. The peak period of infestation was from December to February. The activity declined as the summer advanced and the pest became almost inactive during May, when high temperature prevailed.

Parihar and Singh (1986) found that the larval-population of *H. armigera*was low until the first week of February and increased, rapidly, thereafter words, reaching a peak in the last week of March, in two years. In the last week of April, the population declined to 4 larvae/10 plants. They recommended that the control measures should be applied at the time of flowering, which is also the time of mass oviposition.

Kalra (1992) observed the relationship between number of *H. armigera* larvae per plant and the per cent fruit damage was non-significant. Similarly there was no clear cut correlation between the number of larvae attacking the plants and the prevalent weather factors *viz.* temperature (Av. weekly min. temp. r = 0.298) and relative humidity (R.H.) (av. weekly R.H.r =-0.533).

Borah (1995) revealed that October 25th planting showed lower pest incidence and gave higher yield followed by another planting in October. The results suggest that early planting from August 25th to September 25th had no advantage over late planting from October 10 to November 25 both in respect of pest incidence as well as yield.

Sivaprakasam (1996) studied effect of weather factors on populationdynamics of *H. armigera* on tomato at Tamil Nadu and reported that maximum temperature and relative humidity had the greatest effects on *H. armigera* infestation.

Arif and Kumar (1999) observed that the sporadic infestation of fruit borer (*H. armigera*) on tomatoes grown both in open field and in polyhouse conditions at 1650 M attitude at Kuman hills of Central Himalayas, Uttar Pradesh, India. In F-1 hybrid of tomato planted in polyhouse, infestation of *H. armigera* larvae was observed in March, April and October to mid November. However, the peak infestation period was in May and June.

Hath and Das (2004) studied on incidence of fruit borer *(H. armigera)* in late planted tomato cultivars Pusa Ruby and Abinash-II at Terai Agro ecology of West Bengal. The incidence of *H. armigera* was observed from the third week of March and second week of April and level of infestation was always high. The peak infestation was recorded during the first week of April.

Moral (2006) determined that the *H. armigera* was concentrated at the borders of the tomato field, gradually colonizing the inner area as cloudless days and northeastern winds (the same direction where another tomato field were 500m apart) were predominant.They further revealed that non-existence of correlations between other meteorological factors, temperature and relative humidity, with insect populations.These maps are fundamental to developing effective pest management and a powerful tool of a precision agriculture system.

Bajya and Monga (2009) reported that the pest started its activity from the beginning of July in groundnut and then it moved on to cotton and simultaneously also observed on sunflower and bajra. However, from September, the population moved from cotton to pigeon pea but disappeared as the crop reached maturity. During Rabi season (2005-06 and 2006-07), the pest was active on chickpea and mustard showing its shifting from pigeon pea. The highest population on chickpea was during February (2005-06) and March (2006-07) when the crop was in pod formation stage. From March onwards the pest survived on summer sunflower and remained up to the beginning of June. Thus, if the host crops are available in a given ecosystem, the pest remains active throughout the year.

Subharanani and Singh (2009) reported that first pod borer complex appeared in the early flowering stage followed by *Cydia ptychora, Exelastis atomosa, and Melanagromyza obtusa* which continued till crop maturity in pigeon pea. Thus, the crop remained vulnerable to pod borer complex from second week of January to third week of February and the populations fluctuated from 35.5% to 45.5% in first year and 37.0% to 42.3% in second year. *L. boeticus* dominated throughout and a majority of the pod borers showed negative correlation with temperature, relative humidity, rainfall and wind speed except in few cases; however, a positive correlation was observed with all the pod borers and sunshine hours

Reddy and Kumar (2004b) reported peak population of fruit borer (*H. armigera*) during March to April on tomato at Bangalore, Karnataka.

The population dynamics of *H. armigera*waw studied on chick pea (*Cicerarietinum*), pigeon pea (*Cajanuscajan*), tomato (*Lycopersiconesculentum*), sunflower (*Helianthus annus*) and okra (*Abelmoschusesculentus*). It was observed that from October onwards, the pest infested chick pea and pigeon pea only and was not traceable on other host plants. After the harvest of chick pea in March, the pest was found infesting sunflower and lowest population in tomato in June. Later on, the pest migrated to okra. Among natural enemies, an Ichneumonid parasitoid, *Campoletischloridae* was found to be parasitizing *H. armigera* larvae(Chandel *et al.*, 2005).

Rijal(2006) observed the maximum increase in percent pod damage (15.39%) during 122-129 days after sowing (DAS) and the highest number of larvae (3.10/plant) at 129 DAS. The average pod damage was 36.33% at harvest. The relation of pod damage with grain yield was significant ($P < 0.01$) and negatively correlated ($r = - 0.97$).

Kurl and Kumar (2010) recorded the larvae of *Helicoverpa armigera* on tomato crop in 2nd standard week (January) and continued till 21st standard week. The highest build-up of larvae was recorded in the 15th standard week. Thereafter, the larval population declined. The maximum numbers of larvae were found feeding on top leaves followed by middle leaves and minimum larvae were found feeding on lower leaves. The percent of larval parasitism caused by *Ecphoropsisperdistinctus*(Vier) was highest in the 15th standard week, thereafter the larval parasitism declined to nil in the 18th standard week. They further revealed that average maximum temperature (32.9°C), minimum temperature (17.9 °C), morning humidity (74.2%), evening humidity (30.1%) coupled with rainfall (6.0mm) prevailed during 10^{th} standard week to 15^{th}standard week were found most suitable for larval population build-up. Above and below of these ranges did not favour the development of larvae.

Tripathi and Singh (2011) revealed that the insect passed through five overlapping generations in a year. The growth of the population of *H. armigera* and its generation survival were maximum in second generation followed by fourth, third, fifth and first generations. Parasitoids, predators, fungal and viral diseases and abiotic factors were among the various observed mortality factors, although the role of predation was not specifically investigated. The key mortality factor within generation was an unidentified pupal parasitoid. The key mortality factor operating between generations was the variation in natality (log of ratio of maximum potential natality and actual eggs). In spite of the biotic mortality factors operating on *H. armigera* population, the number of eggs laid was the most important factor that governs the trend of the population growth in all generations.

Bouhachem*et al.* (2012) recorded the greatest number of eggs and larval stages during July which coincided with the maximum moth activity.

Dina and Tudor (2012) described the phenology and seasonal dynamics of cotton bollworm on tomatoes of "Fakel" variety with medium ripening term in the conditions characteristic to the central zone of Moldova. For forecasting terms of phenological events for cotton bollworm, a method of average daily temperatures, as well as pest development curves based on long-term observations have been used. A model of forecasting terms of oncoming phenological events for cotton bollworm on tomatoes of "Fakel" variety with medium ripening term was constructed.

Fakhri and Jamal (2012) recorded maximum range of *H. armigera* from 26.0 to 38.0 larvae/plant at 150 DAS (35th week) and the minimum population was recorded at 60 and 90 DAS (23rd and 27th week) ranged from 0.00 to 2.50 larvae/plant while, at 60 DAS was not found (0.00) population of *H. armigera* on three varieties (R.S.-875, F-1378 and H-1098) of cotton during both cropping years. They also calculated correlation coefficient of *H. armigera*, whichwas negative with maximum and minimum temperatures during 2009-10 and 2010-11, respectively. Whereas, with maximum and minimum relative humidity was calculated positive against *H. armigera* during both cropping seasons. The values of coefficient of determination were high (0.89 to 0.94) of*H. armigera* governed significantly with the weather parameters.

2.1.2 Whitefly *(BemisiatabaciGennadius)*

Bhardwaj and Kushwaha (1984) observed that the incidence of whitefly (*B. tabaci*)on tomato crop commenced from thirdweek of August and continued till end of January in monsoon crop and from first week of February to end of April in summer crop but higher intensity of population was built-up from firstweek of October to third week of November and again during March. The population was negatively correlated with humidity. The correlation was highly significant for monsoon crop. The maximum temperature during monsoon crop (August-January) showed significant positive correlation with the population of whitefly (*B. tabaci*). The average temperature also showed similar trend with population.

Arnal *et al.* (1993) reported that the whitefly (*B. tabaci*)population was maximum on tomato in November and December at the end of rainy season.

Gendi*et al.* (1997) revealed that the highest population of whitefly (*B. tabaci*)on tomato occurred in late August and highest tomato yield was recorded in crops planted in June.

Borah and Bordloi (1998) carried out field experiment at Diphu, Assam and reported that the planting of tomato from October 10 to November 25 recorded significantly lower whitefly *(B. tabaci)* population than the crop planted from August 25 to September 25.

The population dynamics of tomato whitefly *(B. tabaci)* was examined in a field at Giza Governorate, Egypt and found that temperaturehad a significant effect on both egg and nymphal populations, while relative humidity had no significant effect (Megeed *et al.*, 1998).

According to Rafieet *al.* (1999) the heat sum model and population of tomatowhitefly (*B.tabaci*)adults were highly correlated. The regression value (b) indicated that for every 0.5 to 0.6 ^{0}C increase in degree days, on an average, there was a one per cent increased in the infestation level of whitefly (*B. tabaci*) adults during two tomato growing seasons in Egypt.

According to Jovelet *al.* (2000) the daily patterns of movement of *B. tabaci,* both towards and within tomato plants, and their relationship with some climatic variable was carried in farmers fields at Guayabo, Turrialba, Costa Rica. The immigration of whitefly adults and movement between plants were determined and correlated with the speed and direction of the wind, temperature and relative humidity. Both immigration and re-population of pests on the plants were continuous throughout the day, with greatest activity in the morning.

Temperature, relative humidity and rainfall were found negatively correlated with tomato whitefly (*B. tabaci*) population, the population reached at highest level during middle of February and high level was maintained from mid February to mid March (Chadhuri *et al.*, 2001).

Gour and Pareek (2002) revealed that the infestation of whitefly(*B. tabaci*) commenced from the third week of March on tomatoat Jobner, Rajasthan.

Ramos *et al.* (2002) carried out an experiment to evaluate the dynamicsof whitely population on tomato crops at Algave. Population counts of *B. tabaci* were high in the first month of autumn, and then decreased until January.

Reddy and Kumar (2004b) reported that the infestation of white fly (*B. tabaci)* was maximum during January to June on tomato at Bangalore, Karnataka.

Leite*et al.* (2005) studied the population dynamics of the whitefly *B. tabaci* biotype B on two successive *A. esculentus*var. "Santa Cruz" plantations. Leaf chemical composition, leaf nitrogen and potassium contents, trichome density, canopy height, plant age, predators, parasitoids, total rainfall and median temperature were evaluated and their relationships with whitefly on okra were determined. Monthly number estimates of whitefly adults, nymphs (visual inspection) and eggs (magnifying lens) occurred on bottom, middle and apical parts of 30 plants/plantation(one leaf/plant). Plants senescence and natural enemies, mainly *Encarsia*sp., *Chrysoperla* spp. and coccinellidae, were some of the factors that most contributed to whitefly reduction. The second okra plantation, 50 m apart from the first, was strongly attacked by whitefly, probably because of the insect migration from the first to the second plantation. No significant effects of the plant canopy on whitefly eggs and adults distribution were found. A higher number of whitefly nymphs were found on the middle part than on the bottom part.

Prasad *et al*. (2008) studied the incidence of whiteflies, *B. tabaci* was observed in 40^{th} MW (first week of October) up to end of crop growth. The population of whiteflies very low during initial periods of crop growth with gradual increase as crop stage advanced.

Population dynamics of whitefly (*B. tabaci*) was studied throughout the year, for 6 years on oilseed, pulses, sugar, fodder and vegetable crops in cotton growing areas of the Punjab, Pakistan. Infestation based on their abundance was found on 17 fields and 28 vegetable crops. Of those, 16, 22 and 7 were observed as major, minor and incidental hosts, respectively. During winter months (December to February), the insect was present on 22 hosts. However, *Solanummelongena*, *S. incanum, Menthaviridus, Ipomoea batatus*and*Ricimuscommunis* served as main hosts for over wintering whitefly. Spring vegetables like *Citrullus* spp., *Cucumis* spp. *Solanum* spp. and pulse, *Glycine max*, mainly helped in the pre-cotton season build up of whitefly population in addition to early sown cotton. Better and timely management of the pest on these hosts will significantly help to reduce the carry-over of the pest to cotton and other economical crops(Rafiq*et al.*,2008).

Patil (2009) reported that whitefly multiplied at faster rate reaching to peak level (9.77 adults/leaf) during last week of November.

Perveen*et al.* (2010) observed that whitefly population was high with mean value 9.25 per three leaves in 1999 as compared to mean value 5.57 during 2000. Out of 64 cotton varieties infested with whitefly population, 51 exhibited economic threshold level (five nymphs and or adults per leaf) in 1999 but 38 varieties were found in 2000.Peak population was observed at the end of growing season i.e. between 10^{th} and 24^{th} September during both years.

Sarangdevot *et al.* (2010) observed the whitefly population reached to maximum level (3.0 whiteflies/plant) during last week of October (43rd standard meteorological week) and then declined gradually. The mean temperature and relative humidity during the peaks were 24.1 and 24.82 ^{0}C, 38.5 and 47.5 per cent in 2000-01 and 2001-02, respectively. The whitefly population was positively correlated with mean temperature in both the seasons of study but negatively correlated with mean relative humidity.

Mane and Kulkarni (2011) reported that with increase in temperature and humidity, there was increase in the population of *B. tabaci* and *vice-versa.* Number of rainy days exhibited highest positive direct effect and evening relative humidity showed highest negative direct effect on the population of whitefly.

Fakhri and Jamal (2012) revealed that mean population of *B. tabaci*was maximum (ranged from 2.10 to 3.64 nymphs/adult/leaves) at 150 DAS (35th week) and the minimum population was recorded at 60 and 90 DAS (23rd and 27th week) ranged from 0.15 to 0.30 nymph/adult/leaf. They also calculated correlation coefficient of *B. tabaci,* whichwas negative with maximum and minimum temperatures during 2009-10 and 2010-11, respectively. Whereas, with maximum and minimum relative humidity it was calculated positive against *B. tabaci* during both cropping seasons. The values of coefficient of determination (R^2) were high (0.89 to 0.94), indicated that the population of *B. tabaci* governed significantly with the weather parameters.

Srinivasan*et al.* (2012) observed that the peak incidence of whiteflies varied seasonally from year to year. In general, whitefly populations were not uniformly distributed. Tomato genotypes exhibited minor differences in their ability to support whitefly populations.

2.1.3 Leaf miner (*Liriomyza trifolii Burgess*)

Minkenberg and Helderman (1990) reported that the effect of three constant (15, 20 and 25°C) and one alternating (16-22°C, mean 19.5°C) temperatures on development, mortality, fecundity and longevity of *Liriomyzabryoniae*onon tomato cv. *Moneydor*. Development rates for each pre-adult stagewere estimated. Lower thresholds for development and oviposition were at least8°C and approximately 11°C, respectively. The optimum temperature was 25°C for development and reproduction of leaf miner. Pupal length was positively correlated with temperature but not with development time, fecundity, oviposition rate or longevity.

The population of tomato leaf miner (*L. trifolii)*was 3.08 larvae/leaf in the range of 2.30 to 5.75 larval/leaf in first week of January, while it was recorded as lowest (2.80 larvae/leaf) in fourth week of November. There was no infestationof miner during second and third week of November and secondfortnight of December (Anonymous, 1996).

According toUlubilir and Yabas (2000),adult populationof leaf minerwere high during April and May and the populationdecreased in June on tomato crop during 1992, while the Adultpopulation observed in autumn indicated that populationwas high in November with the peak in mid November, then drop down at the end of December. However, in these two studies, larval population development was observed in April and May during spring and again showed parallel development in Autumn and declined to zero in December.

Hemalatha *et al.* (2002) carried out field experiment in Andhra Pradesh, and found that the high relative humidity (69.77%) had positive correlation with the leaf miner (*L. trifolii*) population.

According to Krishnakumar *et al.* (2004) the relative humidity had a significant negative correlation with the number of leaf miner (*L. trifolii)* on tomatocrop at Indian Institute of Horticulture Research (IIHR), Bangalore.

Reddy and Kumar (2004b) reported that the peak infestation of leaf miner (*L. trifolii*)was noticed during March to April and population declined during November to December on tomato at Bangalore, Karnataka.

Hath and Das (2004) found that the highest infestation of leaf miner (*L. trifolii)*was observed during the second week of April, while non-significant level of leaf miner infestation was noticed during the third week ofFebruary on tomato cv. Pusa Ruby and Abinash-II at TeraiAgroecology of West Bengal.

López*et al.* (2010) observed that *Liriomyzahuidobrensis* adults were present throughout the growing season and the population increased along crop development. The same was true for all varieties regarding larval damage, being low on early crop stages and severe in late season. Varieties were grouped in two different categories according to damage scale index. Shepody, Kennebec, Frital and Innovator showed a higher damage index when compared with Santana, Ranger Russet and Russet Burbank, which exhibited a lower damage. Moreover, it could be assumed that damage was related to the foliage greenness, with light green colored varieties

(Shepody, Kennebec, Frital and Innovator) being more attractive and affected by *L. huidobrensis*.

Chakraborty (2011) recorded incidence of leaf miner, *L. trifolii* population in tomato crop by randomized block design during four consecutive seasons (2006-2009) at Alipurduarand Jalpaiguri in West Bengal. The population was initiated at about 46 standard meteorological week (SMW), improved at first slowly up to 01SMWand then steadily up to 6SMWattaining the maximum at about 8 SMW which was maintained up to about 13 SMW. The population then subsumed at first slowly then abruptly. From the present field observation, it was thus evicted that a time-fitted early-season cultivation of tomato crop was economically prudent to minimize leaf miner menace. They also revealed that abiotic conditions such as maximum temperature, minimum temperature, temperature gradient, average temperature, maximum relative humidity, minimum relative humidity and sunshine hours had significant negative influence on *L. trifolii* population. In case of relative humidity gradient a positive influence was observed. In addition, other factors such as average relative humidity, number of rainy days, rainfall expressed insignificant positive effect on population development.

Tshiala*et al.* (2012) revealed that leafminer*Agromyzid*pest and climatic factors exhibit a non-linear relationship best described by polynomial function of order two while in general, the influence of climate change on the spatial distribution of leafminer*agromyzid* pest over Limpopo province is noticeable. This work contributes towards their understanding of the impact of climate change on the population dynamics of leafminer*agromyzid* pest and hence impacts on tomato production in Limpopo province, South Africa.

2.1.4 Leaf eating caterpillar (*S. litura*)

Population dynamics of leaf eating caterpillar, *Spodopteralitura*Fabricius (Noctuidae: Lepidoptera) was studied on castor,*Ricinuscommunis* L. cultivated in middle Gujarat agroclimatic conditions. The higher eggs and larval population as well as leaf damage caused by *S. litura* to castor plants was found in the third and fourth week of November, whereas the lower population and leaf damage was observed in the first and second week of October.Among the various abiotic factors minimum temperature, vapour pressure (morning & evening) and RH (evening) were found most influencing factors showed negative effect on ovipositionbehaviour and larval development of *S. litura*. The maximum temperature showed significant negative influence on oviposition by *S. litura* (Thanki*et al.*, 2003)

Reddy and Kumar (2004b) reported that the leaf eating caterpillar (*S. litura*) was noticed throughout the year except during September to October on tomato at Bangalore, Karnataka.

Wan *et al.* (2008) revealed that common cutworm larvae had low susceptibility to *Bt* cotton. There was no significant difference in larval population densities in conventional and *Bt*cotton fields. However, the larval populations of the insect on conventional plants treated with chemical insecticides for control of target pest of Bt cotton were significantly lower than that in Bt cotton fields. These results indicated that the common cutworm was the potential to become a major and alarming pest in *Bt*cotton fields, and therefore efforts to develop an effective alternative management strategy are needed.

2.2 Population dynamics of *Helicoverpa armigera* through pheromone trap.

Pawar *et al.* (1988) observed that synthetic pheromone mixture attracted more moths than the virgin females as baits. Field tests showed that rubber septum on which pheromone was adsorbed was far more attractive. Eventually, small rubber burette stoppers, on which 2 mg of the pheromone was adsorbed, were adopted as the standard lures. Tests showed that these lures attracted moths for several months but that 4 weeks was the optimum period. Traps placed just above the crop canopy in sorghum, millet, pigeonpea, chickpea, and groundnut caught more moths than at other heights. Dichlorvos used as a fumigant did not decrease catches and killed moths for over 4 weeks.

Srivastava and Srivastava (1989) revealed that both pheromone and light traps showed three periods of moth activity during both the cropping years. Both types of traps showed almost a similar trend in population fluctuation during the cropping years and there were significant positive correlations between light and pheromone trap catches (r = 0.87 for 1984/85 and r = 0.93 for 1985/86). However, pheromone traps had many advantages over light traps in monitoring the *H. armigera* moths.

Malik *et al.* (2003b) record the first moth, in the field was appeared during 4^{th} and 3^{rd} week of transplantation each year (1995-96) respectively. Maximum mean numbers of moths (11 and 09) were captured during 11^{th} and 8^{th} week of transplantations, when the average temperatures were 28.38 and 26.30 °C, each year respectively. A total mean number of 63 and 45 moths were captured during the two years of study, respectively. The adult pest remained in the field till the crop was uprooted. The study strongly recommends the use of pheromones than pesticides against the said pest in tomato.

Malik*et al.* (2003a) record the first moth, in the field was appeared during 7^{th} and 6^{th} week of trap installation each year (1995-96) respectively. Maximum mean numbers of moths (11th and 7th) were captured during 9^{th} and 7^{th} week of trap installation, when the average temperatures were 28.38 and 25.78 °C, each year respectively. A total mean number of 24 and 17 moths were capturing during the two years of study respectively. The adult pest remaining in the field till the 11th and 4th August 1995 and 1996, respectively. The study strongly recommends the use of pheromones than pesticides against the said pest in okra.

A study on pheromone trap monitoring was conducted in two sites (Rampur and Fulbari) of Chitwan during the same year (2004/05) to depict the seasonal occurrence of *H. armigera*. This study indicated that the peak number of moth catch (91 adult males) was found during the second week of March at Rampur while it was at peak (42 adult males) during the third week of March at Fulbari. (Rijal, J., 2006).

Pathania *et al*. (2009) observed that the moth activity of *H. armigera*commenced in the first week of March (10 SW) and ceased by the end of June (25-26 SW) as monitored through pheromone traps. While in 2004, a significant negative correlation existed between moth catches and minimum temperature and positive correlation with wind velocity.

Bouhachem*et al.* (2012) observed that the moths were active from late May to early November and the maximum trap catch occurred in July.

Sharma *et al.* (2012) carried out an experiment on monitoring of *H. armigera* male moths through pheromone traps in chickpea crop at village Kapren, dist. Bundi during 2011-12.

Maximum number of male moths trapped were 105.66/trap/week, while maximum number of larvae was 30.0/10 plants recorded during 12th standard week (19 March -25 March). They further revealed that abiotic factors like maximum temperature and minimum temperature had positive correlation with male moth catches and larval population of *H. armigera* while, relative humidity had negative correlation with male moth catches and larval population of *H. armigera*.

Shivanna*et al.* (2012) carried an experiment on population dynamics of bud worm using pheromone traps indicated the scattered activity of moth throughout the year. The maximum number of moth activity was observed from 35th to 43rd standard week. They further revealed that rainfall and minimum temperature had positive and significant association with trap catches. Whereas, negativeand non significant correlation was observed with maximum temperature and relative humidity.

2.3 Screening of tomato genotypes against major insect pests of tomato

2.3.1 Fruit borer (*H. armigera*)

Chandrakar*et al.* (1999) screened 24 tomato cultivars against fruit borer (*H. armigera*)in Madhya Pradesh. They reported that cultivars Pusa early dwarf, Arka Vikas and Pusa Gaurav had highly hairy peduncles which were less susceptible to the fruit borer damage than those with less baits on the peduncles.

Lai *et al.* (1999) screened 13 tomato hybrid varieties against the fruit borer (*H. armigera*)and found that Ellora and Chaitali were resistant, whereas Heera, Commander and Ganga Kaveri were moderately resistant.

Thakur *et al.* (1999) screened the number of tomato varieties against *H.armigera*at Chamba, Himachal Pradesh. S-12 was mostresistant (0.66 per cent fruit infested) while HS-110 was themore susceptible.

Chaudhari*et al.* (2000) evaluated tomato variety Pusa Ruby and 6 hybrids against *H. armigera* and found that Pusa Ruby was less susceptible to fruit borer (*H. armigera*). Among the hybrids Rasika was more susceptible, while hybrid Arjuna and Rupali were moderately tolerant.

Punjab Uma was more resistant to fruit borer (*H. armigera*)than Denor and Punjab Chhuharain Punjab, India (Singh *et al.*, 2002).

Brar*et al.* (2002) screened 186 tomato varieties against fruit borer (*H. armigera)*. None of the genotype was free from fruit borer damage but variability existed in their susceptibility against fruit borer. The damage due to the fruit borer was low (15%) in 65, medium (16-30%) in 98 and high (>31%) in 23 genotypes.

Among the 11 different determinate type (DT) genotypes screened, significant lower fruit damage by tomato fruit borer *(H. armigera)* was recorded in check variety J. Ruby. However, indeterminate type (IDN) experiment, numerically the lowestfruit damage was recorded in JTL-2 (Anonymous, 2003).

Amutha and Manisegaran (2005) found that resistant accession LE 228 had less trichome density on leaves (10.87 mm^2), calyx (10.03 mm^2) andcorolla (9.03 mm^2). It is evident from the results of fruit characters, the least damaged accessions such as LE 228, EC 398707, LE 525, Arka Surabh and Arka Vikas were of short fruits with lesser diameter of either round or round flat, having lesser volumeindex and RLSA and more RLSR.

Accessions Varushanadu Local, Seijima Jeisei, PT 4287, and Roma and Ac 238 were determined to be highly resistant to *H. armigera*. Accessions Varushanadu Local, PT 4287 and Seijima Jeisei may be used as donors of resistance in future breeding programs, but accessions Roma and Ac 238 were recommended for commercial cultivation, as they possessed insect tolerance as well as gave higher yield (Selvanarayanan and Narayanasamy, 2008).

Sajjad *et al*. (2011) found that Roma VF, NARC-1 and FS-8002 were susceptible genotypes with fruit infestation (37.69, 37.08 and 36.41%, respectively) and larval population per plant (1.02, 1.02 and 0.84 respectively). Whereas, the genotypes Sahil, Pakit and Nova Mecb had fruit infestation (12.30, 13.14 and

13.96%, respectively) and larval population per plant (0.42, 0.42 and 0.43 respectively) and declared as resistant genotypes to tomato fruit borer. Sahil, Pakit and Nova Mecb could be used as a source of resistance for developing tomato genotypes resistant to tomato fruit borer.

Singh *et al.* (2013) screened 13 varieties of tomato against fruit borer. None of the variety was found to be highly resistant. Two varieties, *Viz.*, NS-538 (Namdhari Seed) and Shaktiman were least infested and classified as resistant varieties. Nine varieties *viz.*,NS-501 (Namdhari Seed), Lakshmi, shahenshah, NS-815 (Namdhari Seed), All Rounder, Manithoibi, Manileima, Ms (Marglobe Supreme) and American apple were graded as moderately resistant. Two varieties *viz.*, Dev and Manikhumnu were rated as moderately susceptible.

2.3.2 Whitefly

Deponti*et al.* (1975) found that the cultivar Delicious was more resistant against whitefly than Tiny Tim under artificial light conditions whereas a high degree of resistance was found in *L. hirsutum*Var. g*labratum*and S. *penelli.*

Singh *et al.* (1999) screened the seven varieties of tomato against whitefly (*B. tabaci*) at Zonal Agricultural Research Station, Morena, Gwalior,variety Pusa Ruby recorded minimum population which was significantly less than rest of varietiesexcept PusaSheetal and PusaGaurav, while local variety wasfound more susceptible than other varieties except Punjab Keshari and Pusa earlydwarf.

Chaudhari*et al.* (2000) evaluated seven tomato varieties i.e. Pusa Ruby and six hybrids against whitefly (*B. tabaci*). Pusa Ruby was more susceptibleand Abinash 11 was tolerant to whitefly (*B. tabaci)*while hybrid Rasika observedless susceptible and hybrid Arjuna and Rupali were moderately tolerant.

Razvi*et al.* (2000) screened the tomato cultivar against whitefly *(B. tabaci),* cultivar Fiona, T.Y. King and Top 21 observed more resistant, whileMeghana was found more susceptible.

Ali*et al.*(2002) screened ten tomato cultivars of the determinate type against whitefly (*B. tabaci*). They reported that cultivar Punjab Chhuhara was the most resistant followed by selection-7.

Gour and Pareek (2002) screened the seven varieties of tomatoagainstwhitefly (*B. tabaci*)at Jobner, Rajasthan. They reported that Pusa early dwarf and Pusa Ruby emerged as less susceptible, Punjab Chhuhara, K.S-17 and Priti emerged as moderately susceptible and Arka Vikas and Arth-4 emerged as highly susceptible.

Elanchezhyan*et al.* (2008) reported that the population of whitefly, *B. tabaci* on the hybrid, Sweta was 0.0 number/3 leaves.

Patel *et al.* (2009) reported that MHOK-14, Paras softy and VRO-5 found resistant varieties against whitefly, *B. tabaci* as they recorded less than 1.36 whiteflies/leaf.

2.3.3 Leaf miner (*L. trifolii*)

Chaudhari*et al.* (2000) screened seven tomato varieties against leaf miner (*L. trifolii*). They reported that Pusa Ruby was less susceptible and among the hybrids Abinash-II recorded the highest infestation and hybrid Rasikawas more susceptible, hybrid Arjuna and Rupali were moderately tolerant to leaf miner (*L. trifolii*).

Tandon and Bakthavatsalam (2003) screened 10 tomato genotypes against leaf miner (*L. trifolii)* at Project Directorate of Biological control, Bangalore, Karnataka. The highest number of leaves were damaged in hybrid 101 super (85.97%) followedbyAnjali (83.09%) while lowest damaged leaves was recorded in Varalakshmi. However, maximum number of mines/leaf (2.88) were recorded on ArkaMaghalifollowed by Challenger-1 (2.81) and Arka Vikas (2.74), whileminimum number of mines/leaf was recorded on hybrid 101 super (1.24).

Among the 11 differentdeterminate type (DT) genotypes screened,ATL 96-17 recorded significantly lower leaf damage bytomato leaf miner (*L.trifolii*). In an indeterminate type(IDT) experiment, JTL-2 recordedsignificant minimum leaf damage by leaf miner (*L. trifolii*)than ATL 98-336, J. Ruby and ATL 97-44 (Anonymous, 2003).

Hemalatha and Maheshwari (2005) screened seven tomato cultivars against leaf miner (*L. trifolii*)at Tirupati, Andhra Pradesh, Pusa Ruby had the highest number of mined leaves per branch (6.0), number of maggots per branch (18.4) and miner infestation per plant (75%), however least for hybrid cross-08 (1.7, 5.3 and 2 per cent, respectively).

Lascar and Ghosh (2005) screened ten tomato varieties against leaf miner (*L.trifolii*)at Kalimpong, West Bengal. Kalimpong local and PusaUphar were less susceptible, while hybrid Rupali F-l was highly susceptible to leaf miner.

Materials and Methods

3. MATERIALS AND METHODS

The investigations on "**Pest Abundance and Screening of Genotypes against Major Insect Pests of Tomato**" were carried out at Regional Horticultural Research Station Farm, Navsari Agricultural University, Navsari, Gujarat during *Rabi*season of2011-12 (plate-1). The materials used and techniques employed for conducting various experiments are presented.

3.1 Pest abundance of major insect pests and their natural enemies in tomato

Study on pest abundance of major pests and natural enemies of tomato was carried out at RHRS farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat during *Rabi*season of 2011-12. The other details of the experiment are given below.

3.1.1 Experimental details

1.	Location	:RHRS, Navsari
2.	Year of start	:2011
3.	Year of completion	:2012
4.	Treatment	---
5.	Replication	---
6.	Crop and variety	:Tomato, JT-3
7.	Spacing	:60 cm x 40 cm
8.	Plot size	:19.8 x 20 m^2

Plate: I General view of tomato Plot for pest abundance

Plate: II General view of tomato plot for varietal screening

9. Method of sowing :Transplanting
10. Date of transplanting : 28th Oct. 2011
11. Manure and Fertilizer :As per the recommendation
12. Type of soil :Black soil
13. Observation period :Sampling was done at weekly interval starting from transplanting to the harvest stage of the crop

After transplanting recommended agronomical practices were followed. However, experimental area was kept free from insecticidal spray throughout the crop season in order to record the natural incidence of insect pests as well as their natural enemies.

To find out the incidence of major insect pests on tomato variety JT-3, 20 plants were randomly selected. Population of major insect pests was recorded at weekly interval from randomly selected 20 plants starting from 3 week after transplanting (WAT) till the harvest of the crop.

3.1.2 Method of observations

3.1.2.1 Fruit borer, *Helicoverpa armigera* (*Hubner*)

The observations were recorded by thoroughly observing the randomly selected entire plants and numbers of larvae of fruit borer per plant wererecorded. Percent fruit damage was worked out from total number of damaged and healthy fruits at the time of harvest.

3.1.2.2 Whitefly, *Bemisiatabaci*Gennadius

The number of nymph and adults of whiteflies were recorded during early morning from three leaves i.e. top, middle and lower portion of selected plants.

3.1.2.3 Leaf miner, *Liriomyzatrifolii*Burgess

For recording the tomato leaf miner infestation, the observations were taken on the basis of the nature of damage. For the purpose, total number of leaves and number of infested leaves wererecorded and percent infested leaves wereworked out once in every week.

3.1.2.4 Leaf eating caterpillar, *Spodopteralitura*Fab.

The observations were recorded by thoroughly observing the randomly selected entire plants and percentage of leaf damage were worked out from total number of damaged and healthy leaves.

3.1.2.5 Ancillary observations

Standard week wise data on major abiotic factors *viz.,* maximum, minimum and average temperature, morning, evening and average relative humidity, sun shine hours and wind velocity were obtained from Meteorological observatory, College Farm, NAU, Navsari. Observations were also recorded on available natural enemies on each plant part.The data on pest incidence were correlated with major abiotic factors and regression equations were worked out for those parameters having significant correlation with abiotic factors.

3.2 Population dynamics of *Helicoverpa armigera* through pheromone traps.

Study was carried out on the population dynamics of *Helicoverpa armigera* through pheromone trapat RHRS farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat during *Rabi*season of 2011-12. The other details of the experiment are given below.

3.2.1 Experimental details

1.	Location	:RHRS, Navsari
2.	Year of start	:2011
3.	Year of completion	:2012
4.	Treatment	---
5.	Replication	---
6.	Crop and variety	:Tomato, JT-3
7.	Spacing	:60 cm x 40 cm
8.	Plot size	:19.8 x 20 m^2
9.	Method of sowing	:Transplanting
10.	Date of transplanting	:
11.	Manure and Fertilizer	:As per the recommendation
12.	Type of soil	:Black soil

3.2.2 Method of observations

A phermone trap was installed in the field of tomato. The septa was recharged at four week interval. The number of moths of *Helicoverpa* caught in the pheromne trap was counted at weekly interval and data on moth catches were correlated with weather parameters and regression equation was worked out for the parametrs having significant effect.

3.3 Screening of tomato genotypes against major insect pests

Screening of tomato genotypes for the relative resistance/susceptibility against major insect pests was carried outat RHRS farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat during *Rabi*season of 2011-12. The other details of the experiment are given below.

3.3.1 Experimental details

1. Location :RHRS, Navsari
2. Year of start :2011
3. Year of completion :2012
4. Genotypes

   1. 2011/TOINDVAR - 1
   2. 2011/TOINDVAR - 2
   3. 2011/TOINDVAR - 3
   4. 2011/TOINDVAR - 4
   5. 2011/TOINDVAR - 5
   6. Arka Vikas C)
   7. JT 3 (LC)

5. Replication :4
6. Crop and variety : Tomato, variiety as per Sr. No. 4

7.	Design	:RBD
8.	Spacing	:60 cm x 40 cm
9.	Plot size: Gross plotsize	:4.2 x 3.2 m^2
10.	Method of sowing	:Transplanting
11.	Date of transplanting	: 28th Oct. 2011
12.	Type of soil	:Black soil
13.	Net plot size	:3.0 x 2.4 m^2
14.	Manure and Fertilizer	:As per the recommendation

3.3.2 Cultural operations

After transplanting cultural operations were followed. However, crop was kept free from insecticidal spray during entire crop period. Observations were recorded at weekly interval starting from appearance of the pests.

3.3.3 Method of observations

The observations were recorded in each variety from five randomly selectedplants for screening of tomato varieties for their relative resistance/susceptibility against major insect pestsof tomato*viz*., leaf miner, *Liriomyza trifolii*, fruit borer, *Helicoverpa armigera*, whitefly, *Bemisia tabaci* and defoliator, *Spodoptera litura*. The method of observations for sucking pests and borer were remained same as mentioned in pest abundance. Observations were also recorded on poplution of natural enemies at weekly intervals. For screening of genotypescut off values were worked out by using the formula (Maximum damage + minimum damage/2) suggested by

Bapat andMote (1982), The genotypes which registered less damage or incidence of pest than its mean value were designated as resistant (R) and those showing higher damage or incidence were grouped as susceptible (S).The resistant genotypewith least value of damage or incidence of a pest was assigned numerical rank 1 and the remaining genotypes were ranked in ascending order of damage or pest population. Mean rank of resistance was worked out for only those genotypes which proved resistant against all the pests by addition of the resistant ranks secured by a genotype against different pests and the dividing the total rank value by 4. Combined rank of resistant against fruit borer, whitefly, leaf miner and leaf eating caterpillarwas computed for the genotype that proved resistant against all these pests by summing up the ranks of resistant gained by a genotype and dividing the value so arrived by 4. Smaller value of mean rank combined rank of resistant indicated greater degree of resistance against insect pests.

Results and discussion

4. RESULTS AND DISCUSSION

Investigations were undertaken on pest abundance, population dynamics of *Helicoverpa armigera*through pheromone trap and screening of tomato genotypes against major insect pests of tomato at Regional Horticultural Research Station farm, Navsari Agricultural University, Navsari. The results are presented and discussed in this chapter under following headings.

4.1 Pest abundance of major insect pests and their natural enemies in tomato in relation to major abiotic factors.

4.2 Population dynamics of *Helicoverpa armigera* through pheromone trap and working out correlation coefficients and regression equations between moth catches with weather parameters

4.3 Screening of tomato genotypes against major insect pests.

4.1 Pest abundance of major insect pests of tomato

4.1.1. Fruit borer, *H. armigera*

The data presented in Table-1 and graphically depicted in Fig.-1 showed that the population of fruit borer was started from 8^{th}week after transplanting (WAT) i.e. the fourth week of December (0.5 larva/plant) and reached to a peak level (3.35 larvae/plant) at

Table-1: Abundance of insect pests on tomato during *Rabi* season of 2011-12

Week after transplanting (WAT)	Date	Meteorological week	Mean number of larvae per plant Fruit borer	Mean nymph and adult whitefly/leaf	Per cent damaged leaves	
					Leaf eating caterpillar	Leaf miner
3	19-11-2011	47	0	0	0	0
4	26-11-2011	48	0	1.12	0	1.7
5	03-12-2011	49	0	1.95	0	5
6	10-12-2011	50	0	1.6	0	3.65
7	17-12-2011	51	0	3.4	1.8	4.4
8	23-12-2011	52	0.5	1.13	0.75	5.4
9	01-01-2012	1	0.5	1.56	0.9	7.5
10	07-01-2012	2	0.5	1.91	1.2	10.8
11	14-01-2012	3	3.35	1.87	2.9	16.55
12	21-01-2012	4	0.3	1.28	2	16.05
13	28-01-2012	5	0.65	1.85	1.5	7.55
14	04-02-2012	6	0.5	1.2	2.5	25.53
15	11-02-2012	7	0.25	0.57	3.6	36.15
16	18-02-2012	8	0.15	0.73	2	18.6
17	25-02-2012	9	0.4	0	1.45	9.35
18	03-03-2012	10	0.2	0	2.5	8.25
19	10-03-2012	11	0	0	3.5	7.05
20	17-03-2012	12	0	0	4.16	12.26
21	24-03-2012	13	0	0	4.45	17.45

Figure:1 Abundance of fruit borer and whitefly on tomato during *Rabi* season of 2011-12

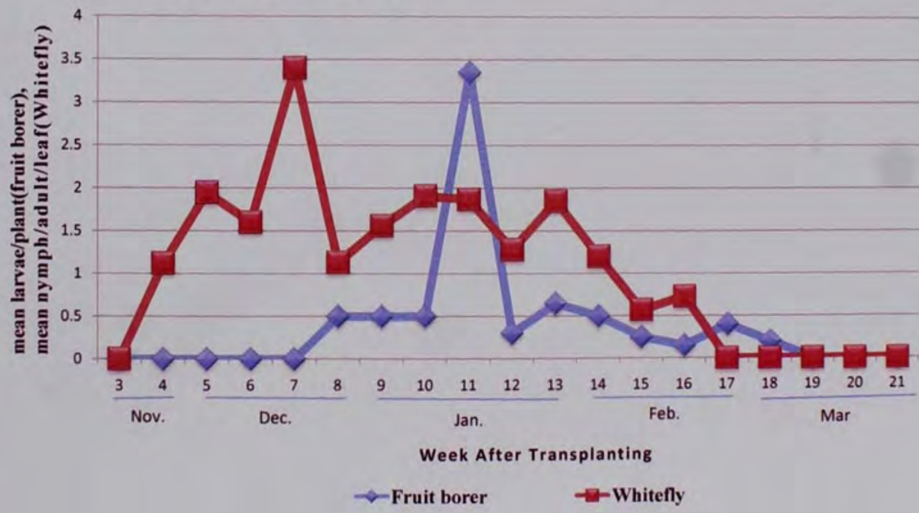


Plate: III Egg of *H. armigera* on flower

Plate: IV Fruit Damaged by *H. armigera*

Plate: V Larvae of fruit borer feed on Leaves

11^{th} WAT i.e. third week of January, after it gradually declined and finally disappeared at the end of the crop.

The results of present investigation are in close confirmation with past report wherein Yadav *et al.* (1986) observed that the peak period of *H. armigera* infestation was from December to February. Borah (1995) also found that tomatoes planted on October 25, had lowest incidence of *H. armigera.* Reddy and Kumar (2004b) reported that the population of *H. armigera* was peak during March to April on tomato. These findings are in agreement with present investigation.

4.1.2 Whitefly, *Bemisia tabaci*Gennadius

The data on whitefly population are presented in Table-1 and graphically depicted in Fig.-l. The results showed that the population of whitefly was started from 4^{th}WAT i.e. the fourth week of November (1.12 whiteflies/leaf) and reached to a peak level (3.4 whiteflies/leaf) during 7^{th} WAT coinciding with third week of December. Thereafter, the whitefly population was gradually declined and reached to zero population after 16^{th} WAT.

In past, Arnal *et al.* (1993) found that *B. tabaci* populations were maximum on tomato in November and December. Chaudhari*et al.* (2001) found that the *B. tabaci*population on tomato reached at highest level during middle of February and high level was maintained from mid February to mid March. Gour and Pareek

Plate: VI Whitefly on tomato leaves

Plate: VII Curling of leaves due to sap feeding of white fly on tomato

(2002) reported that the infestation of *B. tabaci* commenced from the third week of March on tomato. Reddy and Kumar (2004b) reported that the infestation of *B. tabaci* was maximumduring January to June on tomato. The present findings vary from the earlier reports; it might be due to variation in ecological conditions of present investigation and past reports.

4.1.3 Leaf miner, *Liriomyza trifolii* Burgess

The data presented in Table-1 and depicted in Fig.-2 revealed that the damage of leaf miner was started from 4^{th} WAT i.e. the fourth week of November(1.7% damaged leaves/plant). The infestation of this pest reached the peak level (36.15%damage leaves/plant) at 15^{th} WAT coinciding with second week of February. Thereafter, the infestation declined.

In past, the higher population of *L. trifolii* was found in first week of January, while it was recorded lowest in fourth week of November (Anonymous, 1996). Reddy and Kumar (2004) reported that the peak infestation of leaf miner (*L.trifolii)* was noticed during March to April and population declined during November to December on tomato. The results of earlier reports vary from present investigation; it might be due to variation in the ecological conditions of past reports and present investigation.

Figure:2 Abundance of leaf eating caterpillar and leaf miner on tomato during *Rabi* season of 2011-12

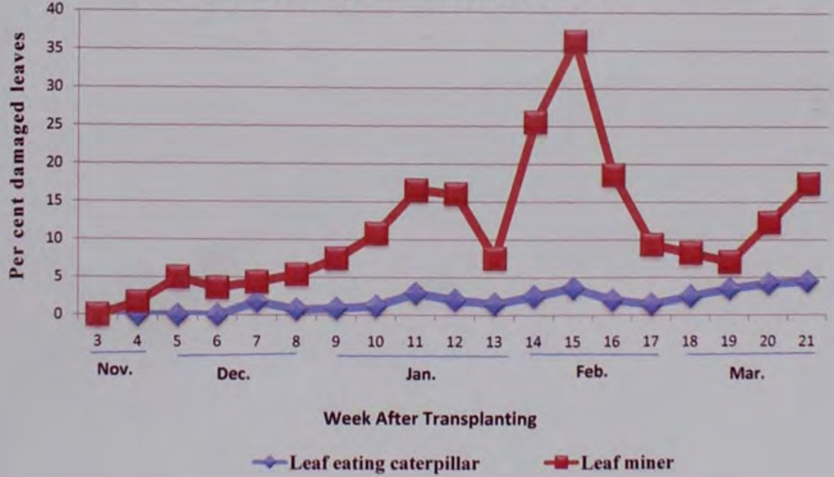


Plate: VIII Maggot of *L. trifolii* on tomato leaves

Plate: IX Tomato leaves damaged by *L. trifolii*

4.1.4 Tobacco leaf eating caterpillar, *Spodoptera litura*Fab.

The data presented in Table-1 and depicted in Fig.-2 revealed that the damage of the leaf eating caterpillar was started from 7th WAT i.e. third week of December(1.8% damaged leaves/plant). The infestation of this pest reached the peak level (4.45% damaged leaves/plant) at the time of harvesting, 21st WAT i.e. fourth week of March.

During the course of investigation, no incidence of any natural enemy was observed.

4.1.5 Correlation matrix of the relationship between weather parameters and population of major insect pests of tomato.

In nature, the population of insect pests is never truly stable. The rise and fall of population density of any organism depends on many abiotic factors liketemperature and humidity. Toknow the effect of various weather parameters on the populationfluctuationofinsectpestsof tomato, simple correlation was worked out between weekly mean incidence of eachpestandweeklymean values of different weather parameters. The data are presented in Table-3.

Table-2: Correlation matrix of the relationship between weather parameters and population of insect pests of tomato during *Rabi* season of 2011-12

Insect pests	Temperature (°C)			Relative humidity (%)			Sunshine hours	Wind velocity (Km/hr)
	Max.	Min.	Ave.	Morning	Evening	Ave.		
Fruit borer	-0.53694*	-0.48616*	-0.53469*	0.25990	0.53550*	0.51358*	0.25899	0.01440
Leaf eating caterpillar	0.22133	-0.00964	0.11778	-0.08386	-0.09344	-0.10401	0.24025	0.47892*
Whitefly	-0.48458*	-0.31930	-0.42511	-0.08224	0.27524	0.18632	-0.26131	-0.37306
Leaf miner	-0.25381	-0.34254	-0.31295	-0.23317	0.05628	-0.04044	0.45715*	0.47352*

*Significant at 5 per cent level (r=±0.45429)

Plate: X Larvae of *S. Litura* feed on tomato leaves

Plate: XI Tomato Leaves damaged by *S. Litura*

4.1.5.1 Fruit borer, *H. armigera*

The data presented in Table-2 showed that the maximum temperature (r=-0.5369), minimum temperature (r=-0.4862) and average temperature (r=0.5347) had significant negative correlation while evening relative humidity (r=0.5355) and average relative humidity (r=0.5136) had significant positive correlation. Whereas, morning relative humidity (r=0.2599), sunshine hours (r=0.2590) and wind velocity (r=0.014) had positive non-significant correlation with fruit borer population on tomato.

4.1.5.2 Whitefly, *Bemisia tabaci* Gennadius.

The data presented in Table-2 indicated that significant negative correlation was found between whitefly population on tomato and maximum temperature (r =-0.4846), while minimum temperature (r = -0.3193), average temperature (r = -0.4251), morning relative humidity (r=-0.0822), sunshine hours (r=-0.2613) and wind velocity (r=-0.3731) had negative non-significant correlation and evening relative humidity (r = 0.2752) and average relative humidity (r=0.1863) had positive non-significant correlation with whitefly population.

In past, Bhardwaj and Kushwaha (1984) found that the *B. tabaci*population was negatively correlated with humidity whilemaximum temperature showed significantly positive correlation withpopulation of *B. tabaci*and average temperature also showed similar trendwith population. Megeed *et al.* (1998)reported that temperature had a significant effect on both egg and nymphal populations of *B. tabaci,* while relative humidity had no significant effect of *B. tabaci* on tomato. Chaudhari *et al.* (2001) found that temperature, relative humidity and rainfall were negatively correlated with *B. tabaci* population on tomato. Thus, the results of present investigation are in close agreement with past reports.

4.1.5.3 Leaf miner, *Liriomyza trifolii* Burgess

The correlation coefficient for incidence of leaf miner with weather parameters revealed that sunshine hour (r=0.4572) and wind velocity (r=0.4735) were positively significantly correlated while maximum temperature (r=-0.2538), minimum temperature (r=-0.3425), average temperature (r=-0.3130), morning relative humidity (r=-0.2332) and average relative humidity (r=-0.0404) were negatively non-significantly correlated. Whereas, evening relative humidity (r=0.0563) had positive non-significant correlation with leaf miner population.

In past, Krishnakumar*et al.* (2004) reported that relative humidity had a significant negative correlation with the number of *L. trifolii* on tomato crop.Thus, the results of present investigation are in close agreement with past reports.

4.1.5.4 Tobacco leaf eating caterpillar, *Spodopteralitura*Fab.

Form the Table-2 it revealed that wind velocity (r=0.4789) had positive significant correlation, while maximum temperature (0.2213), average temperature (r=0.1178) and sunshine hour (r=0.2403) had non-significant positive correlation. Whereas, minimum temperature (r=-0.0096), morning relative humidity (r=-0.0839), evening relative humidity (r=-0.0934) and average relative humidity (r=-0.1040) had negative non significant correlation with tobacco leaf eating caterpillar incidence.According to Thanki*et al.* (2003), among the various abiotic factors minimum temperature, vapour pressure (morning & evening) and RH (evening) were found most influencing factors showed negative effect on oviposition behaviour and larval development of *S. litura*. The maximum temperature showed significant negative influence on oviposition by *S. litura*. The results of present investigation varies from past report it may be due to difference in ecological condition.

4.2 population dynamics of *Helicoverpa armigera* through pheromone trap and working out correlation coefficients and regression equations between moth catches with weather parameters.

4.2.1 Population dynamics of *Helicoverpa armigera* through pheromone trap.

The data presented in the Table-3 and graphically depicted in Fig.-3 indicated that the earliest catch of *H. armigera* males was recorded from 7th WAT (7 Male moth catch/ trap/ week) i.e. 50thstandard week of 2011 and population reached its peak at 13th WAT i.e. 4th standard week of 2012(35 Male moth catch/ trap/ week). The adult activity declined thereafter and, continued fluctuating till the third week of April and then disappeared.

In past, Srivastava *et al.*(1990) reported that moth activity of *H. armigera* started duringthe first fortnight of March and ceased by the end ofJune to early July in north-west Himalayan region.Verma and Sankhayan (1993) also recorded the earliestcatch of *H. armigera* male mothsduring the firstfortnight of March (10-11 SW) which reached its peakwithin a week's time and the activity ceased after mid-June (24 SW) at Nauni (Solan), Himachal Pradesh.The present findings vary from the earlier reports, it might be due to difference in date of planting and variation in ecological conditions.

Table-3: Male moth catches in pheromone trap of *H. armigera* in tomatoduring 2011-12

Standard Week (SW)	Male moth catch/ trap/ week
47-49	0
50	7
51	28
52	23
1	16
2	20
3	24
4	35
5	29
6	26
7	15
8	14
9	10
10	6
11	4
12	3
13	2
14	1
15	1
16-19	0

Figure:3 Male moth catches of *H. armigera* in pheromone trap in tomato during 2011-12.

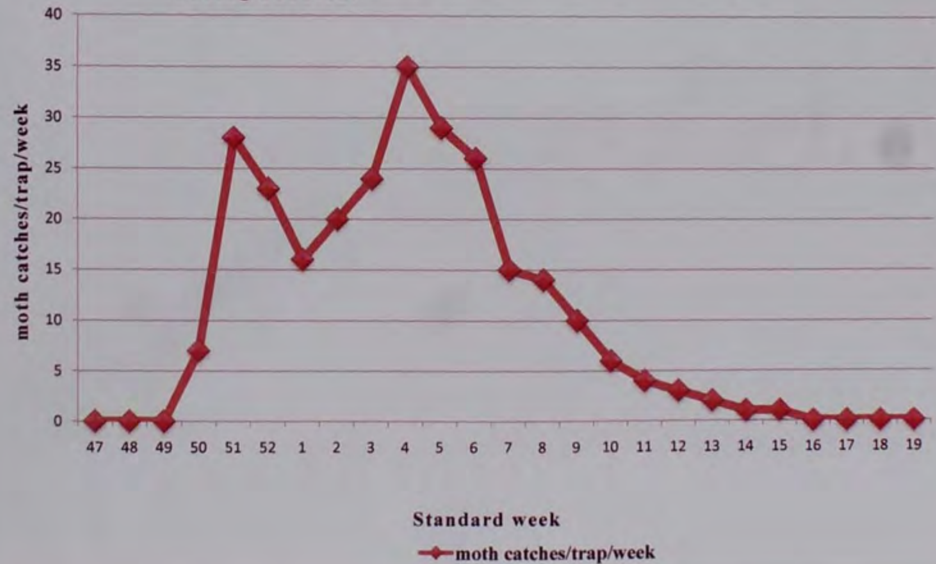


Plate: XII Installation of Pheromone trap in Tomato

Plate: XIII Moth catches of *H. armigera* through Pheromone trap

4.2.2 Correlation coefficient between moth catches andweather parameters.

The data presented in Table-4 showed that maximum temperature (r=-0.7601), minimum temperature (r=-0.7445), average temperature (r=-0.8126) had highly significant negative correlation while morning RH (r=-0.2320), sunshine hours (r=-0.1471) and wind velocity (r=-0.2148) had non-significant negative correlation with number of moth catches of *Helicoverpa armigera.* Whereas, evening RH (r=0.1469) and average RH (r=0.3174) had non-significant positive correlation with moth catches. In past, according toShivanna*et al.* (2012)maximum number of moth activity was observed from 35^{th} to 43^{rd} standard week. They further revealed that Rainfall and minimum temperature had positive and significant association with trap catches. Whereas, Negative and non significant correlation was observed with maximum temperature and relative humidity.

Table: 4 Correlation coefficient between number of moth catches and weather parameters

"r"	Max. Temp.	Min. Temp	Ave. Temp.	Morn. RH	Eve. RH	Ave. RH	SSH	WV
No. of moth catch/week	-0.76013**	-0.74448**	-0.81259**	-0.23204	0.14688	0.3174	-0.14706	-0.21481

*significant at 5 % level of significant(r=±0.39521); **significant at 1 % level of significant(r=±0.5052).

4.2.3 Regression equations of moth catches with weather parameters

$$\hat{Y} = 89.04 + 31.73(X1) + 32.71(X2) - 67.29(X3)$$

Where, $\hat{Y}$ = No. of moth catches,
X1= Maximum Temperature,
X2= Minimum Temperature,
X3= Average Temperature.

4.3 Screening of tomato genotypes against major pests of tomato.

4.3.1. Fruit borer, *Helicoverpa armigera* (Hubner)

4.3.1.1 Larvae

The data presented in Table-5 and graphically depicted in Fig.-4 indicated that none of the genotype was found to be free from attack of *H. armigera*. However, JT-3 recorded the lowest population of *H. armigera* (0.15 larva/plant) which was at par with 2011/TOINDVAR-3 (0.19 larva/plant), followed by 2011/TOINDVAR-4, 2011/TOINDVAR-2, 2011/TOINDVAR-5 and 2011/TOINDVAR-1 they recorded 0.25, 0.28, 0.31 and 0.32 larva/plant, respectively. The highest population of *H. armigera* (0.68 larva/plant) was found in Arka Vikas.

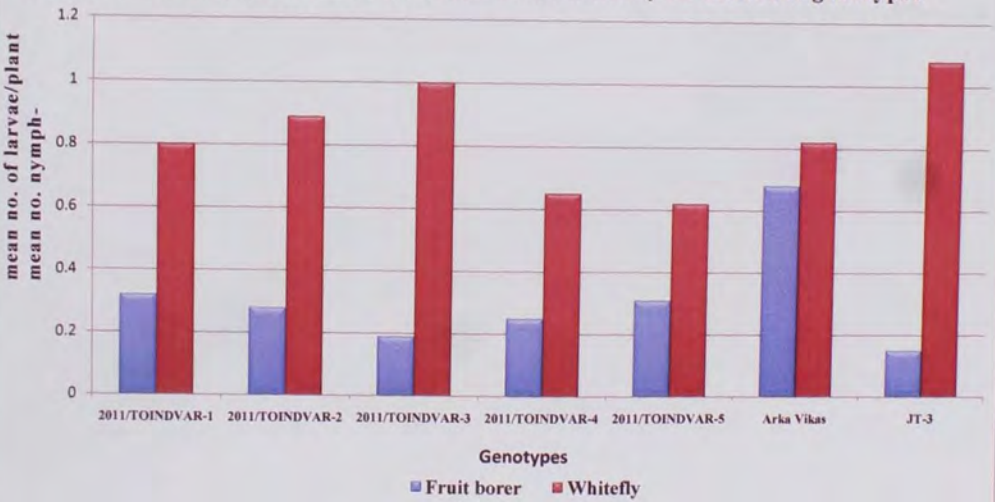
The data presented in Table-7 by using mean value of incidence of pest which was intermediate to the cut off value. The

Table-5: Mean population of fruit borer and whitefly on different genotypes of tomato

Sr. No.	Genotypes	Overall mean	
		Fruit borer (larvae/plant)	Whitefly (nymph-adult/leaf)
1	2011/TOINDVAR - 1	0.55(0.32)*	0.89(0.80)
2	2011/TOINDVAR - 2	0.53(0.28)	0.94(0.89)
3	2011/TOINDVAR - 3	0.43(0.19)	0.99(1.00)
4	2011/TOINDVAR - 4	0.50(0.25)	0.80(0.65)
5	2011/TOINDVAR - 5	0.55(0.31)	0.78(0.62)
6	Arka Vikas (C)	0.82(0.68)	0.90(0.82)
7	JT 3 (LC)	0.39(0.15)	1.04(1.08)
S. Em.±		0.03	0.05
C.D. at 5%		0.10	0.16
C.V.%		10.53	9.73

*Figures in parentheses are original values, those outside are $\sqrt{X}$ transformed values

Figure:4 Mean population of fruit borer and whitefly on different genotypes



tomato fruit borer population varied from 0.15 to 0.68 (Av. 0.42) per plant. The tomato fruit borer population was minimum on JT-3 and maximum on Arka Vikas. Among all the varieties *viz.*,JT-3, 2011/TOINDVAR -3,2011/TOINDVAR -4, 2011/TOINDVAR -2, 2011/TOINDVAR -5 and 2011/TOINDVAR -1were resistant against tomato fruit borer.

4.3.1.2 Percent damaged fruits

The data presented in Table-6 and graphically depicted in Fig.-5 indicated that none of the genotype was found free from fruit borer damage. However, lowest per cent damaged fruits were recorded in JT-3 (4.33% damaged fruits) and it was significantly differ from other genotypes;followed by 2011/TOINDVAR-1, Arka Vikas, 2011/TOINDVAR-5, 2011/TOINDVAR-3 and 2011/TOINDVAR-2 which recorded 7.78, 9.39, 11.86, 12.05 and 18.25 per cent damaged fruits, respectively. The highest per cent damaged fruits were found in 2011/TOINDVAR-4 genotype (20.93% damaged fruits).

Thedata presented in Table-7 by using mean value of damaged fruits was intermediate to the cut off value. The per cent damaged fruits varied from 4.33 to 20.93 (Av. 12.63). The per cent damaged fruits were minimum on JT-3 and maximum on 2011/TOINDVAR -4. Among all the varieties *viz.*, JT-3, 2011/TOINDVAR -1, Arka Vikas, 2011/TOINDVAR -5,

Table-6: Mean per cent damaged fruits by fruit borer; per cent damaged leaves by leaf eating caterpillar and leaf miner on different genotypes of tomato.

Sr. No.	Genotypes	Overall mean of		
		Fruit borer (% damaged fruits)	Leaf eating caterpillar (% damaged leaves)	Leaf miner (% damaged leaves)
1	2011/TOINDVAR - 1	15.80 (7.78)*	27.09 (21.42)	13.25 (5.39)
2	2011/TOINDVAR - 2	25.19 (18.25)	27.27 (21.00)	16.45 (8.05)
3	2011/TOINDVAR - 3	20.30 (12.05)	27.49 (21.31)	13.70 (5.68)
4	2011/TOINDVAR - 4	27.23 (20.93)	28.85 (23.28)	16.27 (7.91)
5	2011/TOINDVAR - 5	20.13 (11.86)	36.70 (35.75)	18.61 (10.18)
6	Arka Vikas (C)	17.85 (9.39)	33.37 (30.25)	19.80 (11.51)
7	JT 3 (LC)	12.00 (4.33)	28.34 (22.53)	18.98 (10.59)
S. Em.±		1.04	1.67	1.02
C.D. at 5%		3.22	5.15	3.14
C.V.%		9.14	9.70	10.56

*Figures in parentheses are original values, those outside are arc sintransformed values

Figure:5 Mean per cent damaged fruits by fruit borer, per cent damaged leaves by leaf eating caterpillar and leaf miner on different genotypes of tomato.

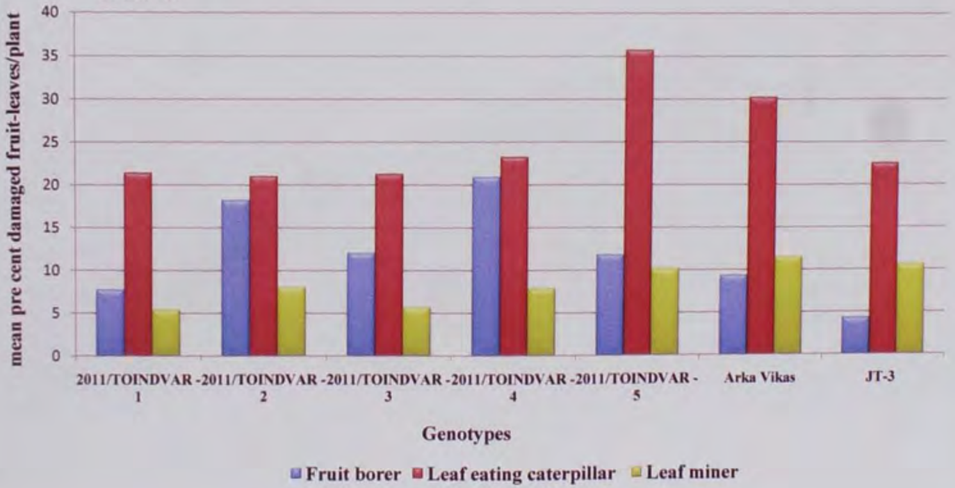


Table-7: Ranking of tomato genotypes for resistance against fruit borer, whitefly, leaf miner and leaf defoliator

Sr. No.	Genotype	Fruit borer (larvae/plant)	Whitefly (nymph-adult/leaf)	Leaf miner (Per cent damaged leaves)	Leaf eating caterpillar (Per cent damaged leaves)	Fruit borer (per cent damaged fruits)	Combined rank for fruit borer whitefly leaf miner and leaf eating caterpillar
1	2011/TOINDVAR - 1	0.32(R6)	0.80(R3)	5.39(R1)	21.42(R3)	7.78(R2)	3.25
2	2011/TOINDVAR - 2	0.28(R4)	0.89(R5)	8.05(R4)	21.00(R1)	18.25(S)	-
3	2011/TOINDVAR - 3	0.19(R2)	1.00(S)	5.68(R2)	21.31(R2)	12.05(R5)	-
4	2011/TOINDVAR - 4	0.25(R3)	0.65(R2)	7.91(R3)	23.28(R5)	20.93(S)	-
5	2011/TOINDVAR - 5	0.31(R5)	0.62(R1)	10.18(S)	35.75(S)	11.86(R4)	-
6	Arka Vikas (C)	0.68(S)	0.82(R4)	11.51(S)	30.25(S)	9.39(R3)	-
7	JT 3 (LC)	0.15(R1)	1.08(S)	10.59(S)	22.53(R4)	4.33(R1)	-
	S. Em.±	0.03	0.05	1.02	1.67	1.04	-
	C.D. at 5%	0.10	0.16	3.14	5.15	3.22	-
	C.V. %	10.53	9.73	10.56	9.70	9.14	-

2011/TOINDVAR -3were resistant against tomato fruit borer. Similar results were obtained in statistical method.

4.3.2 Whitefly, *Bemisia tabaci*Gennadius

The data presented in Table-5 and graphically depicted in Fig.-4 revealed that none of the genotype of tomato was found free from incidence of whitefly. However, among all the genotypes of tomato, 2011/TOINDVAR-5 (0.62 whitefly/leaf) recorded the lowest population of whitefly and which was at par with 2011/TOINDVAR-4 (0.65 whitefly/leaf), 2011/TOINDVAR-1 (0.82 whitefly/leaf), Arka Vikas (0.82 whitefly/leaf) and 2011/TOINDVAR-2 (0.89 whitefly/leaf), followed by 2011/TOINDVAR-3 recorded 1 whitefly/leaf. The highest whitefly population was found on variety JT-3(1.08 whiteflies/leaf).

The data presented in Table-7 by using mean value of incidence of pest which was intermediate to the cut off value. Among the genotypes screened, whitefly population varied from 0.82 to 1.08 (Av. 0.85) per leaf. The whitefly population was minimum on 2011/TOINDVAR -5 and maximum on JT-3. Among all the genotypes,2011/TOINDVAR-5, 2011/TOINDVAR-4, 2011/TOINDVAR -1, Arka Vikas and 2011/TOINDVAR-2wereresistant against whitefly.

4.3.3 Leaf miner, *Liriomyza trifolii* Burgess

The data represented in Table-6 and graphically depicted in Fig.-5 revealed that none of the genotype of tomato was found free from incidence of leaf miner. However, among all the genotypesof tomato, 2011/TOINDVAR-1 (5.39% damaged leaves/plant) recorded the lowest damage of leaf miner and it was at par with 2011/TOINDVAR-3 (5.68%damaged leaves/plant) and 2011/TOINDVAR-4 (7.91% damaged leaves/plant), followed by 2011/TOINDVAR-2,2011/TOINDVAR-5, and JT-3recorded 8.05, 10.18 and 10.59 per cent damaged leaves/plant, respectively. The highest damage was recorded in Arka Vikas variety (11.51%damaged leaves/plant).

The data presented in Table-7 by using mean value of damaged leaves which were intermediate to the cut off value. The per cent damaged leaves varied from 5.39to 11.51 (Av. 8.45). The per cent damaged leaves were minimum on 2011/TOINDVAR-1 and maximum on Arka Vikas. Among all the genotypes,2011/TOINDVAR-1, 2011/TOINDVAR-3, 2011/TOINDVAR-4 and2011/TOINDVAR-2showed resistance against leaf miner.

4.3.4 Tobacco leaf eating caterpillar, *S. litura*

The data represented in Table-6 and graphically depicted in Fig.-5 revealed that none of the genotype of tomato was found free from incidence of leaf eating caterpillar. However, among all the genotypes of tomato, 2011/TOINDVAR-2(21% damaged leaves/plant) recorded the lowest damage of leaf eating caterpillar and it was at par with 2011/TOINDVAR-3 (21.31%damaged leaves/plant)2011/TOINDVAR-1 (21.42% damaged leaves/plant), JT-3 (22.53% damaged leaves /plant) and 2011/TOINDVAR-4 (23.28% Damaged leaves/plant) followed by Arka Vikas (30.25% damaged leaves/plant). The highest percent damage leaves were recorded in 2011/TOINDVAR-5 (35.75% damaged leaves/plant) among all genotypes.

The data presented in Table-7 by using mean value of damaged leaves which were intermediate to the cut off value. The per cent damaged leaves varied from 21to 35.75 (Av. 28.38). The per cent damaged leaves were minimum on 2011/TOINDVAR-2and maximum on 2011/TOINDVAR-5. Among all the genotypes,2011/TOINDVAR-2, 2011/TOINDVAR-3, 2011/TOINDVAR-1, JT-3 and2011/TOINDVAR-4proved resistance against leaf miner. Similar results were obtained in statistical method.

From overall results, it can be inferred that out of seven genotypes, sixwere highly promising against fruit borer as they recorded lowerfruit borer larval population and gained 1 to 6 rank of resistance. Thus, JT-3, 2011/TOINDVAR -3, 2011/TOINDVAR -4, 2011/TOINDVAR -2, 2011/TOINDVAR -5 and 2011/TOINDVAR -1 may be used as source of resistance against fruit borer. Whereas, five genotypeswere highly promising against whitefly as they recorded lower whitefly population and gained 1 to 5 rank of resistance (Table-6).Thus, 2011/TOINDVAR-5, 2011/TOINDVAR-4, 2011/TOINDVAR -1, Arka Vikas and 2011/TOINDVAR-2 may be used as source of resistance against whitefly. While, four genotypes were highly promising against leaf miner as they recorded lowest percent damaged leaves and gained 1 to 4 rank of resistance. Thus, 2011/TOINDVAR-1, 2011/TOINDVAR-3, 2011/TOINDVAR-4 and 2011/TOINDVAR-2 may be used as source of resistance against leaf miner. Five genotypeswere highly promising against leaf eating caterpillar as they recorded lowest per cent damaged leaves and gained 1 to 5 rank of resistance. Thus, 2011/TOINDVAR-2, 2011/TOINDVAR-3, 2011/TOINDVAR-1, JT-3 and 2011/TOINDVAR-4 may be used as source of resistance against leaf eating caterpillar. Similarly, five genotypes were highly promising against fruit borer as they recorded lowest per cent damaged fruits and gained 1 to 5 rank of resistance. Thus, JT-3, 2011/TOINDVAR -1, Arka Vikas, 2011/TOINDVAR -5, 2011/TOINDVAR -3 may be used as source of resistance against fruit borer. One genotype*viz.*,2011/TOINDVAR-1 showed combined resistance against fruit borer, whitefly, leaf miner and leaf eating caterpillar. Thus, they can be utilized for developing genotype having multiple resistance against fruit borer, whitefly, leaf miner and leaf eating caterpillar.

Summary and Conclusion

5. SUMMARY AND CONCLUSION

Tomato (*Lycopersicon esculentum* Miller) is one of the important vegetable crops of India. It is attacked by several insect pests from transplanting to maturity causing considerable damage to the crop. Therefore efforts were made to study the pest abundance, screening of tomato genotypes against major insect pests and population dynamics of fruit borer (*Helicoverpa armigera* Hubner) through pheromone trap. The important conclusions emerged from these investigations are summarized and given hereafter.

5.1 Pest abundance of major insect pests of tomato

5.1.1 Fruit borer, *H. armigera*

The population of fruit borer was started from 8^{th} week after transplanting (WAT) i.e. the fourth week of December (0.5 larva/plant) and reached to a peak level (3.35 larvae/plant) during 11^{th} WAT i.e. third week of January, after it gradually declined and finally reached to disappear at the time of picking.

The maximum temperature (r=-0.5369), minimum temperature (r=-0.4862) and average temperature (r=0.5347) had significant negative correlation while evening relative humidity (r=0.5355) and average relative humidity (r=0.5136) had significant positive correlation. Whereas, morning relative humidity (r=0.2599), sunshine hours (r=0.2590) and wind velocity (r=0.0144) had positive non-significant correlation with fruit borer population on tomato.

5.1.2 Whitefly, *B. tabaci*

The population of whitefly was started from fourth WAT i.e. the fourth week of November (1.12 whiteflies/leaf) and reached to a peak level (3.4 whiteflies/leaf) during 7th WAT coinciding with third week of December. Thereafter, the whitefly population gradually declined and reached to zero population after 16th WAT.

Significant negative correlation was found between whitefly population on tomato and maximum temperature (r =-0.4846), while minimum temperature (r = -0.3193), average temperature (r = -0.4251), morning relative humidity (r=-0.0822), sunshine hours (r=-0.2613) and wind velocity (r=-0.3731) had negative non-significant correlation and evening relative humidity (r = 0.2752) and average relative humidity (r = 0.1863) had positive non-significant correlation with whitefly population.

5.1.3 Leaf miner, *L. trifolii*

The damage of leaf miner was started (1.7% damaged leaves/plant) from 4th WAT i.e. the fourth week of November. The infestation of this pest reached the peak level (36.15% damage leaves/plant) during 15th WAT coinciding with second week of February. Thereafter, infestation declined.

The correlation coefficient for population of leaf miner with weather parameters revealed that sunshine hours (r=0.4572) and wind velocity (r=0.4735) had positive significant correlation while maximum temperature (r=-0.2538), minimum temperature (r=-0.3425), average temperature (r=-0.3130), morning relative humidity (r=-0.2332) and average relative humidity (r=-0.0404) had negative non-significant correlation. Whereas, evening relative humidity (r=0.0563) had positive non-significant correlation with leaf miner population.

5.1.4 Tobacco leaf eating caterpillar, *S. litura*

The damage of the leaf defoliator was started (1.8% damaged leaves/plant) from 7^{th} WAT i.e. fourth week of December. The infestation of this pest reached the peak level (4.45% damaged leaves/plant) at the time of harvesting (21^{st} WAT) i.e. fourth week of March.

The wind velocity (r=0.4789) had positive significant while maximum temperature (0.2213), average temperature (r=0.1178) and sunshine hour (r=0.2403) had non-significant correlation. Whereas, minimum temperature (r=-0.0096), morning relative humidity (r=-0.0839), evening relative humidity (r=-0.09344) and average relative humidity (r=-0.1040) had negative non-significant correlation with tobacco leaf eating caterpillar population.

5.2 Population dynamics of *Helicoverpa armigera* through pheromone trap

The earliest catch of *H. armigera* males was recorded from 7^{th} WAT (7 Male moth catch/ trap/ week) i.e. 51 standard week of 2011 and population reached its peak (35 Male moth catch/ trap/ week) at 13^{th} WAT i.e. 5^{th} standard week of 2012.

The adult activity declined thereafter and, continued fluctuating till the third week of April and then disappeared.

The maximum temperature (r=-0.7601), minimum temperature (r=-0.7445), average temperature (r=-0.8126) had significant negative correlation while morning RH (r=-0.2320), sunshine hours (r=-0.1471) and wind velocity (r=-0.2148) had non-significant negative correlation with number of moth catches of *Helicoverpa armigera*. Whereas, evening RH (r=0.1469) and average RH (r=0.3174) had non-significant positive correlation with moth catches.

5.3 Screening of tomato genotypes against major insect pests

5.3.1 Fruit borer, *H. armigera*

5.3.1.1 Larva

Among all the genotypes of tomato, JT-3 recorded the lowest population of *H. armigera* (0.15 larva/plant) which was at par with 2011/TOINDVAR-3 (0.19 larva/plant), followed by 2011/TOINDVAR-4, 2011/TOINDVAR-2, 2011/TOINDVAR-5 and 2011/TOINDVAR-1 they recorded 0.25, 0.28, 0.31 and 0.32 larvae/plant, respectively. The highest population of *H. armigera* (0.68 larva/ plant) was found in Arka Vikas genotype.

The tomato fruit borer population varied from 0.15 to 0.68 (Av. 0.42) per plant. The tomato fruit borer population was minimum on JT-3 and maximum on Arka Vikas. Among all the genotypes, JT-3, 2011/TOINDVAR -3, 2011/TOINDVAR -4, 2011/TOINDVAR -2, 2011/TOINDVAR -5 and 2011/TOINDVAR -1 were resistant against tomato fruit borer.

5.3.1.2 Per cent damaged fruits

Among all the genotypes of tomato, lowest per cent damaged fruits were recorded in JT-3 (4.33% damaged fruits) and it was significantly differed from other genotypes. It was followed by 2011/TOINDVAR-1, Arka Vikas, 2011/TOINDVAR-5, 2011/TOINDVAR-3 and 2011/TOINDVAR-2 which recorded 7.78, 9.39, 11.86, 12.05 and 18.25 per cent damaged fruits, respectively. The highest per cent damaged fruits were found in 2011/TOINDVAR-4 genotype (20.93% damaged fruits).

The per cent damaged fruits varied from 4.33 to 20.93 (Av. 12.63). The per cent damaged fruits were minimum on JT-3 and maximum on 2011/TOINDVAR -4. Among all, JT-3, 2011/TOINDVAR -1, Arka Vikas, 2011/TOINDVAR -5, 2011/TOINDVAR -3 were resistant against tomato fruit borer.

5.3.2 Whitefly, *B. tabaci*

Among all the genotypes of tomato, 2011/TOINDVAR-5 (0.62 whitefly/leaf) recorded the lowest population of whitefly and which was at par with 2011/TOINDVAR-4 (0.65 whitefly/leaf), 2011/TOINDVAR-1 (0.82 whitefly/leaf), Arka Vikas (0.82 whitefly/leaf) and 2011/TOINDVAR-2 (0.89 whitefly/leaf), followed by 2011/TOINDVAR-3 which recorded 1 whitefly/leaf. The highest whitefly population was found on JT-3 (1.08 whiteflies/leaf).

Among all the genotypes, whitefly population varied from 0.82 to 1.08 (Av. 0.85) per leaf. The whitefly population was minimum on 2011/TOINDVAR -5 and maximum on JT-3. Among all the genotypes 2011/TOINDVAR-5, 2011/TOINDVAR-4, 2011/TOINDVAR -1, Arka Vikas and 2011/TOINDVAR-2 were resistant against whitefly.

5.3.3 Leaf miner, *L. trifolii*

Among all the genotypes of tomato, 2011/TOINDVAR-1 (5.39 damaged leaves/plant) recorded the lowest damage of leaf miner and it was at par with 2011/TOINDVAR-3 (5.68 damaged leaves/plant) and 2011/TOINDVAR-4 (7.91 damaged leaves/plant), followed by 2011/TOINDVAR-2, 2011/TOINDVAR-5, and JT-3; they recorded 8.05, 10.18 and 10.59 damaged leaves/plant, respectively. The highest incidence was recorded in Arka Vikas genotype (11.51 damaged leaves/plant).

The per cent damaged leaves varied from 5.39 to 11.51 (Av. 8.45). The per cent damaged leaves were minimum on 2011/TOINDVAR-1 and maximum on Arka Vikas. Among all the genotypes, 2011/TOINDVAR-1, 2011/TOINDVAR-3, 2011/TOINDVAR-4 and 2011/TOINDVAR-2 were resistant against leaf miner. Similar results were obtained in statistical method.

5.3.4 Tobacco leaf eating caterpillar, *S. litura*

Among all the genotypes of tomato, 2011/TOINDVAR-2 (21 damaged leaves/plant) recorded the lowest damage of leaf eating caterpillar and it was at par with 2011/TOINDVAR-3 (21.31 damaged leaves/plant) 2011/TOINDVAR-1 (21.42 damaged leaves/plant), JT-3 (22.53 damaged leaves /plant), 2011/TOINDVAR-4 (23.28 damaged leaves/plant) Arka Vikas (30.25 damaged leaves/plant) followed by 2011/TOINDVAR-5 (35.75 damaged leaves/plant) which recorded the highest population recorded among all genotypes.

The per cent damaged leaves varied from 21 to 35.75 (Av. 28.38). The per cent damaged leaves were minimum on 2011/TOINDVAR-2 and maximum on 2011/TOINDVAR-5. Among all the genotypes, 2011/TOINDVAR-2, 2011/TOINDVAR-3, 2011/TOINDVAR-1, JT-3 and 2011/TOINDVAR-4 proved resistance against leaf miner. Similar results were obtained in statistical method.

From overall results it was revealed that only one genotype *viz.*, 2011/TOINDVAR-1 was highly promising against fruit borer, whitefly, leaf miner and leaf eating caterpillar population and gained rank 1 of resistance. Thus, 2011/TOINDVAR-1 showed combined resistance against fruit borer, whitefly, leaf miner and leaf eating caterpillar.

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*** Original not seen**

Appendices

Appendix-I: Meteorological data recorded during the course of investigation (weekly mean) during *Rabi* 2011-12

Month	Std. Week	Temperature			Relative humidity (%)			Sunshine hours/day	Wind velocity (km/hr)
		Max.	Min.	Ave.	Morning	Evening	Ave.		
Nov.	47	34.4	17.3	25.85	81	33	57	9.5	2.7
Dec.	48	34.6	20.5	27.55	71	36	53.5	7.5	1.4
	49	33.9	17.2	25.55	82	33	57.5	8.5	1.3
	50	32.1	14.3	23.2	75	19	47	8.2	1.0
	51	32.6	15.2	23.9	76	30	53	7.6	0.6
	52	30.4	11.5	20.95	85	28	56.5	8.0	1.9
Jan.	1	29.2	12.2	20.7	82.5	40.4	61.4	6.5	2.6
	2	28.0	11.9	20.0	72.8	51.0	61.9	9.0	4.4
	3	28.1	11.6	19.9	85.5	63.7	74.6	9.4	2.1
	4	29.7	13.0	21.3	82.6	74.8	78.7	8.9	3.3
Fab.	5	30.6	14.5	22.5	72.2	31.9	52.1	9.1	5.1
	6	28.0	12.0	20.0	59.5	23.9	41.7	9.5	5.6
	7	30.4	12.9	21.6	76.1	27.7	51.9	9.4	3.1
	8	35.1	15.1	25.1	69.9	23.5	46.7	9.4	3.3
March	9	32.4	14.3	23.3	84.2	33.4	58.8	9.1	2.9
	10	31.5	15.7	23.6	82.3	40.4	61.3	8.2	3.6
	11	35.5	15.6	25.6	70.8	18.0	44.4	8.9	3.4
	12	37.6	15.9	26.7	73.2	16.5	44.8	8.6	3.7
	13	37.3	20.2	28.75	84.4	30.3	57.35	8.0	3.9

Appendix-II: Weekly mean population of *H. armigera* on different genotypes of tomato

Sr. No.	Genotypes	Weekly mean larvae/plant				
		3rd WAT	4th WAT	5th WAT	6th WAT	7th WAT
1	2011/TOINDVAR - 1	0.71 (0.00)	0.707 (0.000)	0.831 (0.200)	0.707 (0.000)	1.135 (0.800)
2	2011/TOINDVAR - 2	0.71 (0.00)	0.940 (0.400)	0.707 (0.000)	0.707 (0.000)	0.831 (0.200)
3	2011/TOINDVAR - 3	0.71 (0.00)	0.835 (0.200)	0.707 (0.000)	0.707 (0.000)	0.835 (0.200)
4	2011/TOINDVAR - 4	0.71 (0.00)	0.707 (0.000)	0.707 (0.000)	0.707 (0.000)	0.831 (0.200)
5	2011/TOINDVAR - 5	0.71 (0.00)	0.945 (0.400)	0.707 (0.000)	1.357 (1.400)	0.940 (0.400)
6	Arka Vikas (C)	0.71 (0.00)	1.213 (1.000)	1.037 (0.600)	0.835 (0.200)	2.284 (4.800)
7	JT 3 (LC)	0.71 (0.00)	0.707 (0.000)	0.707 (0.000)	0.707 (0.000)	0.707 (0.000)
S. Em.±		0.00	0.07	0.05	0.06	0.08
C.D. at 5%		NS	0.20	0.14	0.20	0.26
C.V.%		0.00	13.16	10.34	13.57	13.57

*Figures in parentheses are original values, those outside are ($\sqrt{X} + 0.5$) transformed values

WAT – Week After Transplanting

Contd...

Sr. No.	Genotypes	Weekly mean larvae/plant				
		8th WAT	9th WAT	10th WAT	11th WAT	12th WAT
1	2011/TOINDVAR - 1	0.835 (0.200)	1.236 (1.600)	1.290 (1.200)	0.707 (0.000)	0.910 (0.330)
2	2011/TOINDVAR - 2	0.940 (0.400)	1.612 (2.600)	0.707 (0.000)	0.831 (0.200)	0.870 (0.270)
3	2011/TOINDVAR - 3	0.707 (0.000)	1.329 (1.800)	0.707 (0.000)	0.707 (0.000)	0.850 (0.230)
4	2011/TOINDVAR - 4	1.290 (1.200)	0.892 (0.800)	0.831 (0.200)	0.940 (0.400)	0.890 (0.300)
5	2011/TOINDVAR - 5	1.298 (1.200)	0.618 (0.400)	0.940 (0.400)	0.707 (0.000)	0.870 (0.270)
6	Arka Vikas (C)	1.370 (1.400)	0.757 (0.600)	1.046 (0.600)	0.831 (0.200)	0.870 (0.270)
7	JT 3 (LC)	1.449 (1.600)	0.629 (0.400)	0.835 (0.200)	0.707 (0.000)	0.730 (0.030)
S. Em.±		0.09	0.08	0.07	0.05	0.03
C.D. at 5%		0.27	0.24	0.22	0.16	0.10
C.V.%		13.29	13.29	13.80	11.92	6.80

*Figures in parentheses are original values, those outside are ($\sqrt{X} + 0.5$) transformed values

WAT – Week After Transplanting

Contd...

Sr. No.	Genotypes	Weekly mean larvae/plant				
		13^{th} WAT	14^{th} WAT	15^{th} WAT	16^{th} WAT	17^{th} WAT
1	2011/TOINDVAR - 1	0.707 (0.000)	0.707 (0.000)	0.945 (0.400)	0.71 (0.00)	0.71 (0.00)
2	2011/TOINDVAR - 2	0.707 (0.000)	0.707 (0.000)	0.831 (0.200)	0.71 (0.00)	0.71 (0.00)
3	2011/TOINDVAR - 3	0.707 (0.000)	0.707 (0.000)	0.945 (0.400)	0.71 (0.00)	0.71 (0.00)
4	2011/TOINDVAR - 4	0.707 (0.000)	0.707 (0.000)	1.046 (0.600)	0.71 (0.00)	0.71 (0.00)
5	2011/TOINDVAR - 5	0.707 (0.000)	0.707 (0.000)	0.831 (0.200)	0.71 (0.00)	0.71 (0.00)
6	Arka Vikas (C)	0.707 (0.000)	0.932 (0.400)	0.831 (0.200)	0.71 (0.00)	0.71 (0.00)
7	JT 3 (LC)	0.707 (0.000)	0.707 (0.000)	0.707 (0.000)	0.71 (0.00)	0.71 (0.00)
S. Em.±		0.00	0.05	0.06	0.00	0.00
C.D. at 5%		NS	0.15	0.19	NS	NS
C.V.%		0.00	11.10	12.10	0.00	0.00

*Figures in parentheses are original values, those outside are ($\sqrt{X} + 0.5$) transformed values

WAT – Week After Transplanting

Appendix-III: Weekly mean per cent damage of *S. litura* on different genotypes of tomato

Sr. No.	Genotypes	Weekly mean per cent damaged leaves				
		3rd WAT	4th WAT	5th WAT	6th WAT	7th WAT
1	2011/TOINDVAR - 1	4.05 (0.000)	0.00 (0.000)	7.26 (1.600)	5.73 (1.000)	8.53 (2.200)
2	2011/TOINDVAR - 2	4.05 (0.000)	0.00 (0.000)	5.12 (0.800)	3.61 (0.400)	0.00 (0.000)
3	2011/TOINDVAR - 3	9.40 (2.200)	0.00 (0.000)	7.26 (1.600)	0.00 (0.000)	9.62 (2.800)
4	2011/TOINDVAR - 4	4.05 (0.000)	13.04 (0.800)	8.90 (2.400)	6.78 (1.400)	0.00 (0.000)
5	2011/TOINDVAR - 5	12.24 (4.000)	0.00 (0.000)	9.94 (3.000)	9.28 (2.600)	8.07 (2.000)
6	Arka Vikas (C)	4.05 (0.000)	13.08 (0.800)	4.34 (0.600)	6.77 (1.400)	7.61 (1.800)
7	JT 3 (LC)	5.35 (0.400)	0.00 (0.000)	0.00 (0.000)	3.54 (0.400)	7.70 (1.800)
S. Em.±		0.42	0.29	0.40	0.33	0.44
C.D. at 5%		1.29	0.90	1.22	1.02	1.35
C.V.%		11.70	13.59	11.21	11.26	12.81

*Figures in parentheses are original values, those outside are arc sin transformed values

WAT – Week After Transplanting

Contd...

Sr. No.	Genotypes	Weekly mean per cent damaged leaves				
		8^{th} WAT	9^{th} WAT	10^{th} WAT	11^{th} WAT	12^{th} WAT
1	2011/TOINDVAR - 1	4.43 (0.600)	8.78 (2.400)	2.51 (0.200)	6.75 (1.400)	4.25 (0.600)
2	2011/TOINDVAR - 2	5.02 (0.800)	7.23 (1.600)	10.22 (3.200)	7.10 (1.600)	7.23 (1.600)
3	2011/TOINDVAR - 3	6.15 (1.200)	5.70 (1.000)	3.41 (0.400)	8.52 (2.200)	6.27 (1.200)
4	2011/TOINDVAR - 4	5.72 (1.000)	5.07 (0.800)	9.60 (2.800)	8.87 (2.400)	12.34 4.600)
5	2011/TOINDVAR - 5	5.12 (0.800)	10.62 (3.400)	8.90 (2.400)	9.95 (3.000)	5.02 (0.800)
6	Arka Vikas (C)	9.26 (2.600)	5.10 (0.800)	10.30 (3.200)	12.35 (4.600)	8.12 (2.000)
7	JT 3 (LC)	3.54 (0.400)	8.89 (2.400)	10.30 (3.200)	6.23 (1.200)	9.63 (2.800)
S. Em.±		0.42	0.59	0.61	0.68	0.60
C.D. at 5%		1.30	1.81	1.89	2.09	1.85
C.V.%		13.08	13.84	13.48	13.77	13.80

*Figures in parentheses are original values, those outside are arc sin transformed values

WAT – Week After Transplanting

Contd...

Sr. No.	Genotypes	Weekly mean per cent damaged leaves				
		13th WAT	14th WAT	15th WAT	16th WAT	17th WAT
1	2011/TOINDVAR - 1	4.43 (0.600)	6.23 (1.200)	3.41 (0.400)	25.02 (17.900)	25.23(18.200)
2	2011/TOINDVAR - 2	2.51 (0.200)	4.40(0.600)	8.89 (2.400)	15.63 (7.330)	15.19 (7.070)
3	2011/TOINDVAR - 3	6.78 (1.400)	6.93 (1.470)	5.54 (1.000)	12.37 (4.600)	10.93 (3.600)
4	2011/TOINDVAR - 4	6.72 (1.400)	6.60 (1.330)	5.72 (1.000)	10.08 (3.200)	8.52 (2.200)
5	2011/TOINDVAR - 5	11.48 (4.000)	9.38 (2.670)	12.65 (4.800)	8.37(2.200)	6.27 (1.200)
6	Arka Vikas (C)	11.24 (3.800)	8.91 (2.400)	12.11 (4.400)	7.70 (1.800)	5.12 (0.800)
7	JT 3 (LC)	8.52 (2.200)	6.93 (1.470)	5.73 (1.000)	12.88 (5.000)	11.48 (4.000)
S. Em.±		0.51	0.45	0.59	0.97	0.88
C.D. at 5%		1.58	1.38	1.80	2.99	2.71
C.V.%		12.01	11.01	13.13	12.78	12.88

*Figures in parentheses are original values, those outside are arc sin transformed values

WAT – Week After Transplanting

Appendix-IV: Weekly mean population of *B. tabaci* on different genotypes of tomato

Sr. No.	Genotypes	Weekly mean Whitefly/leaf				
		3rd WAT	4th WAT	5th WAT	6th WAT	7th WAT
1	2011/TOINDVAR - 1	0.421 (0.200)	0.949 (0.930)	0.741 (0.600)	0.618 (0.400)	1.456 (2.200)
2	2011/TOINDVAR - 2	0.355 (0.130)	1.030 (1.060)	0.575 (0.333)	0.510 (0.260)	2.049 (4.200)
3	2011/TOINDVAR - 3	0.757 (0.600)	1.153 (1.330)	0.965 (0.933)	0.855 (0.730)	1.093 (1.200)
4	2011/TOINDVAR - 4	0.575 (0.330)	0.956 (0.930)	0.855 (0.733)	0.512 (0.260)	0.773 (0.600)
5	2011/TOINDVAR - 5	0.680 (0.460)	0.960 (0.930)	0.997 (1.000)	0.512 (0.260)	0.571 (0.330)
6	Arka Vikas (C)	1.031 (1.060)	1.210 (1.470)	1.315 (1.733)	0.720 (0.530)	0.812 (0.660)
7	JT 3 (LC)	0.814 (0.660)	1.329 (1.800)	0.680 (0.466)	0.893 (0.800)	1.830 (3.400)
S. Em.±		0.07	0.08	0.07	0.05	0.10
C.D. at 5%		0.21	0.25	0.21	0.17	0.30
C.V.%		17.64	12.89	13.34	14.18	13.88

*Figures in parentheses are original values, those outside are ($\sqrt{X} + 0.5$) transformed values

WAT – Week After Transplanting

Contd...

Sr. No.	Genotypes	Weekly mean Whitefly/leaf				
		8^{th} WAT	9^{th} WAT	10^{th} WAT	11^{th} WAT	12^{th} WAT
1	2011/TOINDVAR - 1	0.996 (1.000)	1.052 (1.130)	1.133 (1.330)	0.790 (0.670)	1.236 (1.600)
2	2011/TOINDVAR - 2	1.057 (1.130)	0.956 (0.930)	0.966 (1.000)	1.233 (1.530)	0.929 (0.860)
3	2011/TOINDVAR - 3	1.031 (1.060)	1.093 (1.200)	1.694 (2.890)	1.060 (1.130)	1.456 (2.200)
4	2011/TOINDVAR - 4	0.929 (0.860)	0.965 (0.930)	1.034 (1.070)	1.085 (1.200)	0.890 (0.800)
5	2011/TOINDVAR - 5	0.733 (0.540)	0.727 (0.530)	1.064 (1.130)	1.154 (1.330)	1.273 (1.620)
6	Arka Vikas (C)	0.929 (0.860)	0.997 (1.000)	1.437 (2.070)	0.855 (0.730)	1.154 (1.330)
7	JT 3 (LC)	1.436 (2.060)	1.126 (1.270)	1.208 (1.470)	1.237 (1.530)	1.289 (1.660)
S. Em.±		0.08	0.07	0.09	0.08	0.09
C.D. at 5%		0.25	0.21	0.29	0.25	0.27
C.V.%		13.74	12.03	13.25	13.03	13.12

*Figures in parentheses are original values, those outside are ($\sqrt{X}$ + 0.5) transformed values

WAT – Week After Transplanting

Contd...

Sr. No.	Genotypes	Weekly mean Whitefly/leaf				
		13th WAT	14th WAT	15th WAT	16th WAT	17th WAT
1	2011/TOINDVAR - 1	0.720 (0.530)	1.085 (1.200)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
2	2011/TOINDVAR - 2	0.807 (0.660)	1.114 (1.260)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
3	2011/TOINDVAR - 3	0.571 (0.330)	1.153 (1.330)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
4	2011/TOINDVAR - 4	0.679 (0.460)	1.236 (1.530)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
5	2011/TOINDVAR - 5	0.667 (0.450)	0.853 (0.730)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
6	Arka Vikas (C)	0.571 (0.330)	0.679 (0.460)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
7	JT 3 (LC)	0.680 (0.460)	0.767 (0.600)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
S. Em.±		0.05	0.07	0.00	0.00	0.00
C.D. at 5%		0.14	0.22	NS	NS	NS
C.V.%		11.88	12.47	0.00	0.00	0.00

*Figures in parentheses are original values, those outside are ($\sqrt{X} + 0.5$) transformed values

WAT – Week After Transplanting

Appendix-V: Weekly mean per cent damage of *L. trifolii* on different genotypes of tomato

Sr. No.	Genotypes	Weekly mean per cent damaged leaves				
		3rd WAT	4th WAT	5th WAT	6th WAT	7th WAT
1	2011/TOINDVAR - 1	12.10 (4.400)	9.55 (2.800)	15.32 (7.000)	16.24 (8.000)	8.02 (2.000)
2	2011/TOINDVAR - 2	12.08 (4.400)	10.53 (3.400)	18.80(10.400)	10.61 (3.400)	20.40(12.200)
3	2011/TOINDVAR - 3	6.93 (1.600)	11.15 (3.800)	16.43 (8.000)	19.50 (11.200)	13.64 (5.600)
4	2011/TOINDVAR - 4	11.91 (4.400)	8.37 (2.200)	18.05 (9.600)	21.94 (14.000)	9.88 (3.000)
5	2011/TOINDVAR - 5	13.93 (5.800)	10.29 (3.400)	17.20 (8.840)	16.08 (8.000)	17.34 (9.000)
6	Arka Vikas (C)	19.17 (11.000)	18.81(10.400)	11.32 (4.200)	16.85 (8.400)	19.32 (11.000)
7	JT 3 (LC)	17.85 (9.400)	12.38 (4.600)	22.01(14.200)	18.81 (10.400)	12.06 (4.400)
S. Em.±		0.92	0.68	1.34	1.35	1.14
C.D. at 5%		2.82	2.08	4.13	4.16	3.50
C.V.%		11.82	10.10	13.66	13.62	13.70

*Figures in parentheses are original values, those outside are arc sin transformed values

WAT – Week After Transplanting

Contd...

Sr. No.	Genotypes	Weekly mean per cent damaged leaves				
		8th WAT	9th WAT	10th WAT	11th WAT	12th WAT
1	2011/TOINDVAR - 1	17.39 (9.000)	20.05 (11.800)	8.37(2.200)	11.16 (3.800)	11.59 (4.200)
2	2011/TOINDVAR - 2	17.91 (9.600)	17.35 (9.000)	18.38(10.000)	15.48 (7.200)	13.61 (5.800)
3	2011/TOINDVAR - 3	8.02 (2.000)	14.86 (6.600)	9.97(3.000)	14.34 (6.400)	18.69(10.400)
4	2011/TOINDVAR - 4	10.62 (3.400)	13.68 (5.600)	18.03(9.600)	21.56 (13.600)	12.29 (5.000)
5	2011/TOINDVAR - 5	14.65 (6.400)	19.99 (11.800)	20.92 (12.800)	22.83 (15.200)	20.92 (12.800)
6	Arka Vikas (C)	9.60 (2.800)	17.30 (9.000)	21.90 (14.000)	24.04 (16.600)	31.13 (26.600)
7	JT 3 (LC)	7.26 (1.600)	20.75 (12.600)	24.10 (16.800)	13.97 (6.000)	24.47 (17.200)
S. Em.±		0.96	1.29	1.17	1.37	1.52
C.D. at 5%		2.97	3.97	3.60	4.22	4.69
C.V.%		13.66	12.60	11.63	13.45	13.84

*Figures in parentheses are original values, those outside are arc sin transformed values

WAT – Week After Transplanting

Contd...

Sr. No.	Genotypes	Weekly mean per cent damaged leaves				
		13th WAT	14th WAT	15th WAT	16th WAT	17th WAT
1	2011/TOINDVAR - 1	12.49 (5.000)	13.28 (5.400)	14.29 (6.200)	12.88 (5.000)	11.48(4.000)
2	2011/TOINDVAR - 2	16.35 (8.000)	18.81 (10.400)	26.29 (20.200)	11.24 (3.800)	9.63(2.800)
3	2011/TOINDVAR - 3	14.05 (6.000)	19.50 (11.200)	16.02 (7.766)	6.27 (1.200)	3.54(0.400)
4	2011/TOINDVAR - 4	22.05 (14.130)	29.51 (24.330)	16.35 (8.000)	6.23 (1.200)	4.40(0.600)
5	2011/TOINDVAR - 5	26.34 (19.730)	24.60 (17.400)	26.98 (20.800)	3.54 (0.400)	3.54(0.400)
6	Arka Vikas (C)	24.91 (17.800)	24.35 (17.200)	28.46 (22.800)	3.61 (0.400)	2.51(0.200)
7	JT 3 (LC)	41.87 (42.600)	16.02 (7.800)	16.56 (8.200)	5.10 (0.800)	2.51(0.200)
S. Em.±		1.73	1.42	1.52	0.51	0.43
C.D. at 5%		5.33	4.39	4.67	1.59	1.32
C.V.%		13.28	11.82	12.64	12.76	13.76

*Figures in parentheses are original values, those outside are arc sin transformed values

WAT – Week After Transplanting

Appendix-VI: Mean per cent damaged fruits by *H. armigera* on different genotypes of tomato

Sr. No.	Genotypes	Weekly mean per cent damaged fruits				
		8th WAT	9th WAT	10th WAT	11th WAT	12th WAT
1	2011/TOINDVAR - 1	8.25 (2.240)	27.08 (20.880)	26.94 (20.690)	5.89 (1.22)	5.79 (1.16)
2	2011/TOINDVAR - 2	11.70 (4.110)	36.65 (35.710)	40.06 (41.393)	9.09 (2.56)	30.93 (26.92)
3	2011/TOINDVAR - 3	12.64 (4.830)	29.00 (23.680)	32.62 (29.110)	16.88 (8.45)	14.93 (6.67)
4	2011/TOINDVAR - 4	15.67 (7.3200	48.61 (56.250)	48.98 (56.900)	19.81 (11.54)	23.97 (16.52)
5	2011/TOINDVAR - 5	12.60 (4.760)	38.71 (39.130)	32.71 (29.230)	18.69 (10.34)	9.06 (2.56)
6	Arka Vikas (C)	6.70 (1.380)	24.04 (16.670)	23.34 (15.910)	14.33 (6.15)	18.10 (9.67)
7	JT 3 (LC)	5.19 (0.820)	14.71 (6.666)	16.27 (7.930)	13.53 (5.51)	14.71 (6.47)
S. Em.±		0.68	2.08	1.93	0.90	1.30
C.D. at 5%		2.10	6.40	5.93	2.78	4.02
C.V.%		11.30	11.51	10.57	11.13	13.46

*Figures in parentheses are original values, those outside are arc sin transformed values

WAT – Week After Transplanting

Contd...

Sr. No.	Genotypes	Weekly mean per cent damaged fruits		
		13^{th} WAT	14^{th} WAT	15th WAT
1	2011/TOINDVAR - 1	11.81 (4.23)	11.79 (4.35)	15.68 (7.50)
2	2011/TOINDVAR - 2	21.16 (13.04)	21.08 (13.10)	17.53 (9.09)
3	2011/TOINDVAR - 3	14.74 (6.50)	15.40 (7.14)	18.20 (10.00)
4	2011/TOINDVAR - 4	14.81 (6.56)	15.40 (7.14)	13.23 (5.26)
5	2011/TOINDVAR - 5	8.09 (2.00)	8.26 (2.06)	12.17 (4.76)
6	Arka Vikas (C)	13.30 (5.32)	14.60 (6.38)	21.67 (13.65)
7	JT 3 (LC)	7.24 (1.76)	8.77 (2.38)	10.10 (3.13)
S. Em.±		0.93	0.97	0.83
C.D. at 5%		2.86	3.00	2.55
C.V.%		12.35	12.40	9.24

*Figures in parentheses are original values, those outside are arc sin transformed values

WAT – Week After Transplanting

CERTIFICATE

This is to certify that I have no objection for supplying to any scientist only one copy or any part of this thesis at a time through reprographic process, if necessary for rendering reference service in a library or documentation centre.

Place : Navsari

Date : April 16, 2013

Shailesh

(Patel S. D.)