Management of major insect pests of tomato with novel insecticide combination of Tetraniliprole and Spirotetromat

काशी हिन्दू विश्वविद्यालय BANARAS HINDU UNIVERSITY

THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

Master of Science (Agriculture)

in

Entomology and Agricultural Zoology

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CERTIFICATE

To,
The Registrar (Academic)
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Through The Head, Department of Entomology and Agricultural Zoology,
Institute of Agricultural Sciences, B.H.U., Varanasi.

Dear Sir,

I have great pleasure in forwarding the thesis entitled **"Management of major insect pests of tomato with novel insecticide combination of Tetraniliprole and Spirotetromat"** submitted by **Ms. Bijayalakshmi Thakur, ID. No.19412EAZ002**, in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in **Entomology and Agricultural Zoology**, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi and placing on record that he has completed the requisite residential requirements as contained in the statutes of the university.

I certify that the entire scheme of investigation presented herein was planned and carried out solely by the candidate under my guidance and supervision. The data presented in the thesis, to the best of my knowledge and belief, are genuine and original.

Thanking you.

Yours sincerely,

(M. Raghuraman)
Supervisor

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2021

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Date:
Place: *tfaranasi* ***(Bijayalakshmi Thakur)***

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Chapter I

INTRODUCTION

Tomato (*Solanum lycopersicum* L., family: Solanaceae) is one of the most commonly and extensively grown vegetable crops all over the country occupying an important place in the food basket of Indian consumers. Tomato tops the list of canned vegetables. Tomato is a widely grown vegetable crop of both tropics and subtropics. It traces its origin from Central and South America (Jenkins, 1948). It is an edible, and nutrition-rich vegetable also called as **'love apple'** belonging to the genus *Lycopersicon* and species *esculentum*. In Solanum family, at present almost 13 wild species has been documented, including *Solanum lycopersicum*. Three of these species *S. pheesmaniae, S. galapagense*, and *S. pimpinellifolium* are fully cross-compatible with domestically cultivated tomato.

Around 809 thousand hectares with an estimated production of 19697 thousand tons of tomato is grown all over in India. The world productivity of tomato is 27 t ha^{-1}, whereas, in India, it is 18.6 t ha^{-1}. Major tomato growing states are Andhra Pradesh (13.9%), Madhya Pradesh (12.25%), Karnataka (10.54%) and Gujarat (6.88%)[NHB,2017-18].

Several biotic and abiotic factors affect the growth of tomato. Among all the biotic factors affecting this crop, insect pests (almost 100 to 200 species) are the chief factor which attack at different stages of crop growth (Lange and Bronson, 1981). There are numbers of insect pests like, Fruit borer (*Helicoverpa armigera* Hub.), Aphid (*Aphis gossypii* Glover, *Myzus persicae* Sulzer), Jassid (*Amarasca biguttula* Ishida), Serpentine leaf miner (*Liriomyza trifolii* Burgess), Tobacco caterpillar (*Spodoptera litura* Fabricius), Whitefly (*Bemisia tabaci* Gennadius), Thrips etc. which have been recorded as serious problem causing economic damage to the crop.

Tomato fruit borer i.e. *Helicoverpa armigera* is one of the most damaging pests in India, which causes severe yield losses ranging from 5 to 80% by boring in tomato (Lal and Lal, 1996). It is a vital pest causing substantial damages in quality as well as the quantity of tomato fruits (Tewari and Moorthy, 1984; Reddy and Zehrm, 2004). In India, *Helicoverpa armigera* is one of the most important pests of tomato as it reduces the production and market value of the produce. This pest is commonly known as tomato fruit borer, American bollworm and gram pod borer. Young larvae generally feed on flowers, foliage and also on flower buds and the fruits were bored by later instars which makes the fruits unmarketable (Meena and Raju, 2014). Almost one thousand crore rupees per year has been lost in India due to insect pest attack (Jayaraj *et al*., 1994) and yield loss reached to 50-80% on tomato (Tewari and Moorthy, 1984).

Bemisia tabaci is one of the most attacking pests which hamper an enormous number of vegetables and countless numbers of essential crops throughout the world (Abdel-Baky and Al-Deghairi, 2008). Since the late 1980s, *Bemisia tabaci* became one of the most endangered pest species by not only sucking the phloem sap directly but also act as a vector for the viral diseases (Abdel-Baky and Al-Deghairi, 2008). The tomato leaf curl virus transmitted by whitefly which severely hampers the plant vitality as well as the yield.

Serpentine leaf miner *Liriomyza trifolii* gradually attaining the major pest status in different region of the country and reported to cause 35% losses in tomato crop (Krishna kumar, 1998). A survey on food plants and pest status of Liriomyza trifolii in Jabalpur district denoted that it feeds on 59 types of plants including vegetables, pulses, oilseeds, ornamentals, medicinal plants and weeds (Sharma and Sharma, 1997). The maximum (76.67%) leaf infestation by leaf miner was recorded in the middle of March, where as white fly attained maximum number (13 files/10 cm twigs) during first week of March and the fruit borer population peaked (26 larvae/10 plant) in the third week of March (Kharpuse, 2005).

To develop any advanced pest management strategies, the effect of climatic factors on the phenology of cop and the pest is most desired as climate change inclined the life cycle of the insect and the host nutritional distribution (Patel and Shekh, 2006). The areas where the occurrence of key pests are founded in consequent years, the cultivators will be benefited if they study the effect of weather parameters upon the crop phenology and insects. By knowing the ecology, behaviour and biology of the pests, a potent management policy can be developed. The larvae of *H. armigera* remain inside the fruit, so, biocontrol is not feasible. Since the past decade, H. armigera and leaf miner became a serious threaten in tomato cultivation. In India, the central and state governmental plant protection agencies and the farmers grow puzzled to control these pests leading to a tremendous economic problem (Hussain and Bilal, 2007).

For controlling the major insects of tomato, i.e. fruit borer, whitefly, leaf miner, thrips, aphid etc. several insecticides (like- organophosphate, synthetic pyrethroids, carbamates, neonicotinoids etc.) are used over more than four decades. But due to indiscriminate use of these insecticides over a longer period, it results in resistance to organophosphate, which ultimately causes a health hazard and environmental pollution (Kramer *et al*., 2012). As OPs are generally nonspecific, it tremendously harms the NEs (Legaspi *et al*., 1996). The application of most conventional insecticides reduces the efficiency of natural enemies. Though, resistance occurs to some NEs as well (Croft, 1990).

However, in most of the insect pest control method, chemical method is economically feasible than the others. To overcome the problems as mentioned above, identification of modern chemical insecticides with a specific target and more incredible insecticidal action, minimum mammalian toxicity with lesser dosage fits sound in the IPM concept.

Therefore, keeping all these facts and figures in mind, the present experiment has been oriented to investigate with the following objective:

I. To study the seasonal incidence of major insect pests on tomato.

II. To study the bioefficacy of some newer insecticides against major insect pests of tomato under field condition.

III. To study the impact of insecticidal treatments on yield of tomato.

REVIEW OF LITERATURE

Comprehensive review of literature is an important component of any research work. It gives information of 'what has already done'' and gives guidance on ' what is to be done'. Being an important vegetable crop for decades, numerous research works is done on the various aspects of tomato cultivation. This chapter deals with the literature, which is relevant to present work entitled - **"Field efficacy of certain newer insecticides and seasonal incidence of major pest complex in rabi Tomato (*Lycopersicon esculentum* Miller)."**

So far the available literature pertinent to the present studies has been grouped under the following headings:

I. To study the seasonal incidence of major insect pests on tomato.

II. To study the bioefficacy of some newer insecticides against major insect pests of tomato under field condition.

III. To study the impact of insecticidal treatments on yield of tomato.

2.1 SEASONAL INCIDENCE OF MAJOR INSECT PESTS ON TOMATO:

2.1.1 Seasonal Incidence of Leaf Miner on Tomato

Senguttuvan (1999) has reported a non-significant positive association of damage and leaf miner population with maximum and minimum temperature.

Choudary and Rosaiah (2000) observed that the leaf miner *L. trifolii* incidence began from the third week of November and attained a summit in the fourth week of January. The effect of weather parameters on the leaf miner incidence revealed that minimum temperature and evening relative humidity had a negative correlation. While wind velocity and sunshine hours showed a positive correlation.

Asalatha (2002) reported that leaf infestation (%) by leaf miner and pest population on leaves were positively correlated with maximum temperature and sunshine hours.

Chaudhuri and Senapati (2004) elucidated that the leaf miner population was initiated at about 46th standard meteorological week (SMW), increased at first slowly up to 01st SMW and then steadily up to 6th SMW attaining the maximum at about 8th SMW which was maintained up to 13th SMW. The population then subsumed slowly. Abiotic conditions such as maximum temperature, minimum temperature, temperature gradient, average temperature, maximum relative humidity, minimum relative humidity and sunshine hours had a significant negative influence on *L. trifolii* population. In case of relative humidity gradient, a positive influence was observed.

Hemalata and Maheshwari (2004) studied the seasonal incidence and biology of *L. trifolii*on tomato. During the first week of July (27th standard week) leaf miner infestation was seen and peak was reported during the first week of October and January(40th and first standard week. During April and May the pest was found absent.

Reddy and Kumar (2005) revealed that the infestation based on mines/leaf attained the highest peak (10.26 mines/ leaf) during the third week of January. The number of larvae per leaf ranged between 0.24 and 2.24 with an average of 0.84. The larval population reached its 1st peak (2.24 per leaf) during the 3rd week of January. Per cent damaged leaves increased as the crop became older and reached 2nd distinct peak during the 4th week of November. The correlation studies indicated that the number of mines, larvae as well as per cent damaged leaves had a significant negative correlation with observed maximum and minimum temperature and relative humidity in morning and evening.

Singh and Nath (2006) experimented with recording the impact of serpentine leaf miner’s infestation rate throughout various stages of tomato plantings. The susceptible stage, degree of damages to the crop, and the yield of tomato under infestation with leafminers were reported. The result suggested that during the seedling period, the plants were very susceptible to attack by the leaf miners, followed by the flowering period. The transplanted tomato crops reported the maximum infestation of the leaf, but none of the plants was destroyed. The severely infected plants did not bear any fruits at the later stage of the crop, whereas plants with minimum infestation showed extended fruiting period and therefore increased yield.

Ganapathy (2010) reported that incidence of leaf miner was minimum in November i.e. 9% whereas it was found maximum i.e. 32.5% in March. During rainy season it was to the extent of 26.2% to 28.3% in august and July respectively. Comparatively it was low in cold season i.e. from 9.0% to 13.70%.

Variya and Patel (2012) concluded that the infestation based on mines (10.26 mines/leaf) and larvae (2.24 larvae/leaf) attained peak during the 3rd week of January. The infestation based on per cent damaged leaves reached to the first peak (16.41%) during 4th week of November and highest peak (29.40%) during the 1st week of January and Overall, the activity was higher during December-January. The correlation studies revealed that maximum temperature, minimum temperature, mean temperature, morning vapour pressure and mean vapour pressure influenced the infestation of leaf miner of tomato.

Goftishu *et al.* (2014) reported that there was a linear increment in the number of captured moths (*Tuta absoluta*) during the surveyed time both in the green house and in the open-field tomato crops. The number of moths counted ranged from 27-47 and 103-255 in the open-field and in the greenhouse, respectively.

Mandloi *et al.* (2015) discussed that *Liriomyza trifolii* was first appeared on 43rd SW on tomato plants and continued till the harvest. An increasing trend was noticed in this case with crop growth stages. The activity was noticed from 43rd to 12th SW (22 Oct 2012 to 25 March 2013) with three distinct peaks during 10th, 11th, and 12th SW (44.56%, 45.95% and 44.02%) and maximum infestation was recorded on 11th SW (45.95%).

Ismaeel *et al.* (2016) studied the damage caused by leaf miner and reported that the maximum damage percentage (52.08%) was showed by tomato plants.

Selvaraj *et al*. (2016) recorded (at Pantnagar) the occurrence of serpentine leafminer on tomato showed that the occurrence of this insect is almost throughout the crop seasons and promoted its first occurrence in the 8th SMW and 9th SMW, i.e. (Feb - March) attaining maximum number in the 14th and 17th SMW (April) respectively. These insects had a non-significant correlation with different abiotic variables, except sunshine hours during 2012-13 and considerable negative correlation with RH.

Nitin *et al.* (2017) investigated that there was a slender rise in the number of captured *Tutaabsoluta*moths on tomato crop. The highest number of moths were reported between March and April. Similarly, the paramount levels of tomato borer infestation were ascertained from January to May.

Singh (2017) reported the first appearance of tomato leaf miner, Liriomyzatrifolii (Burgess) in the 3rd week of January (1.05 live mines/ plant). Highest peak population was observed during last week of march and it was 31.25 live mines/ plant.

Nayana *et al.* (2018) reported that weather parameters influenced leaf miner population more in rabi season than kharif season. Minimum temperature influenced leaf miner negatively both in kharif (r= -0.409) and rabi season (r= -0.821). Positive influence of sunshine hours in kharif (r= 0.534) and rabi (r= 0.523) was also found on leaf miner. Other weather parameter werenon significant in relation to leaf miner.

Saad *et al.* (2019) reported that during the experiments conducted at rabi seasons of 2018 and 2019 and found that tomato leaf miner, Liriomyzatrifolii (Burgess) has attained its peak on 13th February (28.34mines/plant) and 1st January (41.8mines/plant) respectively. Among the weather parameters relative humidity has affected the most and temperature affected the least.

2.1.2 Seasonal incidence of Whitefly on Tomato

Choudhuri and Senapati (2001) stated that the population attained its peak level (1.68/plant) during mid of February and same level of population was maintained from mid-February till mid-March when temperature, relative humidity, sunshine hr/day and rainfall were ranged from 17.07-22.13^{0}C, 65.29-72.78%, 7.79-8.98 hr/day and 5mm, respectively. Temperature, relative humidity and rainfall were found negatively correlated with whitefly population.

Tripathi and Verma (2002) reported that in the winter crop infestation of whitefly was found higher than the summer crop when recorded at the same growth stage.

Barde (2006) researched the seasonal occurrence of whitefly on tomatoes and confirmed that it emerged within January's second week and remained very active until harvesting. In the last week of February, the maximum population was recorded with a max. and min. temp. of 30.5℃ and 16.8℃, respectively 61.5 % RH and 162 mm rainfall.

Shahnaz *et al.* (2006) said *B. tabaci*was prevalent in both summers and winters with a higher incidence of pests in winter. The analyses between the *B. tabaci*population and different abiotic factors displayed a strong positive correlation with temp. (both max. and min.) and a positive but non-significant sunshine hour. Whereas a strong negative correlation with RH (max. and min.) and with rainfall, a negative but non-significant correlation was observed.

Dhaka and Pareek (2008) recorded that the max. temp. had a considerably positive effect on the whitefly population, and the RH at night had a substantial negative effect.

Sarangdevot *et al.* (2010) first noticed the incidence of *B. tabaci*was first noticed in the 14th SMW which reached its peak during 22nd SMW. The whitefly population was found positively correlated with mean temperature and negatively correlated with mean relative humidity. The positive correlation between the temperature and whitefly population can be attributed to the enhanced rate of development and reproduction of whitefly and found that the ovipositional activity of whitefly was maximum between 33 ^{0}C to 37 ^{0}C.

Chakraborty *et al.* (2012) observed that the population of *H. armigera* initiated at about 48 SMW, improved slowly up to 1 SMW then steadily up to 5 SMW attaining the maximum at about 6 SMW.

Mathur *et al.* (2012) said the occurrence of jassids and whiteflies were maximum in December, 52nd standard weeks (SMW) and minimal in March (12th SMW) and revealed that, both max. and min. temperature and wind speed significantly negatively correlated, whereas RH and the rainfall are positively correlated with the occurrence of these insects.

Chavan *et al.* (2013) revealed that aphid and whitefly population commenced from transplanting with 1.35 aphids/leaf and 0.37 whitefly/leaf, reached to a peak level (7.31 aphids/leaf and 6.01 whiteflies/leaf) at 11 DAT. There was a significant negative correlation of aphid (r=-0.491) and whitefly(r=-0.449) population with maximum temperature, and significant negative correlation with minimum temperature. (r=-0.645, r=-0.599), respectively.

Senfu *et al.* (2013) reported that the whiteflies can produce 11 generations per year with an evident generation overlapping. The number of whiteflies in the greenhouse started to increase from June, with a significant increase after July and then reached at its peak during August and September. The whitefly population started to decrease after mid-October with decrease in temperature. The observation of the insects indicated that whiteflies are capable of surviving within the whole year under the greenhouse condition. On the other hand, the overwintering frequency for the whitefly in the open field was approximately 20 per cent.

Shaikh and Patel (2013) concluded that the population of whitefly ranged between 1.52 to 8.50 per leaf with an average of 5.02. The peak population of whitefly (8.50 / leaf) was noticed during 4th week of December and reported that the whitefly population had a significant positive correlation of whitefly population with bright sunshine hours and a significant negative correlation was recorded with rainfall, maximum temperature, minimum temperature, mean temperature, evening relative humidity, mean relative humidity and wind speed.

Sharma *et al.* (2013) noticed that the population of whitefly on tomato was noticed at 14th standard meteorological week which attained its peak during 22nd standard meteorological week. The correlation between whitefly and temperature (maximum and minimum), sunshine was positive, while it was negative with relative humidity (maximum and minimum) and rainfall.

Meena and Bairwa (2014) observed that the peak incidence of whitefly (62.12 mean population/6 leaves) was observed in the first week of November and fruit borer (55.7 mean population/6 leaves) in the first week of February.

Patel *et al.* (2015) inspected the seasonal prevalence of whitefly on brinjal and confirmed that the insects reached its peaked (15.33 whiteflies leaf^{-1}) at the end of April.

Mandloi *et al.* (2015) investigated that *Bemisia tabaci* was active from October 2012 to March 2013 with two distinct peaks during 7th and 9th SW (9.84 and 11.85 flies/10 cm twig) respectively. Correlation coefficient between various weather factors and *B. tabaci* population expressed a non-significant relationship.

Subba *et al.* (2017) stated that the maximum population level was maintained during 11th standard week to 18th SMW that is during 2nd week of March to peak population (0.47/leaf) was recorded. Weekly population counts on whitefly showed a non - significant negative correlation (p=0.05) with temperature and weekly total rainfall had a significant negative correlation with relative humidity.

Sharma *et al.* (2017) revealed that *B. tabaci*appeared during 13th SMW on tomato crop and reached a maximum during 21st SMW. A positive correlation was observed between adult population and abiotic factors like temperature (minimum and maximum) and sunshine hours whereas, a negative correlation was observed with the relative humidity and rainfall.

Chauhan *et al.* (2017) reported that whitefly incidence had begun from the 5th WAS (Week After Sowing), i.e. August 2nd week (0.38 whitefly leaf^{-1}). The insect population slowly increased to the 14th WAS, and subsequently rapidly increased, showing peak development at the 18th WAS (Week After Sowing), i.e. November 2nd week (12.60 whiteflies leaf^{-1}). The population of whiteflies then decreased and persisted till the harvest.

Khan and Hussain (2018) recorded highest per cent plant infestation (56.25%) on 2nd March followed by 1st April (50%) and 17th March (33.33%). While the lowest infestation (9.09%) was recorded on 15th February followed by 30th January (10.98%). The population then declined at 1st slowly then abruptly. Abiotic conditions had a significant negative influence on *B. tabaci*population. Relative humidity gradient, indicated a positive influence.

Moanaro and Choudhary (2018) reported that whitefly appeared in September 1st week (36 SMW) and persisted until December 3rd week (51 SMW). In October, third week (42 SMW), the population slowly increased and attained its limit with 1.88 whiteflies per three leaves, and then gradually decreased, reaching up to 0.26 whiteflies per three leaves.

Sidar *et al.* (2019) reported that the incidence of whiteflies begun from the first week of December and the observed population was 1.20 whitefly/plant. Maximum population 5.56 adults/plant were noticed in 3rdsmw. Positive correlation was found with morning relative humidity (r = 0.396) and sunshine hours (r = 0.001). and significant negative correlation was with the temperature.

Khan (2019) reported that there was strong negative correlation of the whiteflies with the average temperature (r = - 0.713) and average relative humidity (r = - 0.045). However dependence on humidity is low as compared to temperature.

Sushmetha and Hariprasad (2020) reported that there was significant positive correlation of whitefly population with the temperature (r= 0.378) and relative humidity (r= 0.311). While there was significant negative relationship with rainfall. All other abiotic factors were non-significant. Whitefly infestation was lower in rabi season then kharif season.

2.1.3 Seasonal incidence of Fruit borer on Tomato

Khan *et al*. (2003) recorded a positive association between mean temperature and outbreak of *H. armigera* . A substantial negative correlation between the larval population and higher and lower RH (r= -0.700, -0.641) but an insignificant negative correlation with rainfall (r= -0.420). In the field condition, multiple regression determination coefficients (R2) showed that climate factors affected the prevalence of *H. armigera* larvae exceeding 96.80 % (R2 = 96.80).

Reddy and Kumar (2004) performed a research analysis and reported the association regarding abiotic factors and the incidence of *H. armigera* in various locations (Thummalahalli, Singasandra, Kaiwara, Kembodi, Seethi and Kannur) in Chintamani and Kolar regions in Karnataka, India in 1998. Periodical observations of eggs and larval population were recorded from the pre-flowering period on chosen plants from the middle lines of each plot. Upon fruits development, the existence of the larva was investigated. The eggs of *H. armigera* and larval population differed in various regions. In March-April it reached a topmost level, and in October-November, the incidence was reduced. A related pattern of larval populations was found at different locations. In March, the no. of eggs plant^{-1} and larvae plant^{-1} was the maximum for Thummalahalli, Singasandra and Kembodi. The no. of eggs plant^{-1} for Kaiwara and Kannur were maximum in March; however, the no. of larvae plant^{-1} was lowermost in April.

Kamble *et al.* (2005) first recorded *H. armigera* occurrence by 35th SMW. The optimum numbers of larvae were at the 37th SMW, and afterwards, population declined since the 44th SMW. Generally, the tomato had two generations of *H. armigera* ; the maximum larval population has terminated with the flowering and fruiting time. The correlation of the larval population become non-significant with minimum and maximum temperatures, rainfall and minimum and most RH.

Boukhris-Bouhachem *et al.* (2007) stated that to increase the effectiveness of chemicals, the effects of the fruit borer populations in the field are significant. Regularly captured data indicate that the adult of this pest was active during mid-May to the beginning of November, and in July there is the highest capture in traps. Colonies of eggs and larvae were also estimated on 30 collected leaves per week. In July, the highest proportion of eggs and larval phases were found coinciding with the optimum moth activity. These results made it possible for us to carry out the management assay until late June.

Chatar *et al. (*2010) revealed that the population of *Helicoverpa armigera* appeared from the 2nd week of December and attained a peak (3.12 larvae per plant) during the 2nd week of January. Fruit borer was active during the last week of December to 3rd week of January. Later on, the pest population downturned steadily towards the maturity of the crop.

Kurl and Kumar (2010) revealed that the larvae of *Helicoverpa armigera* appeared on tomato crop in the 2nd standard week of January and continued till 21st standard week. The highest population was recorded in 15th standard week. Thereafter the population trend gradually declined.

Chakraborty *et al.* (2011) performed research on tomato infested by *H. armigera* and its incidence and abundance, to the period of cultivation within four alternative time schedules (early, middle, late and very late) in the controlled tomato field of the variety Pusa Ruby and confirmed that the peak frequency of 24.43 larvae per five plants and the minimal rate of 13.92 caterpillars per five plants were observed at 7th and 12th SMWs simultaneously.

Ugale *et al.* (2011) reported that the catches of moths were increased irrespective of varieties, from the 4th week of December, 2007 (9 moths) when maximum and minimum temperatures were 29.00°C and 13.90°C with morning and evening relative humidities of 75.1 and 60.6 per cent, respectively.

Patel *et al*. (2013) stated that incidence of *H. armigera* was more in *Kharif* season than *Rabi* season and none of the weather parameters significantly influenced the incidence of *H. armigera* population during Rabi season.

Chavan *et al.* (2013) elucidated that the highest population of *Helicoverpa armigera* on foliage (2.80-3.40/plant) was noticed during the 3rd week of January to the end of February.

Kachhawa *et al.* (2016) investigated that the population of *Helicoverpa armigera* was recorded at all growth stages of the crop. The incidence began in the first week of December with the population reaching a peak in the 6th SMW and 7th SMW. The larval population of the borer exhibited a significant positive correlation with the mean atmospheric temperature (r=0.608).

Meena and Bairwa (2014) recorded that temperature plays a crucial role in pest borers population dynamics through the study of effects on oviposition and egg-laying activity of fruit (55.7 mean larvae/ 6 leaves) in the 1st week of February.

Mandloi *et al.* (2015) investigated that *Helicoverpa armigera* was observed from November 2012 to March 2013 with two distinct peaks during 11th and 12th SW (6.02 and 6.11 larvae/plant) respectively. Analysis of correlation coefficient between abiotic factors and major insect pests of tomato showed that the population of borer had a significant correlation with rainy days (r=0.428).

Bharadiya *et al*. (2017) concluded that larval population of *Helicoverpa armigera* varied from 0.86 to 2.55 larvae per meter row length at 30 DAS. At 45 and 75 DAS A more or less similar pattern was observed, where larval population varied from 1.45 to 3.20 and 1.26 to 3.02 larvae per mrl, respectively. The activity of male moths began from 50th SMW of December to 9th standard week of February / March. The peak period was observed from 1st standard week to 4th standard week of January.

Ganai *et al.* (2017) stated that *Helicoverpa armigera* (Hubner) commenced from the 7th standard week, which remained till 18th standard week with its peak during the 15th standard week. The correlation studies indicated a highly significant positive association between the larval population of *H. armigera* and mean maximum temperature (r=0.349) and a highly significant negative association between larval population and mean relative humidity (r=-0.284).

Kumar *et al*. (2017) stated that the pest touched the peak with a mean of 1.20 larvae/plant during 12th SMW. Thereafter, the pest population inflated steadily and reached a minimum of 0.80 larvae / plant in 15th SMW. The correlation between fruit borer population and the maximum, minimum and mean atmospheric temperatures (r=0.628, 0.610, 0.633) were positive and significant. A positive correlation was found between *Helicoverpa armigera* larvae and damaged fruits in tomato.

Safna *et al.* (2018) clarified that the initiation of pest incidence was found in the 1st week of January. During the cropping season the fruit damage varied from 7.88 to 42.83 per cent whereas on number basis the minimum (7.88%) fruit borer infestation was recorded in 14thSMW, while maximum (42.83%) fruit borer infestation was recorded during 11th SMW.

Vikram *et al.* (2018) conducted their research throughout the rabi season of 2014-2015 and demonstrated the prevalence of tomato fruit borer initiated in 8th SMW of an overall two larval population per plant; subsequently, the larvae steadily increased and peaked in 12th SMW (Third week of March) at 6.0 larvae $plant^{-1}$. Environment parameters, temperatures [max. (r = 0.625) and min. (r = 0.668)], wind speed, sunshine hours (r = 0.722) and (r = 0.527) associated substantially and favourably with the population of larvae. RH [morn. (r = -0.160) and even. (r = -0.388)] had an insignificant -ve correlation, whereas rainfall had an insignificant +ve correlation (r= 0.091) with the larvae population.

Bhanuprakash *et al.* (2019) reported that fruit borer start appearing from 6^{th}smw and the population was 0.32 larvae/plant. The population increased gradually and reached to its peak 12^{th}smw and was 5.98 larvae/plant. Temperature influenced aphid population negatively and with the rise of temperature, aphid population declined.

Mondal *et al.* (2019) reported that fruit borer appeared first during the 7thsmw and was present with the crop till 15thsmw. Rainfall was non significant but negatively affected the *H. armigera* population (r= -0.208). All weather parameters contributed 18.6% (R2= 0.186) to the fruit borer population.

Wade *et al.* (2020) reported that *Helicoverpa armigera* infestation started from 5thsmw of January and sustained till 16thsmw of march. The peak was observed during 13thsmw and it infested 43.13% of the total fruits. Evening relative humidity had positive influence on the fruit borer population (r= 0.407) but it was found to be non-significant.

2.2 BIO-EFFICACY OF NEWER INSECTICIDES AGAINST MAJOR INSECTS PESTS OF TOMATO

2.2.1 Bio-efficacy of Insecticides against Leaf Miner on Tomato

Ahmed *et al.* (2001) tested the result of imidacloprid on the occurrence of tomato yellow leaf curl virus in two sprayings at four different dosages (47.6, 71.4, 95.2 and 119 g a.i ha^{-1}). They confirmed that Imidacloprid prevented tomato plants from the disease instantly after planting and six weeks later after panting. Both imidacloprid levels decreased disease incidence over the growing season relative to cypermethrin at 10-15 days interval. The disease frequency has been reduced from 2 to 17 % via imidacloprid application. Plots applied with Imidacloprid was observed to have a greater production than the untreated check, and yield reduced with a lower rate of application.

Chowdhary and Rosaiah (2001) reported significantly higher Tomato yield and effective control of leaf miner infestation due to the treatment of 5 % NSKE and 0.5 % Neemazal.

Schoonejan *et al.* (2001) reported that effective control of leaf miner infesting green house vegetables including tomato was observed by the spraying spinosad at the rate of 4.8 to 36 g a.i./ ha.

Schuster and Morris (2002) reported that Thiamethoxam @ 4 oz acre^{-1} and Imidacloprid @ 3.75 oz acre^{-1} both were effective resulted in minimizing leaf-mining by serpentine leafminer on tomato when sprayed both as soil application or as foliar however Thiamethoxam was somehow more effective.

Mote and Puri (2003) reported that in the IPM programme on tomato use of 5 % NSKE or NSE was significantly effective for the control of leaf miner and other pests of tomato crop.

Seal *et al.* (2007) reported thatAbamectin 0.15 EC @ 10 oz acre^{-1} significantly controlled the larval and pupal population of leafminers followed by Chlorantraniliprole 5 SC @ 5.1 oz acre^{-1} and Spinetoram 120 SC @ 7.0 oz acre^{-1} but the highest yield is obtained with the treatment of Chlorantraniliprole @ 5.1 oz acre$^{-1.}$

Ganapathy *et al*. (2010) reported that in a experiment conducted at Coimbatore, Tamil Nadu, India to evaluate the efficacy of Botanicals andinsecticides against leaf miner. Among the botanicals, neem seed kernel extract was the most effective and caused mean larval mortality of 53.4 per cent and low damage level (25.5%). Among the insecticides, chlorpyriphos 20 EC was the most effective and caused larval mortality of 74.9% followed by triazophos 40 EC (67.3% larval mortality).

Mandal (2012) reported that Cyantraniliprole 10 % OD @ 60 g and 105 g a.i ha^{-1} were more effective in controlling the infestation of *L. trifolii* followed by Imidacloprid 17.8% SL @ 22.5 g a.i ha^{-1} and Fipronil 5% SC @ 60 g a.i ha^{-1}.

Shalaby *et al.* (2012) reported that cyfluthrin, lufenuron, profenofos, indoxacarb, chlorpyriphos-methyl were found effective against leaf miner.

Misra (2013) reported that cyantraniliprole 10% OD @ 90 and 105 g *a.i.* /ha treated plots recorded the lowest number of serpentine leafminer adults/5 plants after 7 days of spraying (0.66-0.74 in 2009–10 and 0.77-0.85 in 2010–11). A mean of 80.65-82.61% reduction in adult population of serpentine leaf miner *Liriyomizatrifolii* was recorded over control plots.

Larrain *et al.* (2014) reported that on application of Cyantraniliprole 10 OD (oil dispersion) with or without surfactants (Dyne-Amic, Codacide) to leaves and cyantraniliprole 20 SC (suspension concentrate) to soil it was observed that both formulations of cyantraniliprole were effective to reduce damage caused by the tomato moth larva.

Pereira *et al.* (2014) reported that novel insecticides, especially cyantraniliprole, may be better suited to sustainable integrated management programmes of the tomato leaf miner and Indoxacarb and cyantraniliprole exhibited a lower toxicity to the pirate bug predators than to the tomato leaf miner. He assessed the toxicity of eight insecticides against leaf miner and its pirate bug predators *Oriustristicolor*, *Amphiareusconstrictus*and *Blaptostethuspallescens*(Hemiptera: Heteroptera: Anthocoridae).

Abdelgaleil *et al.* (2015) reported that chlorpyriphos treatment was resulted in 54.8 % reduction in leaf miner infestation. In this experiment he examined the efficacy of imidachloprid (Admire 20% SC), spinosad (Tracer 24% SC), chlorpyriphos (lirifos 48% EC), abamectin 152.4 g/l + thiomethoxam 33.2 g/l (Agriflex 18.6 % SC).

Silva *et al.* (2016) reported that in a experiment conducted at Northeast and Central regions of Brazil to test the efficacy of efficacy of diamides against the leaf miner it was observed that there was reduced efficacy of diamides against most populations. The LC50 values of chlorantraniliprole varied from 0.0044 (Brasilia) to 1,263 (America Dourada) mg *a.i.*liter^{-1} (the resistance ratios [RR50] ranged from 1.0- to 288,995-fold) for cyantraniliprole and flubendiamide, respectively.

Selvaraj *et al.* (2017) reported that on evaluating the bio-efficacy of Chlorantraniliprole 4.3% + Abamectin 1.7% SC @ 24, 30, 36 and 60 g a.i. ha^{-1} along with standard check, Chlorantraniliprole 18.5% SC @ 30 g a.i. ha^{-1} abamectin 1.9 EC @ 15 g a.i. ha^{-1} and lambda cyhalothrin 4.9 CS @ 15 g a.i. ha^{-1} against population of Leafminer, L. trifolii during 2011-12 and the Results showed that Chlorantraniliprole 4.3% + Abamectin 1.7% SC was significantly effective when sprayed twice at 15 days interval, minimized the incidence of L. trifoli and increased fruit yield.

Sapkal *et al.* (2018) reported that among spinosad 45% SC, chlorantraniliprole 18.5% SC, emamectin benzoate 5% SG, indoxacarb 14.5% SC, cyantraniliprole 10.26% OD, spinatoram 11.7% SC and flubendiamide 39.35% SG insecticides chlorantraniliprole 18.5% SC found most effective than all other treatment on spraying thrice followed by emamectin benzoate 5% SG >spinatoram 11.7% SC >spinosad 45% SC >flubendiamide 39.35% SG > indoxacarb 14.5% SC > cyantraniliprole 10.26% OD.

Ali and Zedan (2018) reported that The average reduction percentages for insecticides alone against leaf miner after first spray were 68.9, 64.9, 56.2, 50.5, 47.3 and 44.3% for emamectin benzoate, indoxacarb, spinosad, imidacloprid, lambda-cyhalothrin and acetamiprid, respectively. The average reduction after second spray for the above mentioned insecticides were 80.6, 75.2, 74.9, 72.7, 67.6 and 54.3%. Ali, R. A. E., &Zedan, O. A. A. (2018).

Floret *et al.* (2019) reported that the decreasing order of efficacy against L. trifolii was chlorantraniliprole 9.3% w/w + lambdacyhalothrin 4.6% w/w 150 ZC > novaluron 5.25% + indoxacarb 4.5% SC >chlorantraniliprole 18.5% SC >lambdacyhalothrin 4.9% CS against L. trifolii. chlorantraniliprole 9.3% w/w + lambdacyhalothrin 4.6% w/w 150 ZC treatments resulted in significantly higher yield as compared to untreated check.

Patel and Mehta (2019) reported that maximum population reduction (77.05%) of leaf miner was observed with treatment flubendiamide (0.014%) followed by emamectin benzoate (0.002%), dichlorvos (0.02%), dimethoate (0.03%), followed by thiamethoxam (0.01%) reduced leaf miner population by 75.91%, 74.77%, 32.79%, and 35.96% respectively.

Kachave *et al.* (2020) reported that the Lowest mean larval population of leaf miner was observed in Emamectin benzoate 5 SG @ 200 g/ha (0.33 larva/plant) followed by Spinosad 45 SC @ 100 L/ha (0.44 larva/plant) and Indoxacarb 14.5 SC @ 200 L/ha (0.52 larva/plant, While The highest fruit yield of tomato was observed by Flubendiamide 20 WG @ 100 g/ha (59.72 q/ha). Kachave, D. R., Sonkamble, M. M., & Patil, S. K. (2020).

Kotak *et al.* (2020) reported that on evaluating insecticides namely, profenofos + cypermethrin 0.044%, chlorantraniliprole 0.006%, Deltamethrin + triazophos 0.036%, emamectin benzoate 0.0025%, thiodicarb 0.15%, diafenthiuron 0.05%, and dimethoate 0.03% against the leaf miner on tomato, The treatment of profenofos + cypermethrin 44 EC (0.044%) was found to be more effective for the control of leaf miner and the highest yield of 21722.22 kg/ha.

Kumar *et al*. (2020) reported that the LC50 ranged from 0.27 to 2.0 ppm for chlorantraniliprole, from 1.01 to 2.25 ppm for flubendiamide, from 0.32 to 0.90 ppm for spinosad, from 0.98 to 6.52 ppm for imidacloprid, from 0.82 to 6.38 ppm for indoxacarb, from 967.32 to 1911.98 ppm, for chlorpyriphos. Results showed that chlorantraniliprole and spinosad were the most toxic insecticides as compared to other chemicals and showed homogenous response to them.

Taleh *et al.* (2020) reported that on testing the The toxicity of acetamiprid, eforia (thiamethoxam + lambda-cyhalothrin) and hexaflumuron alone and in mixture with emamectin benzoate against 4 th -instars of against the 4^{th} instar of leaf miner, it was observed that . The highest toxicity was found for emamectin benzoate after 72 h (LC50 = 0.48 mg a.i./l), followed by acetamiprid (LC50 = 46.94 mg a.i./l), eforia (LC50 = 156.24 mg a.i/l) and hexaflumuron (LC50 = 670.32 mg a.i/l). however the mixtures of eforia and acetamiprid with emamectin benzoate was more effective against 4 th -instars compared to emamectin benzoate alone and the control.

2.2.2 Bio-efficacy of Insecticides against Whitefly on Tomato

Muhammad *et al.* (2004) reported that on testing seven insecticides, viz. Mospilan 20SP (acetamaprid), Confidor 200SL (Imidacloprid), Talstar 10EC (bifenthrin), Advantage 20EC (carbosulfan), Actara 25WG (thiomethoxam), Polo 500EC (diafenthiuron) and Tamaron 60SL (methamedophos) for their efficacy against sucking it was found that Against whitefly the most effective insecticides were Mospilan and Actara.

Kalawate and Dethe (2005) reported that The acetamiprid 20 SP @ 40 and 30 g ai/ha, followed by acetamiprid 20 SP @ 20 g ai/ha were found to be most effective in controlling the sucking pests (jassids, whitefly and aphid) population with maximum Cost: Benefit ratio (1:3.93 and 1:3.90).

Raghuraman and Gupta (2005) reported that acetamiprid 48 g a.i/.ha and imidacloprid 100 g a.i./ha were the most effective treatment against *B. tabaci* and increase in yield is also reported with their treatment.

Bairwa *et al* (2006) reported that acephate 75 WP (0.037%), imidacloprid 17.8 SL, whitefly, *Bemisiatabaci*(Genn).

Sarangdevot *et al.* (2006) reported that the chemical combination of cypermethrin and organophosphorus compound when sprayed twice showed better efficacy against whitefly on tomato.

Prabhatkumar and Poehling (2007) reported that on testing spinosad and abamectin against different life stages of whitefly, *Bemisiatabaci*Abamectin caused 100% immature mortality within 24 hrs of treatment. Nymphal stageswith the first instars being most susceptible. It also reduced egg deposition.

Solangi and Lohar (2007) reported that in a experiment conducted to evaluate the efficacy of Confidor [imidacloprid], Sundaphos [methamediphos], Polo [diafenthiuron] and Mospilan [acetamprid]. against the different sucking pests, it was found that Confidor was more effective compared to Sundaphos, Polo and Mospilan.

Due to confidor whitefly population reduced from 8.31 $plant^{-1}$ to 1.18 $plant^{-1}$ (pre treatment).

Biswas and Chatterjee (2008) reported that compared these to conventional insecticides, viz., monocrotophos, acephate, methyl demeton, dimethoate and phosphamidon it was found that the efficacy of two new insecticides, thiamethoxam (35 g a.i./ha) and acetamiprid (30 g a.i./ha) were the highly effective against the sucking pests.

Dhanalakshmi and Mallapur (2008) reported that imidacloprid 200 SL at 5.0 ml/litre and acetamiprid 20 SP at 0.2 g/litre were the highly effective against sucking pests along with Spinosad 45 SC at 0.1 ml/liter.

Gosalwad *et al.* (2008) reported imidacloprid 17.8 SL at 40 g a.i./ha was more effective than imidacloprid 17.8 SL at 20 g a.i./ha and acetamiprid 20 SP at 40 g a.i./ha in the management of sucking pests, such as jassids, aphids, and whiteflies.

Yasmin *et al.* (2009) performed a trial to observe the effectiveness of Imidacloprid and Thiamethoxam on the population of Jassids and Whiteflies and their effects on the infestation of viruses in okra. They mentioned that the minimum mean population of Jassid (1.33) and whitefly (1.86) was shown in Imidacloprid treated checks, followed by Thiamethoxam. In both chemicals, the percentage reduction of the Whiteflies and Jassids population over-regulation was exceeded by 50 %. In Imidacloprid treated plots, the number of plants and leaves infected with okra yellow vein clearing mosaic virus (OkYVCMV) was considerably low.

Pandey *et al*. (2010) reported that the most effective treatment for whitefly and thrips was Imidacloprid 17.8 SL (0.003 %), followed by Spinosad 48 EC (0.02 %), Malathion 50 EC (0.05 %), Acephate 75 SP (0.1 %) and Methyl-demeton 25EC (0.025 %) .

Patel *et al*. (2010) documented successful suppression of whitefly population by Imidacloprid 200 SL and Thiamethoxam 25 WG. In collaboration with other insecticides, dimethoates and malathion have also proven potent in reducing the whiteflies.

Ali *et al*. (2011) reported that the highest mortality of whiteflies of about 86.6% caused by 250 gm/ac dose of sharp 20 SL (Acetamiprid 20% SP) lowest mortality (85.3%) is observed with the treatment of talent 48 SC (imidacloprid 200g/l) @ 125 ml/acre dose.

Shivanna *et al.* (2011) reported that on testing dimethoate 30 EC, triazophos 40 EC, fenpropathrin 30 EC, imidacloprid 17.8 SL, spinosad 45 SC, eco neem 3% against sucking insect pest *viz.,* leafhopper, aphid, whitefly and thrips and their effect is compared with the standard check of acetamiprid 20 SP. In this experiment it was recorded that Acetamiprid. Dimethoate and imidacloprid were most effective against aphid while Dimethoate and fenpropathrin alone can control leafhopper, whitefly and thrips effectively.

Raghuraman and Birah (2011) measured Imidacloprid's efficacy against sucking pest complex under field conditions. Imidacloprid 17.8 % SL @ 80 g a.i ha^{-1} increased the total yield by greatly decreased the populations of whiteflies and leafhoppers. Imidacloprid (40 g a.i ha^{-1}) recorded 455.5 kg ha^{-1} and 1055.5 kg ha^{-1} whereas, Imidacloprid (80 g a.i ha^{-1}) gave the maximum production of 508.8 kg ha^{-1} and 1188.8 kg ha^{-1} across 2004 and 2005 respectively.

Ali *et al.* (2011) reported the peak mortality rates of *B. tabaci*occurred by Sharp 20 SL @ 250 gm $acre^{-1}$ which was around 86.6 % while Talent 48 SC @ 125 ml $acre^{-1}$ on potato was the minimum (85.3 %).

Al-Kherb (2011) recorded the whiteflies on tomato plants are substantially decreased by the neonicotinoid insecticides, while Acetamiprid 20 SP minimized the adults by 63.6 % on an average; however, Imidacloprid 20 SL reduced by 71.5 % and Thiamethoxam 25 WG was the most effective compound (82% reduction).

Sinha and Vishwanath (2011) observed that bifenthrin @ 25g a.i./ha, fipronil @50g a.i./ha, indoxacarb @70g a.i./ha insecticide mixture, profenophos+

cypermethrin @ 440 g a.i./ha were effective in managing the population of sucking pests viz., leafhopper and whitefly.

Mann *et al.* (2012) stated that Spiromesifen could be a valuable resource for the reduction of *B. tabaci*ingrown vegetables. Spiromesifen compounds have a unique mode of action which inhibits lipid metabolism, leading to decreased in adult fecundity and reduce insect growth. Mortality of whitefly occurs by both ingestion and contact. It was also recorded that immature stages of the whitefly population were disrupted faster than adults, and the Spiromesifen-treated nymphs didn't moult accurately and failed to achieve adulthood **(Nauen *et al.*, 2005)**.

Kalyan *et al.* (2012) reported that spinosad, imidacloprid, acephate and fipronil effectively control the population of jassids and whiteflies and gave significantly higher yield compared to untreated plots and standard check insecticides. Six molecules i.e.acephate 75 SP @ 500 a.i./ha, triazophos 40 EC @ 600 a.i./ha, fipronil 5 SC @ 40 a.i./ha, imidacloprid 70 WG @ 50 a.i./ha, spinosad 45 SC @ 75 a.i./ha and dimethoate 30 EC @ 300 a.i./ha were evaluated.

Mandal (2012) reported that cyantraniliprole 10% OD @ 90 and 105 g *a.i.*ha^{-1} was highly effective in controlling the fruit borer, *H. armigera* , aphid, *Aphis gossypii* and white fly, *Bemisiatabaci*in tomato crop. They were tested along with the standard checks of imidacloprid 17.8% SL and fipronil 5% SC and the results showed that they were comparatively more than standard checks.

Quisar *et al.* (2012) reported that Crown (imidacloprid) 25% WP, Actara (thiomethoxam) 24 WG and Asault (acetamiprid) 20% SL) were very effective against jassid and whitefly and caused significant reduction in their population. They were effective even till 7 days after the spraying and not affected by the type of cultivar.

Ghosal and Chatterjee (2013) reported that imidacloprid 17.8 SL @ 50 g a.i./ha, was the the best treatment against whiteflies infestation and offered maximum reduction of whiteflies (83.15%) as well as highest marketable fruit yield (146.50

q/ha). Thiamethoxam 25 WG also provided similar levels of protection as that of imidacloprid 17.8 SL.

Govindappa *et al.* (2013) reported that Among the tested insecticides , cyantraniliprole 10 OD at 60 and 75 g *a.i*.ha^{-1} have rapid knockdown effect and caused 100 % mortality at 2nd day after treatments and also recorded least leaf curl virus transmission (10 and 5 %) respectively. cyantraniliprole 10 OD at 45 g *a.i*.ha^{-1} was found to be least effective against white fly.

Parmar *et al.* (2013) reported that after evaluating bioefficacy of deltamethrin (0.0028 %), alphamethrin (0.01 %), deltamethrin + triazophos (0.036 %), ethion + cypermethrin (0.045 %), profenophos (0.1 %), imidacloprid (0.0053 %) and acetamiprid (0.02 %) it was revealed that the treatment of deltamethrin + triazophos (0.036 %) proved effective against *B. tabaci*and stood third in rank after imidacloprid and acetamiprid.

Civolani *et al.* (2014) reported that cyantraniliprole treated tomato plants were safe from whitefly infestation as the *B. tabaci*biotype Q adults avoided to feed from their phloem.

Das and Islam (2014) stated that imidacloprid, fipronil and buprofezin proved to be the superior against whiteflies followed by thiamethoxam + emamectin benzoate.

Kumar and Singh (2014) reported that the nymphal mortality of whiteflies were in the range of 30 to 96, 28 to 92, 22 to 92, 32 to 88, 26 to 86 and 28 to 88 % was found in the spiromesifen, cyantraniliprole, diafenthiuron, chlorfenapyr, buprofezin and oxy-demeton methyl and two botanicals azadirachtin 1500 ppm and aqueous dharek drupe extract treated plots . On the basis of LC50 and LC90 values, spiromesifen was found to be most effective followed by cyantrabniliprole.

Kwon and Youn (2014) reported that cyantraniliprole act as an anti-feeding agent for whitefly *B. tabaci*. He analysed cyantraniliprole against whitefly, *Bemisiatabaci*with an Electrical Penetration Graph (EPG). He reported that cyantraniliprole was very effective for the management of whitefly infestation on tomato.

Patel *et al.* (2014) reported that on evaluation of cyantraniliprole 10% OD @ 45, 60, 75, 90 and 105 g *a.i.*/ ha along with indoxacarb 14.5 SC @ 75 g.*a.i.*/ha and endosulfan 35 EC @ 350 g.*a.i.*/ha as standard checks it was found that The two higher doses of cyantraniliprole 10% OD i.e. 90 and 105 g a.i./ha were most effective against whitefly, *Bemisiatabaci*, aphid, *Aphis gossypii*, andthrips, *Thrips tabaci*. He recommended cyantraniliprole 10% OD @ 90 g a.i.ha- 1 for effective management of sucking pests.

Roditakis *et al.* (2014) reported Flonicamid significantly minimized the nymphs of Whiteflies by longer the growth time (DT50) of the treated population by 7.2 days. Moreover, it is not safe to *Eretmoceruseremicus*and toxic for *Nesidiocoris tenuis* adults and nymphs. Flonicamid also reduces the fecundity of *A. swirskii*by 36% and decrease the feeding capacity of *N. tenuis* and *A. swirskii*by 28 and 37 per cent respectively.

Yadav and Raghuraman (2014) evaluated the bio-efficacy of some newer insecticides viz; Buprofezin 25% SC @ 800 g a.i ha^{-1}, (MAIBA - 01) Buprofezin 15% + Acephate 35% WP @ 1250g a.i ha^{-1} (MAIBA - 01) Buprofezin 15%+Acephate 35% WP @ 1500 g a.i ha^{-1}, Imidacloprid 17.8% SL@ 125g a.i ha^{-1}, Acephate 75 SP @1000 g a.i ha^{-1}, Fipronil 80 WG @100g a.i ha^{-1} against whiteflies in brinjal and recorded the overall efficacy of different treatment over control of % decrease in pest population over untreated check and yield response of the crop was in the order of MAIBA - 01 @ 1500 g a.i ha^{-1} > MAIBA - 01 @ 1250 g a.i ha^{-1} > Buprofezin-25 SC >Acephate 75 SP > Imidacloprid 17.8 SL > Fipronil 80 WG.

Raghuvanshi *et al.* (2014) reported that among the eight insecticides namely, triazophos, lambda cyhalothrin, profenofos, indoxacarb, thiamethoxam, dimethoate, emamectin benzoate and cypermethrin it was found that Thiamathoxam was found most effective against whitefly followed by indoxacarb and emamectin benzoate.

Vemuri *et al.* (2014) reported that flubendiamide at the rate of 60 g a.i./ha was found to be most effective treatments against white flies (*Bemisiatabaci*) among the tested insecticides viz., bifenthrin 10 EC at 80 g a.i. ha^{-1}, fipronil 5 SC at 500 g a.i. ha^{-1}, flubendiamide 480 SC at 60 g a.i. ha^{-1}, quinalphos 25 EC at 350 g a.i. ha^{-1}, profenofos 50 EC at 400 g a.i. ha^{-1} and beta-cyfluthrin 25 SC at 18.75 g a.i. ha^{-1}.

Yadav *et al.* (2015) reported that dimethoate (0.03%),imidacloprid (0.005 %) and thiamethoxam (0.025 %) were most effective against the white flies and other sucking pests, The acephate (0.037 %), profenophos (0.05 %) and lambda -cyhalothrin (0.008%) were moderately active while novaluron (0.02 %), diflubenzuron (0.05 %), NSKE (5.0 %) and *Metarrhiziumanisopliae*(2 x107 spores l^{-1}) were least effective.

Choi *et al.* (2016) reported that on evaluating four insecticides for control of white flies *Bemisiatabaci*adults in tomato the percentage mortality of white fly adults was observed as dinotefuran SG 50% - 80%, cyantraniliprole – 51%, pyridaben – 12.4% and clothianidin – 11%. dinotefuran SG 50% above 200 ppm caused the maximum reduction of white fly population i.e. 88.4%. The effect of dinotefuran SG 50% was observed for up to 9 days.

Pandey (2016) reported that on testing insecticides namely, Chlorantraniliprole 20SC @ 30g a.i/ha, emamectin benzoate 5SG @ 12g *a.i.*/ha, flubendiamide 48SC @ 55 g a.i.ha, bifenthrin 10EC @ 25g *a.i.*/ha, deltamethrin 2.8EC 15g a.i./ha and lamda-cyhalotrin 5EC @ 15g 13 *a.i.*/ha against the pest complex of okra it was found that Flubendiamide and bifenthrin was most effective against whitefly with the lowest recorded population of 4.24 and 11.48 per plant, respectively.

Pawar *et al.* (2016) reported that Spinosad 45 SC @ 125 g was the most successful against the white fly and least population of whiteflies i.e. 0.84-2.27 per 3 leaves were observed with this treatment. Other insecticides evaluated in these experiments were Chlorantraniliprole 18.5 SC, Flubendamide 39.35 SC @ 60 g a.i ha^{-1} and Novaluron 10 EC @ 75 g a.i ha^{-1}.

Kar A. (2017) reported that Imidacloprid 17.8 % SL @ 175 ml ha^{-1}, sprayed thrice resulted in the highest reduction of whitefly population and higher fruit yield of tomato followed by the Imidacloprid 17.8 % SL @ 150 ml ha^{-1}. Different dosages of imidacloprid were observed with the single dose of thiamethoxam.

Karthik *et al.* (2017) reported that cyantraniliprole 10% OD at 90 g *a.i.*ha^{-1} reduced the population of sucking pests when applied twice. It is also found that Cyantraniliprole 10% OD treatments @ 90, 180 and 320 g.*a.i.*ha^{-1} concentrations does not caused any phytotoxicity.

Kumar *et al.* (2017) reported that the highest fruit yield (127.05 qha^{-1}) and lowest population of whitefly was found with the thiamethoxam 25 WG @ 100 gha^{-1} treated plots followed by imidacloprid 17.8 SL @ 100 $mlha^{-1}$. But cost benefit ratio (1:12.90) was highest with imidacloprid. Insecticides evaluated in these experiments were thiamethoxam 25 WG, imidacloprid 17.8 SL, acephate 20 SP, fipronil 5 SC, thiacloprid 240 SC anddimethoate 30 EC.

Singh *et al*. (2017) reported that in reducing infestation of whitefly emamectin benzoate 5 SG was found to be most effectiveEmamectin benzoate 5 SG was applied at the rate of 8 g a.i./ha at the time of sowing and hoeing has given the highest cost benefit ratio (1:2.15) followed by Phorate 10 G applied at the time of Hoeing (1:1.37).

Bambhaniya *et al.* (2018) reported that in a experiment conducted at anandgujrat in the year 2017 imidacloprid 0.005 %, difenthiuron 0.05%, acetamiprid 0.008 %and thiacloprid 0.024 % were found to be the most effective insecticides against whitefly *Bemisiatabbaci*. The highest cost benefit ratio (1:77.51) was obtained from the treatment of imidacloprid 0.005% followed by acetamiprid 0.008% (1:74.83), dimethoate 0.03% (1:74.06) and flonicamid 0.015% (1:26.80).

Chaitanya *et al.* (2018) reported that the Imidacloprid (1.52 whiteflies/3leaves) was the most effective treatment against whitefly Bemisiatabaci (Genn.), followed by Thiamethoxam (2.30 whiteflies/3leaves), Acetamiprid (2.71 whiteflies/3leaves) Dimethoate (3.05 whiteflies/3leaves), lambdacyhalothrin (3.59

whiteflies/3leaves), and Neem oil (4.32 whiteflies/3leaves). While whileNske 5% (5.88 whiteflies/3leaves) is least effective among all the treatments.

Jahanzaib *et al.* (2018) reported that on evaluating the bio efficacy of insecticides namely, Acetamaprid @ 125ml/acre, Imidacloprid @ 250 ml/acre, Diafenthiuron @ 200ml/acre, and plant extracts of Neem 5ml/L, Garlic 5ml/L and Onion 5ml/L against the whitefly Bemisiatabaci (Genn.), it was found that among the insecticides, acetamaprid was most effective and neem among plant extracts was most effective for controlling whitefly population.

Kumar (2018) reported that that the root treatment done with Imidaclorprid70 WS solution @ 3 g/L of water for 30 minutes followed by one spray with Imidaclorprid 17.8 SL@ 0.3 ml/L and second spray with Dimethoate 30 EC @1.5ml/L water was very effective in managing whitefly infestation in tomato and showed no or mininmum damage to natural enemies.

Meghana *et al.* (2018) reported that flonicamid 50 WG, dinotefuran 20 SG and diafenthiuron 50 WP found highly effective against whiteflies and the whitefly incidence was nil in all these three treatments at 3 DAS, followed by acetamiprid 20 SP, thiamethoxam 25 WG and fipronil 5 SC.which were found superior and on par with each other with the white fly population of (0.07, 0.11, 0.11 whiteflies / 3 leaves).

Patel *et al.* (2019) reported that Thiacloprid @ 60 g a.i./ha treatment reduced the highest population of whitefy (83%) followed by Triazophos @ 320 g a.i. /ha with a reduction of 82% percent. Other insecticides evaluated for efficacy against whitefly with the above two were Indoxacarb 15.8% EC, Profenophos 50% EC, Flubendiamide 39.35% SC, Chlorantraniliprole 18.5% SC, Betacyfluthrin 8.49%+ Imidacloprid 19.81% 300 OD and Thiamethoxam 12.6%+ Lambda cyhalothrin 9.5% ZC.

Dake *et al.* (2019) reported that 14 days after first and second spray the whitefly population is recorded as 0.64 and 0.87 per leaf from Imidacloprid 0.003%, spinosad 0.007 per cent (1.02 and 1.07 whiteflies per leaf), indoxacarb 0.005 per cent

(1.07 and 1.10 whiteflies per leaf) and chlorantraniliprole 0.005 per cent (1.20 and 1.30 whiteflies per leaf), Fenpropathrin 0.01 per cent (1.31 and 1.42 whiteflies per leaf), emamectin benzoate 0.002 per cent (1.36 and 1.29 whiteflies per leaf) and flubendiamide 0.007 per cent (1.43 and 1.20 whiteflies per leaf).

Jat *et al.* (2020) reported that acetamiprid 20 SP was most effective as it recorded the maximum population reduction with 65.66%, in whitefly *Bemisiatabaci* in a experiment conducted at , MPUAT, Udaipur with the treatments as acephate 75 SP, acetamiprid 20 SP, diafenthiuron 30 WP, spiromesifen 22.9 SC, Beauveria bassiana and neem oil (1%) tested against whitefly and mealybug.

Sharma and Kumar (2020) reported that on testing seven treatments viz., T1: Indoxacarb 4.5 SC 0.005%; T2: Dimethoate 30 EC 0.03%; T3: Lambda-cyhalothrin 5 EC 0.003%; T4: Spiromesifen 22.9 SC 0.028%; T5: Quinalphos 25 EC 0.05%; T6: Thiamethoxam 25 WG 0.008% and T7 control, The efficacy orderrecorded in descending order was: thiamethoxam 25 WG 0.008% >spiromesifen 22.9 SC 0.028% > dimethoate 30 EC 0.03% > indoxacarb 14.5 SC 0.005% > lambda-cyhalothrin 5 EC 0.03% > quinalphos 25 EC 0.05% > control.

Thorat *et al.* (2020) reported that Lowest population of *Bemisiatabbaci* (2.18 adults/leaf) was recorded with treatment of imidacloprid 17.8 SC @ 0.005% (2.8 ml/10 L of water) followed by 2.22 adults/leaf with treatment of dimethoate 30 EC @ 0.03% (10 ml/10 L of water).

2.2.3 Bio-efficacy of Insecticides against Fruit borer on Tomato

Dandale *et al.* (2000) reported that the treatment of spinosad 48 % SC formulation at 50 and 75 g a.i./ha effectively controlled *H. armigera* up to 14th days after spray and gave higher yield.

Hadapad *et al.* (2001) reported that tomato fruit borer *H. armigera* larvae were susceptible to novaluron although lufenuron was more effective in laboratory experiments.

Chiranjeevi *et al* (2002) reported that the efficacy of beta-cyfluthrin at 2.5 or 8.5 g a,i./ha, Rimon at 50 or* 75 g a.i/ha, profenophos at 750 or 1000 g a.i./ha, nuclear polyhdrosis virus (NPV) at 300 POB/ha, NPV + endosulfan at 300/700 g a.i7ha and endosulfan at 700 g a.i./ha against the tomato fruit borer *(H. armigera)* resulted in a lower Suit borer incidence and higher fruit yield compared to the control.

Ramesh (2003) reported that the bio efficacy of cypermethrin 25 EC at 0.01 per cent was excellent against tomato fruit borer, followed by spray treatment of @ 0.0015 % spinosad 2.5 % EC in recorded significantly lower fruit infestation (9.06 %) on tomato.

Udikeri *et al.* (2004) reported that lowest larval *(H. armigera)* population was noticed in emamectinbenzoaten 5 SG used at 11 g a.i./haand was found at par with present day promising insecticide spinosad 48 SC@ 50 g a.i./ha and indoxacarb 15 SC 75 g a.i/ha.

Ameta and Bunker (2007) reported that in a experiment conducted to evaluate the relative efficacy of flubendiamide (24, 38 and 48 g a.i. /ha) along with indoxacarb (75 g a.i./ha) and spinosad (75 g a.i./ha), it is observed that all three insecticides were superior to untreated control in reducing *H. armigera* infesting tomato.

Hussain and Bilal (2007) reported that Imidacloprid at 0.03 % was most effective against H. *armigera* on tomato at Srinagar, followed by deltamethrin and fluvalinate. Imidacloprid yielded consequent higher yield (>78%) over control and prevented the loss of yield by 46 %.

Razaq *et al.* (2007) reported that abamectin was more effective against *H. armigera* while fenpropathrin, cypermethrin and fenvalerate also had similar result. He also suggested that the rotational use of spinosad, abamectin and indoxacarb will be the better combination for resistance management.

Kubendran *et al.* (2008) reported that flubendiamide 480 SC @ 125 m/ha and emamectin benzoate 5 SG @ 220 g/ha recorded lowest population of Fruit borer *Helicoverpa armigera* Hubner in tomato crop.

Kuttalam *et al.* (2008) reported that against fruit borer *H. armigera* Hub., Flubendamide 480 SC at 48 g a.i./ha recorded lowest population than indoxacarb 14.5 SC, spinosad 2.5 SC and flubendiamide 480 SC at 24, and 36 g a.i./ha dosage.

Mishra (2008) reported that rynaxypyr (Chlorantraniliprole) 20% SC @ 40 and 50 g a.i./ha gave 95-97 and 87-90% reduction in fruit damage which was effective than flubendamide 480 SC treated plots. Significantly higher yield also observed in plot treated with rynaxypyr (Chlorantraniliprole) 20 SC @ 40 and 50 g a.i./ha.

Kumar and Shivaraju (2009) reported that on evaluating insecticides, beta cyfluthrin 9% + imidacloprid 21% 300 OD @ 18+42 g a.i./ha, monocrotophos 36 SL @ 450 a.i./ha, Beta cyfluthrin 2.5 SC @ 18 g a.i./ha and lambdacyhalothrin 5 EC + Thiamethoxam 25 EC @15.62 + 31.25 g a.i./ha it recorded that mean larval population reduction of *Helicoverpa armigera* was 75.95% , 68.67%, 68.64%, and 68.53% respectively.

Nishantha *et al*. (2009) reported that Chlorantraniliprole @ 40 g *a.i*./ha had reported that lowest damage by *H. armigera* followed by chlorantraniliprole @ 30 g a.i.ha^{-1}. In this experiment bio-efficacy of chlorantraniliprole 18.5%SC @ 10, 20, 30 and 40 g ai/ha was evaluated against standard checks of HaNPV125 LEha^{-1} + endosulfan @ 175 g *a.i*.ha^{-1}+ dimethoate @ 170 g *a.i*.ha^{-1} for management of *H. armigera* .

Temple *et al*. (2009) reported that novel insecticide anthranilic diamide class, chlorantraniliprole highly toxic to *H. armigera* and other several lepidopteran pests.

Dhaka *et al.* (2010) reported thatIndoxacarb has the minimum fruit damage of 2.53 and 2.83 and the highest yield of 39.45 and 38.85 q ha^{-1} among the several new insecticidal formulations, namely Novaluron 10 EC, Indoxacarb 14.5 SC., Bifenthrin 10 EC, Lambda-cyhalothrin 5 EC, and biopesticides, namely HaNPV, Bt. var. *kurstaki*and Neemarin tested against *H. armigera* .

Mohapatra *et al*. (2011) reported that flubendiamide was very effective in controlling the fruit borer (*H. armigera)*.Flubendiamide completely dissipated from tomato within 20 days and not detected in tomato fruits at any time during the study period.

Babar *et al.* (2012) reported that on evaluation of ten insecticides emamectin benzoate 0.0025 %, thiodicarb 0.075 %, indoxacarb 0.007 %, spinosad 0.0135 %, novaluron 0.01 %, lufenuron 0.005 %, flubendiamide 0.01 %, Chloranthraniliprole 1.06 % and endosulfan 0.07 % against *H. armigera* it is observed that Flubendamide, emamectin, Chloranthraniliprole and spinosad recorded more than 90 % larval mortality while Flubendamide and thiodicarb recorded more than 70 % egg mortality.

Ghosal *et al*. (2012) reported that in a experiment to observe the bioefficacy of some insecticides against the *H.armigera* it is concluded that the decreasing order of of their effectiveness was - Chloranthraniliprole 18.5% SC @ 40 g a.i./ha >spinosad 45% SC @ 60 g a.i./ha>flubendiamide 20% WG @ 30 g a.i./ha > and indoxacarb 14.5 SC @ 75 g a.i./ha. The percent mortality of fruit borer larvae caused by them is 98.04%, 88.03%, 87.96%, 80.21% respectively in the same order.

Mandal (2012) reported that cyantraniliprole 10% OD @ 90 and 105 g *a.i.*ha^{-1} dosage were more effective against the fruit borer *H.armigera* than the standard checks of imidacloprid 17.8% SL and fipronil 5% SC. Highest yield is also obtained with the same treatments.

Patel *et al.* (2012) reported that on evaluating Four different doses of cyantraniliprole 10 OD @ 40, 50, 60 and 70 g *a.i*.ha^{-1} with standard checks of methomyl 40 SP,Ethion +Cypermethrin 55 EC, spinosad 45 SC, it is observed that 60 and 70 g a.i.ha^{-1} dosage of of cyantraniliprole 10OD reduced the maximum fruit damage.

Hanafy *et al.* (2013) reported that chlorantraniliprole and emamectin benzoate was effective in controlling the fruit borer *H.armigera* from damaging the tomato fruits.

Hanumantharaya *et al.* (2013) reported that mean fruit borer population in different tomato plots treated with flubendiamide 24 SC, chlorantraniliprole 20 EC, profenophos 50 EC, and spinosad 45 EC was 0.10 larva/ plant, 0.14 larva/plant, 0.20 larvae/plant and 0.30 larva/plant respectively. Flubendiamide 24 SC treatment was reported as most effective against the *H.armigera* damage.

Jat and Ameta (2013) reported that flubendiamide 480 SC @ 200 mL/ha caused highest mortality to the *H.armigera* larvae (89.94%). Mortality percent due to other evaluated insecticides were reported as - spinosad 45 SC @ 200 ml/ha (74.67%), HaNPV @250 LE/ha (74.10%) Beta-cyfluthrin 2.5 SC @ 750 mL/ ha (67.37%) and BT@ 1.5 kg/ha(60.03%).

Carneiro *et al.* (2014) reported that Flubendiamide, acephate, methomyl, *Bacillus thuringiensis*, dimethoate, chlorantraniliprole and fipronil had effective to control of *H. armigera* . While chlorpyrifos and spinosad were effective against third instar fruit borerlarvae. He evaluated different insecticides of different pesticide groups.

Chavan *et al.* (2014) reported that the decreasing order of effectiveness of different tested insecticides was Chloranthraniliprole 20 SC(3.5%) >Flubendiamide 48 SC (4.8%)>, Emamectin benzoate 5 SG (6.05%)> and Profenophos (13.9%) in terms of percent damage due to *H.armigera* .

Gadhiya *et al*. (2014) reported that among the nine insecticides emamectin benzoate 5 WG @ 0.002%,thiodicarb 75 WP @ 0.075%, indoxacarb 14.5 SC @ 1.07 %, spinosad 45 SC @0.018%, novaluron 10 EC @ 0.01%, lufeneuron 5 EC @ 0.005%, flubendiamide 480 SC @ 0.014%, chlorantraniliprole 20 SC @ 0.006% and metaflumizone 22 SC@ 0.044% evaluated against *Helicoverpa armigera* (Hubner) and *Spodoptera litura*(Fabricius) and found that chlorantraniliprole (0.006%), spinosad (0.018%) and emamectin benzoate (0.002%) were most effective.

Roopa and Kumar (2014) reported that on evaluation of eleven insecticides *viz*. Spinosad 45 SC , Chlorantraniliprole 18.5 SC, Emamectin benzoate 5 SG, Lambda-cyhalothrin 5 EC, Fipronil 5 SL, Novaluron 10 EC, Indoxacarb 14.5 SC , Thiamethoxam 25 WG, Dimethoate 30 EC, Imidacloprid 17.8 SL and Quinalphos 25

EC, lowest number of larvae (1.19 plant^{-1}) was observed in the spinosad 45 SC treated plots and highest number of larvae (1.5/plant) was observed in the plots treated with Imidacloprid 17.8 SL.

Abbas *et al.* (2015) reported that Chlorantraniliprole + Thiamethoxam and Spinetoram recorded the mean highest mortality, i.e. 89.3 per cent and 85.09 per cent, respectively. While Chlorantraniliprole, Flubendiamide and Indoxacarb were also found effective indvidually against the fruit borer infestation.

Ambule *et al.* (2015) reported that plots treated with Flubendiamide 0.004 % recoreded the lowest larvae (0.43 larva plant^{-1}), and 10.09 % weight-based damaged fruits followed by Chlorantraniliprole (0.58 larvae per plant and 10.62 per cent fruit infestation and 0.0068% Spinosad (0.68 larvae per plant and 11.34 per cent fruit damage). Same pattern is also observed in terms of fruit yield i.e. 25.21, 24.8 and 22.2 t ha^{-1} respectively.

Dhar *et al*. (2015) reported that out of the seven insecticidal treatments, viz. imidacloprid 17.8% SL,Spinosad 45% SC, Profenophos 50% EC (500 g a.i./ha), Chlorpyriphos 20% EC(200 ga.i./ha) , Deltamethrin 2.8% EC (10g a.i./ha), Lambda Cyhalothrin 5%EC (15 g a.i./ha), Cypermethrin 10 % EC(60 g a.i./ha), Triazophos 40% EC (500ga.i./ha), evaluated against the fruit borer of tomato, single application of imidacloprid 17.8% SL followed by twiceapplications of Spinosad 45% SC was found most effective.

Kousika *et al.* (2015) reported that Pyridine 20 SC @ 60 g a.i/ha reduced the highest *H. armigera* (Hub.) population i.e. 94.60% while the other two insecticides novaluron 10 EC @ 75 g a.i/ha and Chlorantraniliprole 20 SC @ 30 g a.i/ha reduced the fruit borer population by 72.96% and 85.60% respectively.

Misra (2015) reported that on evaluation of new anthranilic diamide cyantraniliprole against the tomato fruit borer it was observed that the bio efficacy of cyantraniliprole (HGW86) 10% OD @ 90 & 105 g *a.i.*ha^{-1} reduced the maximum larval population of *H. armigera (*85.8–89.6 and 84.4–85.9% respectively). After 7 days of spraying also larval population was as low as (0.3–0.4) and (0.5) larvae per 5 plants in this treatment.

Babar *et al.* (2016) reported that among the six insecticides *viz.* spintoram12% SC, spinosad 240 SC, emamectin benzoate 5% SG, lufenuron 5% EC, chlorantraniliprole 20 SC and chlorofenapyr 36% SC. Bio insecticides spintoram 12% SC and spinosad 240 SC caused maximum mortality of fruit borer larvae and protected crop from fruit borer infestation for next seven days. While among the synthetic chemical insecticides lufenuron 5% EC proved to be most effective.

Hasan *et al*. (2016) reported that Indoxacarb reduced the *H. armigera* damage at 30, 40, 50 g a.i ha^{-1} by 35.94%, 40.57% and 48.72% respectively but these doses were less successful as compared to chlorpyriphos. Indoxacarb 75 g a.i ha^{-1} and 60 g a.i/ha treated plots reported 7.0% and 8.0 % fruit damage respectively.

Selvaraj *et al.* (2016) reported that two sprays of Cholrantraniliprole 4.3 % + Abamectin 1.7 % SC was most effective among new formulation of Cholrantraniliprole 4.3% + Abamectin 1.7% SC. Chlorantraniliprole 4.3% + Abamectin 1.7 % SC @ 24, 30, 36 and 60 g a.i ha^{-1}, Abamectin 1.9 EC @ 15 g i.e. ha^{-1}, lambda-cyhalothrin 4.9 CS @ 15 g a.i ha^{-1} and Cholrantraniliprole 18.5 %SC @30 g a.i ha^{-1} against *H. armigera* .

Singh *et al*. (2016) reported that among the different combinations of Flubendiamide 90 SC + Deltamethrin 60-150 SC evaluated against *Helicoverpa armigera* (Hubner) it was found that Flubendiamide 90 SC + Deltamethrin 60-150 SC @ 22.5 + 15 g a.i ha^{-1} was most effective followed by Flubendiamide 90 + Deltamethrin 60-150 SC @ (18+12 g ai ha^{-1}.

Kumar *et al*. (2017) reported that maximum yield (26.43 kg), minimum fruit damage (28.80%), and highest reduction of larvae (65.20%) is due to the treatment of Profenophos 50 EC @ 1000 g a.i./ ha against the fruit borer. Other insecticides used in the experiment were Bifenthrin 10 EC @ 100 g a.i./ ha, Profenophos 50 EC @ 1000 g a.i./ ha, Benzoate 5 SG @11 g a.i./ ha, Bt @ 25 g a.i./ ha, Spinosad 45 SC @ 100 g a.i./ ha.

Vivan *et al.* (2017) reported that on testing 17 insecticides of different pesticide groups against the *Helicoverpa armigera* (Hubner), Thiodicarb, chlorantraniliprole, indoxacarb, chlorpyrifos,andchlorfenapyr eliminated larvae of fruit borer completely. chlorpyrifos,andchlorfenapyr eliminated the pest within two days of application.

Javed *et al.* (2018) reported that, emamectin benzoate and indoxacarb caused the most significant reduction of fruit borers, followed by abamectin and lambda-cyhalothrin. emamectin benzoate, indoxacarb, abamectin, spinosad and lambda-cyhalothrin increased marketable fruit yield by 45, 44, 38, 25 and 18%, respectively over control plot.

Patil *et al.* (2018) reported that Among the different insecticidal treatments, significantly minimum (9.07%) fruit damage of H. armigera was recorded in treatment chlorantraniliprole 18.5 SC. Followed by spinosad 45 SC (10.99%) and indoxacarb 14.5 SC (11.53%). The ascending order of remaining insecticides was emamectin benzoate 5 SG (13.38%) <profenofos 50 EC (14.82%) < azadirachtin 10000 ppm (15.54%) < Beauveria bassiana

Safna *et al.* (2018) reported that on conducting experiment to find the find the efficacy of 6 different insecticides against the tomato fruit borer, it was noticed that the decreasing order of there bioefficacy was chlorantraniliprole 18.5 SC (13.82), spinosad (17.39), indoxacarb (21.64), lambda cyahalothrin (23.50), *B. thuriengenisis*(27.26), azadiractin (30.51) and quinalphos 25 EC (32.70) per cent fruit infestation.

Sapkal *et al.* (2018) reported that chlorantraniliprole 18.5% SC was most effective against the tomato fruit borer among the seven insecticides namely spinosad 45% SC, chlorantraniliprole 18.5% SC, emamectin benzoate 5% SC, indoxacarb 14.5% SC, cyantraniliprole 10.26% OD, spinatoram 11.7% SC and flubendiamide

39.35% SG. 1.15 WP (16.81%) <HaNPV (17.61%) <Metarhiziumanisopliae 1.15 WP (19.03%).

Usman *et al.* (2018) reported that, Comparative efficacy of synthetic insecticide Indoxacarb 150 EC was more than the of indigenous plant extracts against the *Helicoverpa armigera* Hub. It was observed that Fruit damage was lowest (on weight as well as on number basis) in Indoxacarb treated plot 10.29 % and 10.53% respectively and highest in control with 30.88% and 29.11% The maximum mean reduction (61.01%) in the larval population of *H. armigera* .

Bhanupraksh *et al.* (2019) reported that spinosad 45% SC (7.37%) treatment resulted into lowest fruit borer *Helicoverpa armigera* (Hubner) infestation in tomato followed by indoxcarb 14.5% SC (12.54%) and chlorpyrifos 20 EC (13.76%) respectively. Tomato fruit yield recorded was of spinosad 45% SC (198 q/ha) followed by indoxcarb 14.5% SC (180 q/ha) and chlorpyrifos 20 EC (169 q/ha).

Patel *et al.* (2019) reported that flubendiamide 20% WDG @ 2.5 ml treatment caused lowest larval population (0.56 larva/plant) of *Helicoverpa armigera* (Hubner) on Tomato and chlorantraniliprole 8.5% SC @ 3.0 ml, emamectin benzoate 5% SG@ 2.0 gm/10 lit, chlorfenpyre 10% SC 7.5 ml, indoxacarb 14.5% SC 5 ml, spinosad 2.5% SC 8 ml caused 0.66 larva/plant, 0.73 larva/plant, 1.13 larvae/plant, 1.20 larvae/plant, 1.39 larvae/plant respectatively.

Regupathy *et al.* (2019) reported that, chlorantraniliprole 9.3% w/w + lambdacyhalothrin 4.6% w/w 150 ZC was recorded as the most effective treatment for the control of *Helicoverpa armigera* . It was evaluated with chlorantraniliprole 9.3% w/w + lambdacyhalothrin 4.6% w/w 150 ZC, chlorantraniliprole 18.5 SC, lambda-cyhalothrin 4.9 CS, novaluron 5.25 % + indoxacarb 4.5% SC in Two sequential application of each insecticides at 30 days interval.

Thara *et al.* (2019) reported that Among all the insecticides, the lowest mean larval number and fruit damage of fruit borer, *Helicoverpa armigera* (Hub.) was noticed in Chlorantraniliprole 18.5 % SC (0.27 larvae/plant, 3.3%,) followed by

Emamectin benzoate @0.36g/L(0.65 larvae/plant, 5.8%) and flubendiamide 480 SC(0.98 larvae/plant, 7.2%) respectively. Spinosad 45 SC and cyantraniliprole 10.26 OD were statistically on par with each other and all other treatments showed significantly superior over untreated check.

Kachave *et al.* (2020) reported that minimum mean larval population of H. armigera was observed in treatment plots of Flubendiamide 20 WG @ 100 g/ha (0.54 larva/plant) followed by Spinosad 45 SC @ 100 L/ha (0.63 larva/plant), Indoxacarb 14.5 SC @ 200 L/ha (0.71 larva/plant), Novaluron 10 EC @ 375 L/ha (0.86 larva/plant), Emamectin benzoate 5 SG @ 200 g/ha (0.92 larva/plant) and Profenophos 50 EC @ 1250 L/ha (0.92 larva/plant) treated plots. The highest cost: benefit ratio was observed with Lambda cyhalothrin 5 EC @ 300 L/ha (1:12.99).

Maity *et al.* (2020) reported that On evaluating the bio efficacy of bio control agents, Beauveria bassiana (109 spores/gm), Bacillus thuringiensis (109 IU/gm), and HaNPV (109 POB/ml) with 5 insecticides viz. Emmamectin Benzoate 5 SG, Spinosad 45 SC, Flubendiamide 480 SC, Chlorantraniliprole 20 SC and Cyantraniliprole 10.26 OD against tomato fruit borer *Helicoverpa armigera* (Hubner) it is observed that Median lethal time (LT50) was estimated for Emmamectin Benzoate (8.81 hour) was observed lowest followed by Cyantraniliprole (15.09 hour), Chlorantraniliprole (35.54 hour), Flubendiamide (44.41 hour), Spinosad (44.62 hour), B. thuringiensis (83.72 hour), HaNPV (114.58 hour) and B. bassiana (154.63 hour).

Prasanna *et al.* (2020) reported that Cyclaniliprole 100 DC different dosages Viz., 30,35 and 40 g a.i./ha are evaluated with Chlorantraniliprole 18.5 SC @ 25 g a.i./ha and Novaluron 10% EC @ 75 g a.i./ha against the *Helicoverpa armigera* larval population and result showed that the treatment Cyclaniliprole 100DC @ 40 ml a.i./ha has given highest larval mortality (92.31%) followed by Cyclaniliprole 100DC @ 30 and 35 ml a.i./ha and Chlorantraniliprole 18.5 SC @ 25 g a.i. /ha (88.46%, respectively at first spray. Where in second spray, Cyclaniliprole 100DC @ 40 and 35 ml a.i./ha gave cent per cent reduction in borer population followed by Cyclaniliprole 100DC @ 30 ml a.i./ha and Chlorantraniliprole 18.5 SC @ 25 g a.i. /ha (92.31%).

Sharma and Kumar (2020) reported that Indoxacarb 14.5 SC 0.005% was proved to be most effective among the thiamethoxam 25 WG 0.008 per cent, spiromesifen 22.9 SC 0.028 per cent, Quinalphos 25 EC 0.05 per cent, lambdacyhalothrin 5 EC 0.003 per cent and dimethoate 30 EC at 0.03 per cent. Lowest larval population i. e. 0.46 /plant were found by Indoxacarb 14.5 SC 0.005% followed by lambdacyhalothrin 5 EC 0.003 per cent (0.65).

Chapter III

MATERIAL AND METHODS

The experiment was conducted to observe the seasonal incidence of some major insects pests and bio-efficacy of some newer insecticides against major insect pests of tomato crop during the winter season of 2020-21. The details of the experimental site, climatic conditions, experimental details, materials used, procedures and techniques followed during the study are described as under.

3.1 SITE AND LOCATION OF THE EXPERIMENT

The present trial was carried out on Vegetable Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

3.2 GEOGRAPHICAL SITUATION

The Vegetable Research Farm, Banaras Hindu University's Institute of Agricultural Science, Varanasi, which is located in the North-East Plain Zone of Eastern Uttar Pradesh. Varanasi is located between 25018' North latitude and 80036' East longitude, at an elevation of 80.71 metres above mean sea level. The experimental site was uniformly fertile, with even topography and uniform textural makeup.

3.3 SOIL TYPE

The farm is located at B.H.U, Varanasi, in the alluvial tract of eastern Uttar Pradesh. The drainage and irrigation systems on the field were excellent. The experimental field's soil is sandy loam with average fertility.

3.4 CLIMATIC CONDITION

Varanasi has a climate that ranges from semi-arid to sub-humid, with a moisture deficit index of 20-40. The monsoon season in this area usually starts in the third week of June and lasts until the end of September, or sometimes until the first week of October. During the winter months, rain showers are usual. The average annual rainfall in this area is around 1100 mm. The average maximum and minimum temperatures were 20°C-42°C and 9°C-28°C, respectively. The hottest months are May and June, with maximum temperatures ranging from 39°C to 42°C. The cold season lasts from November to January, with minimum temperatures ranging from 90 to 100 degrees Celsius. The average relative humidity is 68 percent, rising to 82 percent during the rainy season and dropping to 30 percent during the dry season.

3.5 TEST PLANT

Common Name	Tomato
Sc. Name	*Lycopersicon esculentum* Mill.
Family	Solanaceae
Variety	Pusa Mukti
Source	IARI

The hybrid tomato cultivar Pusa Mukti was selected for the experiment. It is released by IARI, New Delhi. These plants are semi-determinate with dark green foliage, and fruits are oblate, medium-large (80-90 g) with a light green shoulder. It is suitable for table purpose and tolerant of heat and moisture stress. It is generally a 130-140 days crop, and the average yield is 35-40 t ha^{-1}.

3.6 PREPARATION OF NURSERY BEDS AND SOWING OF SEEDS

Nursery beds were used to grow tomato seedlings. 2 x 1 m2 nursery beds were prepared by mixing well rotten farmyard manure in the soil at a rate of 10 kg per square metre. To prevent seedling mortality due to damping off, the beds were drenched with Bavistin at a rate of 15 g per 10 litres of water. Thiram was applied to seeds at a rate of 2 g per kg of seeds prior to sowing. Tomato seeds were sown @10 kg ha-1 in the nursery beds. Timely irrigation and plant protection measures were followed.

3.7 PREPARATION OF THE FIELD

The field was ploughed thrice thoroughly with a tractor-drawn cultivator and frivolously levelled after eliminating all the stubbles and weeds. Furrows of 20 cm deep, 15 cm extensive have been formed at a spacing of 10 cm. The experiment was carried out in a Randomized Block Design (RBD) with ten treatments, including untreated control, replicated thrice. With an individual plot size of 9 m^2 (3m X 3 m) with bunds all around and irrigation channels in between the replications. After this, the field is irrigated, to make the field ready for transplanting.

3.8 MANURES AND FERTILIZERS

At the time of land, preparation applies well rotten farmyard manure/compost @ 20 t ha-1 and mix well with the soil. A fertilizer dose 120:80:60 (N-P2O5-K2O) kg ha-1 was applied through Urea, Di- Ammonium Phosphate (DAP) and Muriate of Potash (MOP), respectively. Half dose of nitrogen and potash and full dose of phosphate were applied as basal before transplanting. One-fourth of nitrogen and half of potash was applied 20-30 days after planting. The remaining quantity applied before flowering.

3.9 TRANSPLANTING

The seedlings of 30 days old, vigorous and uniform size were selected and transplanted on 27th November 2019 with a spacing 60 x 40 cm^2 at a shallow depth of 2-2.5 cm. Light irrigation was applied immediately after transplanting to prevent ‘transplantation shock’ or wilting of transplanted seedlings.

3.10 IRRIGATION

A tomato needs very careful irrigation that is just sufficient water at the right time, and the size of the irrigation channel is 0.75 meter between each replication. First irrigation was done before the transplanting, and remaining irrigation is done time to time when required.

3.11 CULTURAL PRACTICES

The training of tomato plants was taken at weekly intervals starting from 15 to 20 days after transplanting. Weeding was done at regular intervals as and when needed. Total five rounds of weeding and four rounds of earthing up were followed immediately after weeding. Stalking is also done. Gap filling was done ten days later to ensure a uniform plant population in each plot.

3.12 TEST INSECTS

Tomato fruit borer (*Helicoverpa armigera*), Whitefly (*Bemisia tabaci*), Leafminer (*Liriomyza trifoli*).

3.13 SELECTION OF INSECTICIDE

The following formulations of insecticides were used in this study are listed below.

Table 3.1: List of Insecticides and their doses

S.No.	Insecticides	Formulations	Trade Name	Group of Chemicals	Dosage (g a.i. ha^{-1})
1	Tetraniliprole + Spirotetramat	120+240 g/L SC	_		30+60
2	Tetraniliprole + Spirotetramat	120+240 g/L SC	_		37.5+75
3	Tetraniliprole + Spirotetramat	120+240 g/L SC			45+90
1	Tetraniliprole	200 g/L SC	Coragen	Diamide insecticide	45
2	Spirotetramat	150 g/L OD (15.31% w/w OD)	Movento	Keta-enol insecticide	90
3	Cyantraniliprole	10.26% OD	Exirel	Diamide insecticide	90
4	Spiromesifen	22.9% SC	Oberon	Keta-enol insecticide	150

3.14 PREPARATION OF SPRAY SOLUTION

The recommended amount of solution was sprayed separately in each plot of the experiment except control plots with the help of following formula:

$$\text{Amount of formulation} = \frac{\text{Percentage of require concentration} \times \text{volume required (lit)}}{\text{Concentration of toxicant in insecticide}}$$

3.15 SPRAYING

Spraying was done at different interval of time; first spraying was done at 83 days after transplanting and the second sprays were conducted at 15 days after first spraying, respectively with the help of **knapsack sprayer.**

3.16 EXPERIMENTAL DESIGN AND LAYOUT

The experiment was put in RBD (Randomized Block Design) with eight treatments, including control, and each treatment was in three replications in a randomized manner.

3.16.1 Details of the layout

- ✓ **Crop** - Tomato
- ✓ **Variety** – Pusa Mukta
- ✓ **Design of experiment -** Randomized Block Design
- ✓ **Replications** - 3
- ✓ **Number of treatments** - 8
- ✓ **Number of plots** - 24
- ✓ **Plot size** - 3m x 2m (6m2)
- ✓ **Distance between replications** - 1m

- ✓ **Plot to plot distance** - 0.5m
- ✓ **Plant to plant distance** - 60cm
- ✓ **Row to row distance** - 40cm
- ✓ **Plant population per plot** – 25
- ✓ **Total number of plants** – 600
- ✓ **Date of Sowing-** 25/10/2020
- ✓ **Date of transplanting** - 27/11/2020

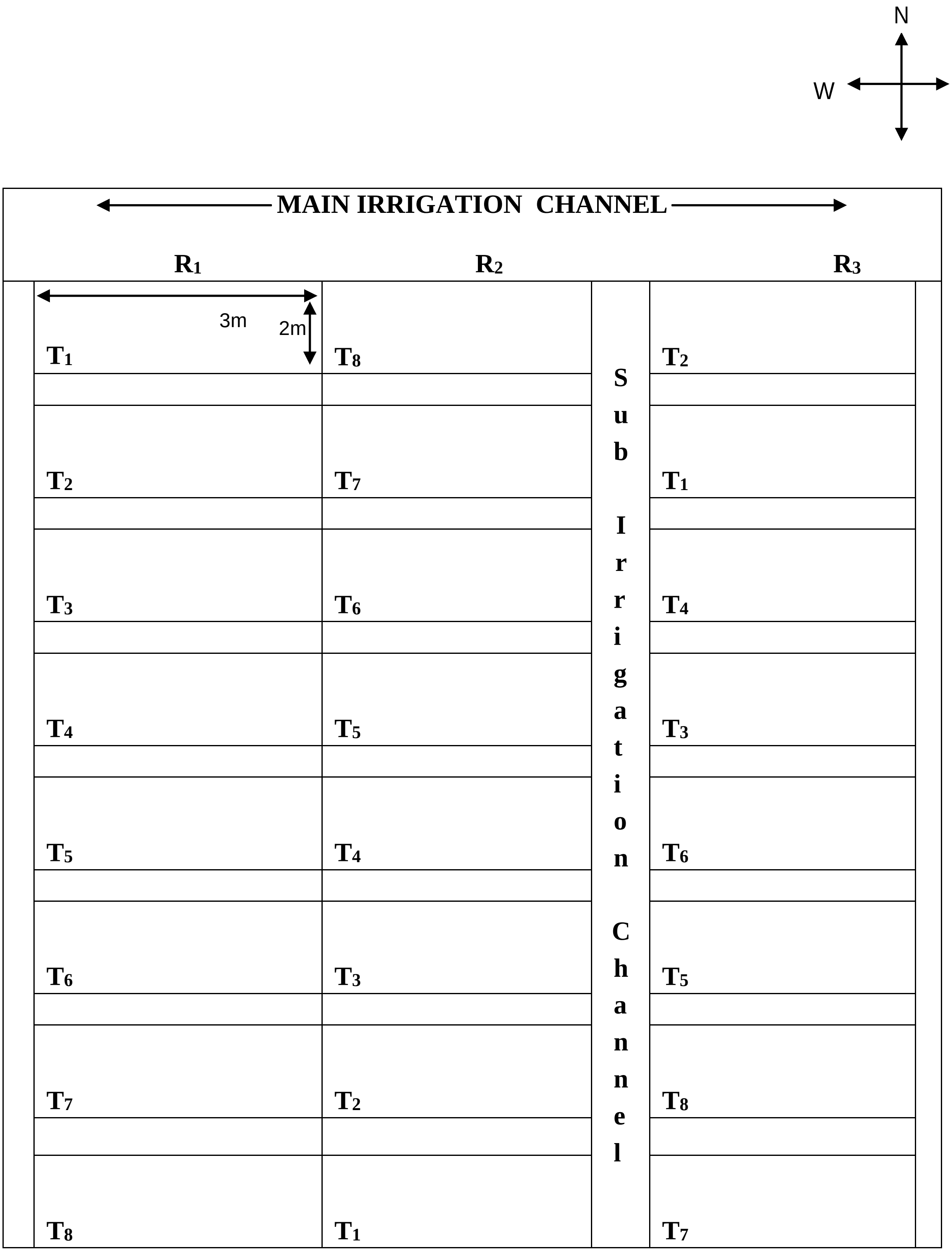


Fig. 3.1: Lay-out of the Experimental Field

PLATE 1: LAYOUT AND FIELD VIEW OF TOMATO

PLATE 2: INFESTATIONS OF LEAF MINERS ON TOMATO

PLATE 3: INFESTATION OF WHITEFLY ON TOMATO

PLATE 4: INFESTATION OF FRUIT BORER ON TOMATO

3.16.2 Details of treatments

Table 3.2. Details of treatments

Treatment No.	Treatment Details	Dosage/ha	
		a.i.(g)	Forml.(ml)
T_1	Untreated Control	-	-
T_2	Tetraniliprole 120g/L + Spirotetramat 240g/L SC	30+60	250
T_3	Tetraniliprole 120g/L + Spirotetramat 240g/L SC	37.5+75	312.5
T_4	Tetraniliprole 120g/L + Spirotetramat 240g/L SC	45+90	375
T_5	Tetraniliprole 200g/L SC	45	225
T_6	Spirotetramat 150g/L OD	90	600
T_7	Cyantraniliprole 10.26% SC	90	900
T_8	Spiromesifen 22.9% SC	150	625

3.17 Spraying

The recommended amount of solution was sprayed separately in each plot with separate insecticides of the experiment except control plots. Application of insecticides was done by a hand-operated knapsack sprayer by using 400 liters of water/hectare. One spraying was done as soon as the pest population reached ETL and then one more spraying was done when the pest population reached ETL again.

3.18 Observations to be recorded

3.18.1 Seasonal incidence of major insect pests of tomato

3.18.1.1 Sucking pests

The population of nymphs and adults of the whitefly, *Bemisia tabaci* (Genadius)and Leaf miner *Liriomyza trifoli* (Burgess) were recorded at weekly interval. The observations on live mines were recorded on three leaves (upper, middle, and bottom) per plant on five randomly selected plants per plot leaving border rows.

3.18.1.2 Tomato fruit borer, *Helicoverpa armigera* (Hub.)

Fruit borer population was recorded based on the number of larvae or holes /plant at weekly intervals. Five plants are selected from each plant for observation The percentage of infestation was calculated by the following formula –

3.18.1.3 Study influence of weather parameters

Weather parameters like maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall, etc., and their influence on the population of insect pests of tomato, the simple correlation coefficient was worked out with mean weekly meteorological data.

3.18.2 Field efficacy of newer insecticides against major pest complex of tomato

3.18.2.1 Whitefly, *Bemisia tabaci* (Gennadius)

Observations on pest count were recorded on five randomly selected plants in each treatment plot. On each selected plant, three leaves each from the upper, middle, and bottom portion were observed from the lower side for whiteflies count. Pre count was taken one day before first spray and 1, 3, 5, 7 and 10 days interval as a post count.

3.18.2.2 Leaf miner *Liriomyza trifoli* (Burgess)

The observations on live mines were recorded on three leaves (upper, middle, and bottom) per plant on five randomly selected plants per plot. The observations were recorded one day before each spray as a pre count and 1, 3, 5, 7 and 10 days intervals as a post count. The percent decline of live mines was worked out as:-

3.18.2.3 Tomato fruit borer, *Helicoverpa armigera* (Hub.)

Fruit borer larval population was recorded on five randomly selected plants per plot on one day before spray and1, 3, 5, 7 and 10 days after each Spray. Fruit borer population was recorded based on the number of larvae or holes/plant. Damage is calculated by the formula –

3.19 Statistical analysis

Table 3.3 Skeleton of ANOVA

Source of variance	Degree of freedom	Sum of square (SS)	Mean sum of square (MSS)	Calculated F value	Table value at 5%
Replication	(r-1)	SSR	MSR	MSR/MSE	
Treatments	(t-1)	SSTr	MSTr	MSTr/MSE	
Error	(r-1)(t-1)	SSE	MSE		
Total	(rt-1)	TSS			

To compare the treatment effect the natural counts were subjected to transformation based on field experiment data. Panse and Sukhatme, 1985). The data on counts of aphids, thrips, whiteflies, and coccinellids were converted to square root transformed values + 0.5 i.e. ($\sqrt{\quad}$) where 'n' is the mean value of the actual count of concerned pests or predator. The data on percent fruit borer, (*Helicoverpa armigera*) infestation was transformed to arc sin values. The critical difference was worked out at a 5 percent level of significance for every treatment to compare significance between them. Standard error and critical difference were calculated by the following formula -

$$\frac{\sqrt{}}{\sqrt{}} \quad \sqrt{}$$

Where,

S.Ed	=	Standard error of differences between two treatment means.
MSE (Ve)	=	Error mean sum of square (Error variance).
CD	=	For treatment at 5% = S.Ed X + (E.d.f) at 5% x √

Where,

CD	=	Critical difference
r	=	Number of replication
t	=	Value for fishers table for error degree of Freedom at 5%
E.d.f.	=	Error degree of freedom

The data were subjected to analyses after suitable transformation.

3.20 YIELD

The yield data of marketable fruits at different pickings were reported separately in each treatment and subjected to statistical analysis to evaluate the significance of mean yield in different treatments. For each treatment, the per cent increase in yield over control was calculated using the following formula:

$$\text{Per cent increase of yield over control} = \frac{(\text{Yield in treatment} - \text{Yield in control}) \times 100}{\text{Yield in control}}$$

First picking was performed 91 days after transplanting when fruit attain their full maturity, and next picking was subsequently done after seven days intervals. All picking was combined to calculate the average yield (qt. ha^{-1}).

Chapter Itf

EXPERIMENTAL FINDINGS

This chapter deals with the data obtained during the present research work. The data has been analysed statistically, duly supported by tables and graphs. The results are presented experiment wise, along with the explanation.

4.1 INSECT-PEST COMPLEX AND RELATIVE ABUNDANCE OF INSECT-PESTS ON TOMATO DURING 2020-21

One species of borers.*Helicoverpa armigera* (Hbn.),one species of sap suckes, *Bemisia tabaci* (Gennadius) and one species defoliaters, *Liriomyza trifolii* (Burgess) considered as major pests, as they seemed to show relatively higher bundance as compared to those major species. The occurrence of these pests varied concerning different stages of crop growth. Out of several insect pests observed to attack tomato crop Fruit borer *Helicoverpa armigera* (Hub.), Whitefly *Bemisia tabaci* (Gennadius), leafminer *Liriomyza trifolii* (Burgess) occupied subsequent position and showed their incidence from December to April.

Among the minor pests, tobacco caterpillar, *Spodoptera litura* (Fab.) showed its impact from January to February, Grasshopper, *Hieroglyphus banian* (Fab.) from March to May, Red cotton bug, *Pyrrhocoris apterus* F. from February to March, and Mites, *Tetranychus spp.* from January to February during the experimental year of 2020-21; whereas Red pumpkin beetle, *Aulacophora foveicollis* L. and Spotted leaf beetle, *Epilachna vigintioctopunctata* F. exhibited its incidence only during January and Leaf bug, *Nesidiocoris tenuis* (Reuter) only during March.

4.2 POPULATION DYNAMICS AND FLUCTUATIONS IN POPULATION OF MAJOR INSECT-PESTS OF TOMATO AND IMPACT OF ABIOTIC FACTORS ON THEM:

4.2.1 Tomato fruit borer,*Helicoverpa armigera*

The data on population fluctuation of fruit borer per plant recorded throughout the cropping season of 2020-21.The recorded data of fruit borer larvae presented in Table 4.1 and graphically depicted in Figure 4.1.

The first presence of larva with a mean number of 0.09 larvae per plant in the 47th SMW (of 2020) when the rainfall, max., min., avg. temp., morning, evening and average RH were 13.2mm, 26.3, 12.5, 19.4˚C, 91, 48 and 69.5% RH respectively. Then the no of larva became negligible due to weather condition and it becomes visible in 50th SMW (0.24 larvae per plant).The number of larvae steadily increased and reached its peak (4.38 larvae/plant) in the 10th SMW(of 2021) (rf, max, min, avg temp, morn, evng and avg RH were found to be 0mm, 32.7, 17, 24.85˚C, 88, 36 and 62% RH respectively) followed by a steady decrease in the number. However, no larvae were found from 43rd to 46th SMW (of 2020) (Table-4.1).

The correlation between the weather factors and number of larvae revealed a non-significantly positive correlation with maximum and average temp (r=0.113^{NS} and 0.051^{NS} respectively), though it showed negative non-significant correlation with rainfall, minimum temperature, morn, even and avg RH (r=-0.257^{NS},-0.029^{0}C,-0.004%,-0.339%,-0.226% respectively), (Table-4.2).

4.2.2 White fly, *Bemisia tabaci* (Gennadius)

The data on population fluctuation of whitefly per plant recorded throughout the cropping season of 2020-21.The recorded data of whitefly is presented in Table 4.1 and graphically depicted in Figure 4.1.

The first presence of pest with a mean number of 0.001 adults per plant is seen in the 45th SMW (of 2020) when the rainfall, max., min., avg. temp., morning, evening and average RH were 0 mm, 29.6, 13.9, 21.75˚C, 90%, 48% and 69% respectively. The number of adults steadily increased and reached its peak (7.880 adults/plant) in the 9th SMW(of 2021) (rf, max, min, avg temp, morn, evng and avg RH were found to be 0, 30.7, 15.4, 23.05$^{°C}$, 79%, 34%, 56.5% respectively) followed by a steady decrease in the number. However, no pest was found from 43rd to 44th SMW (of 2020) (Table-4.1).

The correlation between the weather factors and number of adults revealed a non-significantly positive correlation with morning and avg. RH ($r=0.183^{NS}$ and 0.028^{NS} respectively), though it showed negative non-significant correlation with rainfall, maximum, minimum, average temperature and evening RH ($r=-0.324^{NS}$,-0.208^{NS},-0.313^{NS},-0.267^{NS} and -0.079^{NS} respectively) (Table-4.2).

4.2.3 Leafminer, *Liriomyza trifolii* (Burgess)

The data on population fluctuation of number of no of mines per plant recorded throughout the cropping season of 2020-21.The recorded data of no of mines per plant presented in Table 4.1 and graphically depicted in Figure 4.1.

The first presence of mined leaves in plant with a mean number 0.02 mine per plant were recorded in the 47th SMW (of 2020) when the rainfall, max., min., avg. temp., morning, evening and average RH were 13.2mm,26.3,12.5,19.4^{0}C,91,48 and 69.5% RH respectively. Then the mined leaves become negligible due to weather parameters and was seen again during the 50th SMW of 2020(0.78 mines/plant).The number of mines per plant steadily increased and reached its peak (7.15 mines per plant) in the 10th SMW(of 2021) (rf, max, min, avg temp, morn, evng and avg RH were found to be 0mm, 32.7, 17, 24.85°C, 88, 36 and 62% RH respectively) followed by a steady decrease in the number. However, no mined leaves were found from 43rd to 46th SMW (of 2020) (Table-4.1).

The correlation between the weather factors and number of mines revealed a non-significantly positive correlation with morning and average RH ($r=0.176^{NS}$ and 0.027^{NS} respectively), though it showed negative non-significant correlation with rainfall, maximum, minimum, average temperature and evening RH($r=-0.304^{NS}$,-0.202^{NS},-0.300^{NS},-0.258^{NS} and -0.075^{NS} respectively).

Table 4.1: Population fluctuation of Insect pests of tomato with weather parameters during 2020-21

									Insects		
Standard Week No.	**Month & Date**	**Temperature °C**			**R.H. %**			**Rainfall mm**	**Whitefly**	**Fruit borer**	**Adult**
		Max	**Min**	**Avg.**	**Morn.**	**Even**	**Avg.**				
43	Oct 22-28	32.4	21.1	26.75	90	62	76	32.4	0.000	0	0
44	29-04	30.3	16.6	23.45	78	40	59	0	0.000	0	0
45	Nov 05-11	29.6	13.9	21.75	90	48	69	0	0.001	0	0
46	12 to 18	25	18.1	21.55	89	54	71.5	0	0.006	0	0
47	19-25	26.3	12.5	19.4	91	48	69.5	13.2	0.342	0.09	0.02
48	26-02	26.3	11.1	18.7	92	43	67.5	0	0.231	0	0
49	Dec 03-09	27.7	12	19.85	93	53	73	0	0.621	0	0
50	10 to 16	23.9	14.8	19.35	93	64	78.5	3.6	1.880	0.24	0.78
51	17-23	20.5	7.5	14	91	59	75	0	1.321	0.12	1.24
52	24-31	22.3	7.8	15.05	94	49	71.5	0	2.732	0.58	1.99
1	Jan 01-07	25.4	12.3	18.85	90	54	72	0	4.611	1.18	2.93
2	08 -14	21.7	13	17.35	92	59	75.5	0	4.920	1.91	3.78
3	15-21	19.4	8.1	13.75	95	65	80	0	5.140	1.08	5.09
4	22-28	17.5	9.2	13.35	95	71	83	0	5.321	1.23	5.12
5	29-04	22.3	7.3	14.8	96	46	71	0	6.120	1.89	5.17
6	Feb 05-11	24.6	10.8	17.7	91	50	70.5	0.6	6.791	2.16	5.59
7	12-18	28.4	12.4	20.4	90	37	63.5	0	7.160	3.39	5.62
8	19-25	29	13.7	21.35	85	41	63	0	7.321	3.36	5.82
9	26-04	30.7	15.4	23.05	79	34	56.5	0	7.880	3.96	6.63
10	Mar 05-11	32.7	17	24.85	88	36	62	0	7.123	4.38	7.15
11	12-18	32.3	17.7	25	87	39	63	0	3.490	2.03	2.94
12	19-25	34.5	20.7	27.6	64	40	52	0	1.092	0.44	0.76
13	26-01	36	17.8	26.9	73	23	48	0	0.012	0	0

Table 4.2: Correlation of weather parameters with insect population

Pest of tomato	**Temperature °C**			**R.H. %**			**Rainfall (mm)**
	Max.	**Min.**	**Avg.**	**Morin.**	**Even.**	**Avg.**	
Whitefly	-0.208^{NS}	-0.313^{NS}	-0.267^{NS}	0.183^{NS}	-0.079^{NS}	0.028^{NS}	-0.314^{NS}
Fruitborer	0.113^{NS}	-0.029^{NS}	0.051^{NS}	-0.004^{NS}	-0.339^{NS}	-0.226^{NS}	-0.257^{NS}
Leafminer	-0.202^{NS}	-0.300^{NS}	-0.258^{NS}	0.176^{NS}	-0.075^{NS}	0.027^{NS}	-0.304^{NS}

(NS-Non significant)

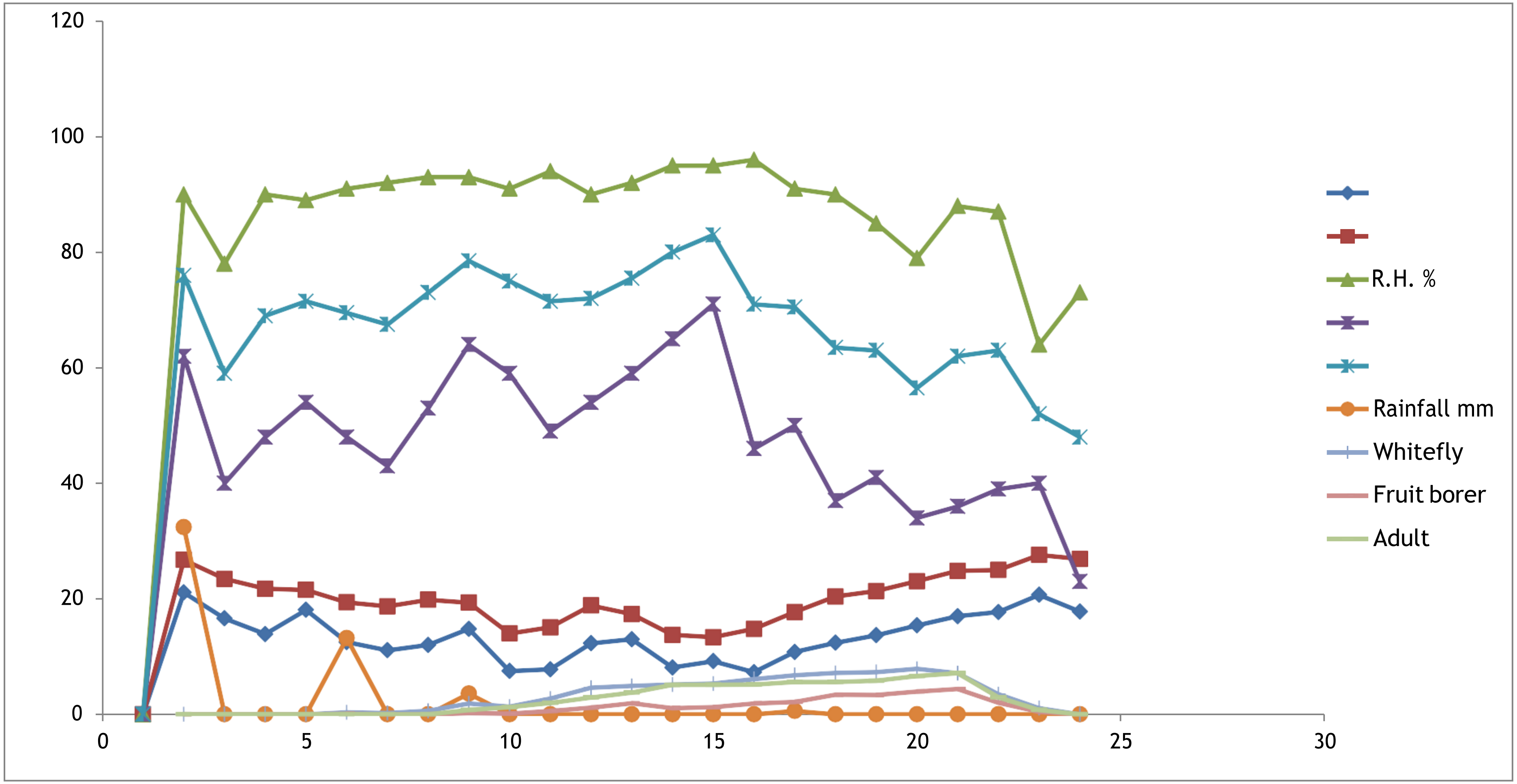


Fig. 4.1: Interaction of weather parameters and abundance of the major insect population in tomato during 2020-21

4.3 FIELD EFFICACY OF NEWER INSECTICIDES AGAINST MAJOR INSECT PESTS OF TOMATO

The efficacy of some newer insecticides viz Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC in different doses, Tetraniliprole 200 g/L SC (Tetraniliprole 18.18% w/wSC), Spirotetramat 150 g/L OD (Spirotetramat 15.31% w/w OD), Cyantraniliprole 10.26% OD, Spiromesifen 22.9% SC were assessed against the major pests of tomato under three replications. Two sprays of each insecticide were carried out at different dates during the crop seasons, 2020-21. The first spray was accomplished at 83 day after transplanting (DAT) while the second spray was at 98 DAT.

4.3.1 Effect of newer insecticides against the larval population of *H. armigera* in tomato during 2020-21

The data of *H. armigera* population on tomato in various treatments was recorded one day before and 1^{st}, 3^{rd}, 5^{th}, 7^{th} and 10^{th} days after each spraying in each replication during the cropping season 2020-21. The observed data are summarized in Table 4.3 and Table 4.4 and graphically depicted in Figure 4.2.

It revealed that before first spray the mean population of *H. armigera* varied from 4.26 to 4.78 larvae plant-1, which was non-significant. At one day after 1^{st} spray, the larval population was minimum (1.04 larvae plant^{-1}) with T_2 (with a significant difference from all other treatments) followed by T_3 (1.18 larvae plant^{-1}), T_5 (1.54 larvae plant^{-1}), T_4 (1.68 larvae plant^{-1}), T_6 (1.87 larvae plant^{-1}), T_7 (1.89 larvae plant^{-1})and T_1 (2.08 larvae plant^{-1}) (all being at par with each other)showing the decreasing order of efficacy.

However, the larval population in all the treatments was significantly less than untreated control (4.67 larvae plant^{-1}).

At 3^{rd} day after 1^{st} spray, the larval population was recorded minimum (0.54 larvae plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (0.74 larvae plant^{-1}), T_5 (0.88 larvae plant^{-1}), T_4 (1.08 larvae plant^{-1}), T_7 (1.28 larvae plant^{-1}), T_6 (1.48 larvae plant^{-1}) and T_1 (1.68 larvae plant^{-1}) indicating the decreasing trend of their efficacy. However, the larval population in all the treatments was significantly less than untreated control (5.12 larvae plant^{-1}).

Table 4.3: Effect of newer molecules of insecticides against the population of fruit borer, *H. armigera* in tomato after first application during 2020-21

Treatments	Dose a.i (g)	Formulation (ml)/h.	Mean no. of Helicoverpa armigera larva per plant and percent field efficacy											
			DBS	1 DAS	PFE	3 DAS	PFE	5 DAS	PFE	7 DAS	PFE	10 DAS	PFE	Over all mean	Over all mean PFE
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	30+60	250	4.26 (2.29)	2.08 (1.75)	51.7556	1.68 (1.63)	61.8193	1.48 (1.57)	67.0296	1.81 (1.68)	60.6606	2.08 (1.75)	56.3436	2.23167	60.3162
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	37.5+75	312.5	4.51 (2.34)	1.04 (1.42)	77.215	0.74 (1.32)	84.1146	0.28 (1.13)	94.1081	0.74 (1.32)	84.808	1.21 (1.49)	76.0115	1.42	85.0614
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	45+90	375	4.55 (2.35)	1.18 (1.47)	74.375	0.54 (1.24)	88.5098	0.08 (1.04)	98.3314	0.41 (1.19)	91.6568	0.74 (1.32)	85.4583	1.25	88.2182
Tetraniliprole 200 g/L SC (Tetraniliprole 18.18% w/w SC)	45	225	4.51 (2.34)	1.68 (1.63)	63.1934	1.08 (1.44)	76.8159	0.68 (1.29)	85.6912	1.14 (1.46)	76.5962	1.61 (1.61)	68.0814	1.78333	75.5741
Spirotetramat 150 g/L OD (Spirotetramat 15.31% w/w OD)	90	600	4.78 (2.40)	1.54 (1.59)	68.1664	0.88 (1.37)	82.1763	0.48 (1.22)	90.4702	0.81 (1.34)	84.3103	1.28 (1.51)	76.0571	1.62833	81.2807
Cyantriniliprole 10.26% OD	90	900	4.47 (2.33)	1.87 (1.69)	58.6641	1.48 (1.57)	67.9448	1.08 (1.44)	77.0709	1.41 (1.55)	70.7941	1.81 (1.68)	63.7952	2.02	68.6184
Spiromesifen 22.9% SC	150	625	4.68 (2.38)	1.89 (1.70)	60.0967	1.28 (1.51)	73.5206	0.94 (1.39)	80.9387	1.34 (1.53)	73.4895	1.74 (1.65)	66.7572	1.97833	72.0113
Control			4.5 (2.34)	4.67 (2.38)		5.12 (2.47)		5.43 (2.54)		5.98 (2.64)		6.27 (2.70)		5.32833	
CD			NS	0.03		0.025		0.03		0.025		0.022			
SE(m)			0.037	0.01		0.008		0.01		0.008		0.007			

(DBS-Days before spray; DAS-Days after spray; PFE-Percentage field efficacy;NS-Non significant)
Values in parenthesis are Square root transformed values

At 5th day after 1st spray, the larval population of *H. armigera* was once again recorded minimum (0.08 larvae plant^{-1}) with T_3 (significantly different from all other treatments) followed by T_2 (0.28 larvae plant^{-1}), T_5 (0.48 larvae plant^{-1}), T_4 (0.68 larvae plant^{-1}), T_7 (0.93 larvae plant^{-1}), T_6 (1.08 larvae plant^{-1}) and T_1 (1.48 larvae plant^{-1}) indicating decreasing order of efficacy. However all other treatments have less population as compared to untreated control where it was to the extent of 5.43 larvae plant^{-1}.

At 7th day after 1st spray, the larval population of *H. armigera* was once again recorded minimum (0.41 larvae plant^{-1}) with T_3 (significantly different from all other treatments) followed by T_2 (0.74 larvae plant^{-1}), T_5 (0.81 larvae plant^{-1}), T_4 (1.14 larvae plant^{-1}), T_7 (1.34 larvae plant^{-1}), T_6 (1.41 larvae plant^{-1}) and T_1 (1.81 larvae plant^{-1}) indicating decreasing order of efficacy. However all other treatments have less population as compared to untreated control where it was to the extent of 5.98 larvae plant^{-1}.

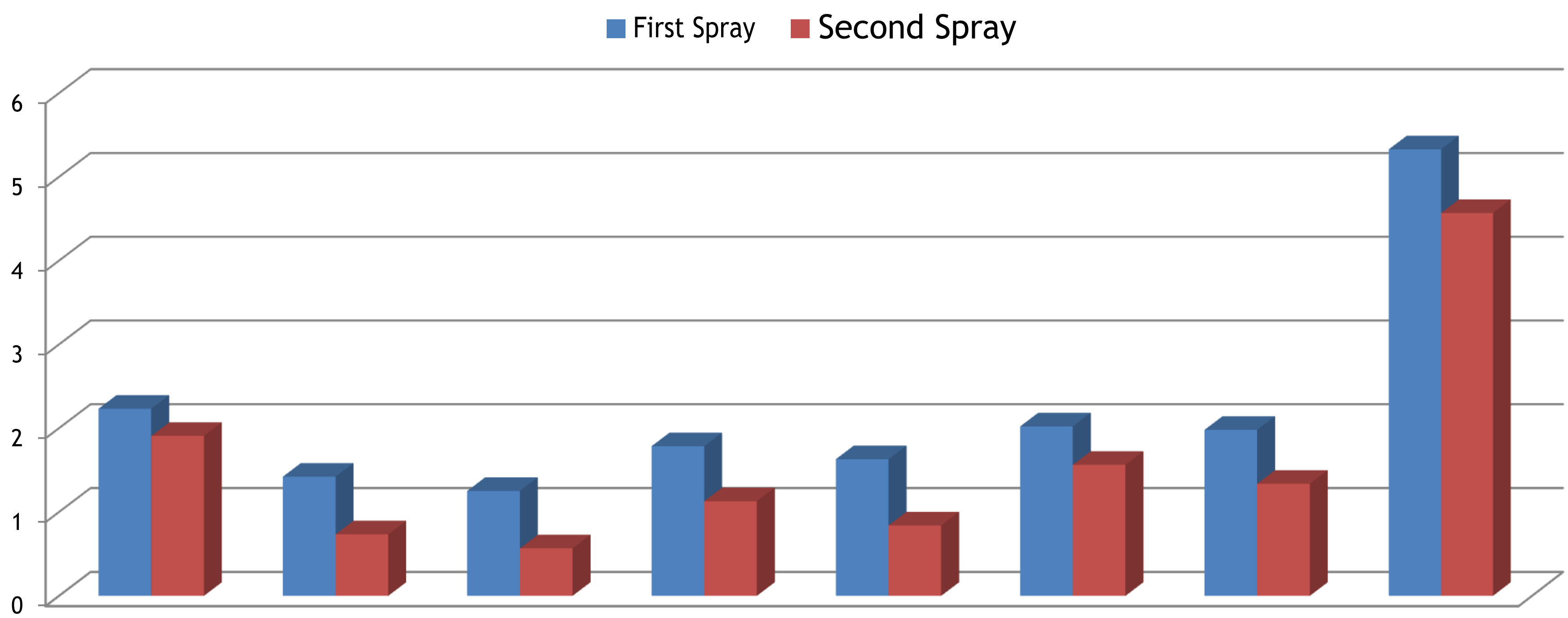
At 10th day after 1st spray, the larval population of *H. armigera* was once again recorded minimum (0.74 larvae plant^{-1}) with T_3 (significantly different from all other treatments) followed by T_2 (0.1.21 larvae plant^{-1}), T_5 (1.28 larvae plant^{-1}), T_4 (1.61 larvae plant^{-1}), T_7 (1.74 larvae plant^{-1}), T_6 (1.81 larvae plant^{-1}) and T_1 (2.08 larvae plant^{-1})indicating decreasing order of efficacy. However all other treatments have less population as compared to untreated control where it was to the extent of 6.27 larvae plant^{-1}.

Thus, based on overall mean of larval population of tomato fruit borer, the decreasing order of efficacy of different treatments in the present study was as follows:**T_3 > T_2> T_5 > T_4 > T_7 > T_6 > T_1> T_8**(untreated check) and the percentage field efficacy was found to be in order of **T_3 (88.21%) > T_2 (85.06%)> T_5 (81.21%) > T_4(75.57%) > T_7(72.01%) > T_6(68.61%) > T_1(60.31%) > T_8(untreated check)** (Table 4.3)

Table 4.4: Effect of newer molecules of insecticides against the population of fruit borer, *H. armigera* in tomato after second application during 2020-21

Treatments	Dose a.i (g)	Formulation (ml)/h.	Mean no. of Helicoverpa armigera larva per plant and percent field efficacy												
			DBS	1 DAS	PFE	3 DAS	PFE	5 DAS	PFE	7 DAS	PFE	10 DAS	PFE	Over all mean	Over all mean PFE
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	30+60	250	3.18 (2.04)	2.21 (1.79)	31.3314	1.81 (1.68)	44.8944	1.61 (1.62)	51.9526	1.41 (1.55)	58.9465	1.21 (1.49)	65.9785	1.905	46.781
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	37.5+75	312.5	2.31 (1.82)	1.24 (1.49)	46.9601	0.41 (1.19)	82.8163	0.28 (1.13)	88.4968	0.14 (1.07)	94.3886	0.01 (1.01)	99.6129	0.73167	78.165
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	45+90	375	1.84 (1.68)	1.32 (1.52)	29.1158	0.14 (1.07)	92.6336	0.08 (1.04)	95.8739	0.01 (1.01)	99.4968	0 (1.00)	100	0.565	79.280
Tetraniliprole 200 g/L SC (Tetraniliprole 18.18% w/w SC)	45	225	2.71 (1.93)	1.28 (1.51)	53.3304	0.94 (1.39)	66.4183	0.68 (1.29)	76.1872	0.61 (1.27)	79.159	0.54 (1.24)	82.1836	1.12667	68.773
Spirotetramat 150 g/L OD (Spirotetramat 15.31% w/w OD)	90	600	2.31 (1.82)	1.01 (1.42)	56.7981	0.68 (1.29)	71.5003	0.48 (1.22)	80.2803	0.41 (1.18)	83.5665	0.14 (1.07)	94.5811	0.83833	73.036
Cyantriniliprole 10.26% OD	90	900	2.91 (1.98)	1.74 (1.65)	40.9188	1.61 (1.62)	46.4355	1.21 (1.49)	60.5394	1.01 (1.42)	67.8644	0.88 (1.37)	72.9614	1.56	53.939
Spiromesifen 22.9% SC	150	625	2.84 (1.96)	1.54 (1.59)	46.4209	1.14 (1.46)	61.1375	0.94 (1.39)	68.5891	0.81	73.5926	0.74 (1.32)	76.7026	1.335	62.435
Control			7.12 (2.85)	6.38 (2.72)		5.57 (2.56)		5.16 (2.48)		4.92		3.88 (2.21)		4.568	
CD			0.028	0.032		0.025		0.026		0.021		0.02			
SE(m)			0.009	0.01		0.008		0.008		0.007		0.007			

(DBS-Days before spray; DAS-Days after spray; PFE-Percentage field efficacy)
Values in parenthesis are Square root transformed values



x-axis: Treatments y-axis: Larval population per plant

T1 = Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 30+60 g a.i./250 ml, T2 = Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml, T3= Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i. /375 ml., T4 Tetraniliprole 200 g/L SC, T5 = Spiromesifan 22.9%SC, T6 = Cyantriniliprole 10.26 % OD, T7 = Spiromesifan 22.9%SC, T8 = Control

Fig. 4.2. Efficacy of some newer insecticides against the population of tomato fruit borer, *H. armigera* in tomato during 2020-21

A perusal of data collected one day before 2nd spray revealed that the population of *H. armigera* varied from 1.84 to 7.18 larvae plant^{-1} (Table 4.4) but, at 1st day after 2nd spray, the larval population was found to be minimum in T_5 (1.01 larvae plant^{-1}) (with a significant difference from all other treatments) followed by T_2 (1.24 larvae plant^{-1}), T_4 (1.28 larvae plant $^{-1}$), T_3 (1.32 larvae plant^{-1}), T_7 (1.54 larvae plant^{-1}), T_6 (1.74 larvae plant^{-1}) and T_1 (2.21 larvae plant$^{-1)}$ respectively, being at par with each other showing decreasing order of efficacy. Though, the population of larvae in all the treatments was significantly less than untreated control (6.38 larvae plant^{-1}).

At 3rd day after 2nd spray, the larval population was recorded minimum (0.14 larvae plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (0.41 larvae plant^{-1}), T_5 (0.68 larvae plant^{-1}), T_4 (0.94 larvae plant^{-1}), T_7 (1.14 larvae plant^{-1}), T_6(1.61 larvae plant^{-1}) and T_1 (1.81 larvae plant^{-1}) indicating the decreasing trend of their efficacy. However, the larval population in all the treatments was significantly less than untreated control (5.57 larvae plant^{-1}).

At 5th day after 2nd spray, the larval population of *H. armigera* was once again recorded minimum (0.08 larvae plant^{-1}) with T_3 (significantly different from all other treatments) followed by T_2 (0.28 larvae plant^{-1}), T_5 (0.48 larvae plant^{-1}), T_4 (0.68 larvae plant^{-1}), T_7 (0.94 larvae plant^{-1}), T_6 (1.21 larvae plant^{-1}) and T_1 (1.61 larvae plant^{-1})indicating decreasing order of efficacy. However all other treatments have less population as compared to untreated control where it was to the extent of 5.16 larvae plant^{-1}.

At 7th day after 2nd spray, the larval population of *H. armigera* was once again recorded minimum (0.01 larvae plant^{-1}) with T_3 (significantly different from all other treatments) followed by T_2 (0.14 larvae plant^{-1}), T_5 (0.41 larvae plant^{-1}), T_4 (0.61 larvae plant^{-1}), T_7 (0.81 larvae plant^{-1}), T_6 (1.01 larvae plant^{-1}) and T_1 (1.41 larvae plant^{-1})indicating decreasing order of efficacy. However all other treatments have less population as compared to untreated control where it was to the extent of 4.92 larvae plant^{-1}.

At 10th day after 2nd spray, the larval population of *H. armigera* was once again recorded minimum (0.00 larvae plant^{-1}) with T_3 (significantly different from all other treatments) followed by T_2 (0.01 larvae plant^{-1}), T_5 (0.14 larvae plant^{-1}), T_4 (0.54 larvae plant^{-1}), T_7 (0.74 larvae plant^{-1}), T_6 (0.88 larvae plant^{-1}) and T_1 (1.21 larvae plant^{-1})indicating decreasing order of efficacy. However all other treatments have less population as compared to untreated control where it was to the extent of 3.88 larvae plant^{-1}.

Thus, based on overall mean of larval population of tomato fruit borer, the decreasing order of efficacy of different treatments in the present study was as follows:**T_3 > T_2> T_5 > T_4 > T_7 > T_6 > T_1 > T_8(untreated check)** and the percentage field efficacy was found to be in order **of T_3 (79.28%) > T_2 (78.16%)> T_5 (73.03%) > T_4(68.77%) > T_7(62.43%) > T_6(53.93%) > T_1(46.78%) > T_8(untreated check) (Table 4.4)**

4.3.2 Effect of newer insecticides against the population of whitefly, *B. tabaci* in tomato during 2020-21

The data on the number of whiteflies after various insecticidal checks noted one day before and 1st, 3rd, 5th, 7th and 10th days after each application during the cropping season 2020-21 are shown in Tables 4.5 and 4.6 and graphically depicted in Figure 4.3.

On one day before the first spray, the mean population of whitefly varied from 9.12 to 9.89 plant^{-1}. At 1st day after 1st spray, all the treatments were recorded to have a significantly lower population of whitefly than untreated control (9.23 larvae plant^{-1}). The population of whitefly was lowest (3.31 whitefly plant^{-1}) in the check where T_3 was sprayed, which was significantly superior over the rest of the treatments. The declining order of next best insecticides were T_2 (3.79 whitefly plant^{-1}), T_4 (4.01 whitefly plant^{-1}), T_1 (4.11 whitefly plant^{-1}), T_5 (4.11 whitefly plant^{-1}), T_6 (4.10 whitefly plant^{-1}) and T_7 (4.11 whitefly plant^{-1}).

Table 4.5: Effect of newer molecules of insecticides against the population of whitefly, *B. tabaci* in tomato after first application during 2020-21

Treatments	Dose a.i (g)	Formulation (ml)/h.	Mean no. of whiteflies per plant and percent field efficacy												
			DBS	1 DAS	PFE	3 DAS	PFE	5 DAS	PFE	7 DAS	PFE	10 DAS	PFE	Over all mean	Over all mean PFE
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	30+60	250	9.79 (3.28)	4.11 (2.26)	58.5187	3.79 (2.18)	62.5199	3.5 (2.12)	66.0721	3.77 (2.18)	64.3453	5.54 (2.55)	49.4034	5.08333	62.8640019
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	37.5+75	312.5	9.44 (3.23)	3.79 (2.18)	60.3302	3.28 (2.06)	66.3608	2.78 (1.94)	72.0524	3.27 (2.06)	67.9274	5.01 (2.45)	52.5474	4.595	66.6676903
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	45+90	375	9.69 (3.26)	3.31 (2.12)	66.2482	2.91 (1.97)	70.9254	2.48 (1.86)	75.7116	3.14 (2.03)	69.997	4.88 (2.42)	54.9712	4.40167	70.7205492
Tetraniliprole 200 g/L SC (Tetraniliprole 18.18% w/w SC)	45	225	9.77 (3.28)	4.01 (2.23)	59.4451	3.84 (2.20)	61.9477	3.31 (2.12)	67.8482	3.74 (2.17)	64.5566	5.34 (2.51)	51.1301	5.00167	63.4494180
Spirotetramat 150 g/L OD (Spirotetramat 15.31% w/w OD)	90	600	9.89 (3.30)	4.18 (2.27)	58.2388	4.08 (2.25)	60.06	3.78 (2.18)	63.7284	3.28 (2.06)	69.2931	6.53 (2.74)	40.9647	5.29	62.8300686
Cyantriniliprole 10.26% OD	90	900	9.31 (3.21)	4.1 (2.25)	56.4862	3.88 (2.20)	59.6516	3.51 (2.12)	4.48	3.88 (2.20)	61.413	5.54 (2.55)	46.7947	5.03667	45.5077083
Spiromesifen 22.9% SC	150	625	9.13 (3.18)	4.11 (2.26)	55.5201	3.81 (2.19)	59.5984	3.5 (2.12)	63.6195	4.48 (2.34)	54.5676	5.74 (2.59)	43.7871	5.12833	58.3263948
Control			9.12 (3.18)	9.23 (3.19)		9.42 (3.22)		9.61 (3.25)		9.85 (3.29)		10.2 (3.34)		9.57167	
CD			NS	0.053		0.016		0.068		0.018		0.038			
SE(m)			0.038	0.017		0.005		0.022		0.006		0.012			

(DBS-Days before spray; DAS-Days after spray; PFE-Percentage field efficacy;NS-Non significant)
Values in parenthesis are Square root transformed values

At 3rd day after 1st spray, all the treatments were recorded to have a significantly lower population of whitefly than untreated control (9.42 larvae plant^{-1}). The population of whitefly was lowest (2.91 whitefly plant^{-1}) in the check where T_3 was sprayed, which was significantly superior over the rest of the treatments. The declining order of next best insecticides were T_2 (3.28 whitefly plant^{-1}), T_1 (3.79 whitefly plant^{-1}), T_4 (3.84 whitefly plant^{-1}), T_5 (4.08 whitefly plant^{-1}), T_6 (3.88 whitefly plant^{-1}) and T_7 (3.81 whitefly plant^{-1}).

At 5th day after 1st spray, all the treatments were recorded to have a significantly lower population of whitefly than untreated control (9.61 larvae plant^{-1}). The population of whitefly was lowest (2.48 whitefly plant^{-1}) in the check where T_3 was sprayed, which was significantly superior over the rest of the treatments. The declining order of next best insecticides were T_2 (2.78 whitefly plant^{-1}), T_4 (3.31 whitefly plant^{-1}), T_1 (3.5 whitefly plant^{-1}), T_5 (3.78 whitefly plant^{-1}), T_6 (3.51 whitefly plant^{-1}) and T_7 (3.50 whitefly plant^{-1}).

At 7th day after 1st spray, all the treatments were recorded to have a significantly lower population of whitefly than untreated control (9.85 larvae plant^{-1}). The population of whitefly was lowest (3.14 whitefly plant^{-1}) in the check where T_3 was sprayed, which was significantly superior over the rest of the treatments. The declining order of next best insecticides were T_2 (3.27 whitefly plant^{-1}), T_4 (3.74 whitefly plant^{-1}), T_1 (3.77 whitefly plant^{-1}), T_5 (3.28 whitefly plant^{-1}), T_6 (3.88 whitefly plant^{-1}) and T_7 (4.48 whitefly plant^{-1}).

At 10th day after 1st spray, all the treatments were recorded to have a significantly lower population of whitefly than untreated control (10.2 larvae plant^{-1}). The population of whitefly was lowest (4.88 whitefly plant^{-1}) in the check where T_3 was sprayed, which was significantly superior over the rest of the treatments. The declining order of next best insecticides were T_2 (5.01 whitefly plant^{-1}), T_4 (5.34 whitefly plant^{-1}), T_1 (5.54 whitefly plant^{-1}),T_6 (5.54 whitefly plant^{-1}), T_7 (5.74 whitefly plant^{-1}) and T_5 (6.53 whitefly plant^{-1})

Thus, on the basis of overall mean population of whitefly, the order of efficacy of different insecticides in the present study was as follows: **T_3 > T_2 > T_4 > T_1 > T_5 > T_7 > T_6 >T_8 untreated check** (Fig 4.5)

The Percentage field efficacy (PFE) of the insecticides are also found to be in the following order**: T_3 (70.72%)> T_2 (66.66%) > T_4 (63.44%) > T_1 (62.86%)> T_5 (62.83%)> T_7 (58.32%)> T_6 (45.50%)>T_8 untreated check.**

One day before 2nd spray, the populations of whitefly varied from 6.39 to 11.5 whitefly plant^{-1} (Table 4.4). At 1st day after 2nd spray, all the treatments were recorded to have a significantly lower population of whitefly than untreated control (10.30 larvae plant^{-1}). The population of whitefly was lowest (3.14 whitefly plant^{-1}) in the check where T_3 was sprayed, which was significantly superior over the rest of the treatments. The declining order of next best insecticides were T_2 (3.68 whitefly plant^{-1}), T_4 (4.28 whitefly plant^{-1}), T_1 (4.20 whitefly plant^{-1}), T_5 (4.61 whitefly plant^{-1}), T_7 (4.52 whitefly plant^{-1}) and T_6 (4.78 whitefly plant^{-1}).

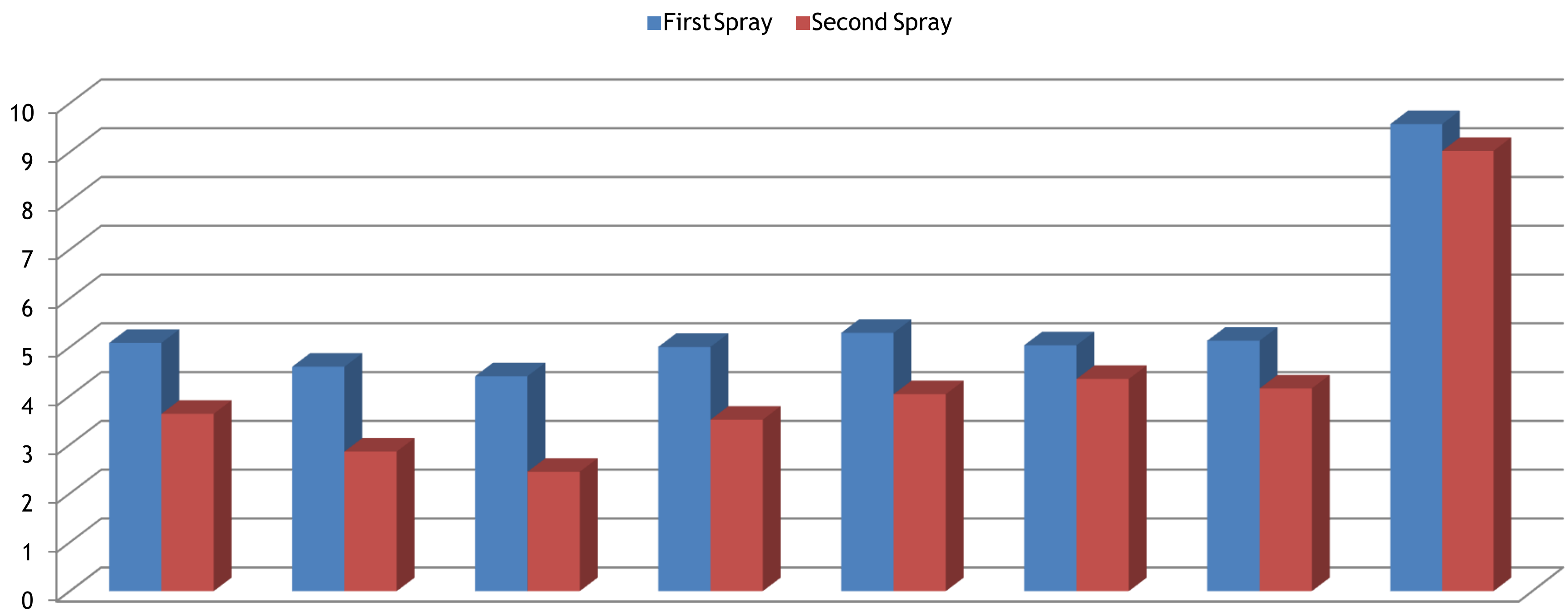
At 3rd day after 2nd spray, all the treatments were recorded to have a significantly lower population of whitefly than untreated control (9.83 larvae plant^{-1}). The population of whitefly was lowest (1.98 whitefly plant^{-1}) in the check where T_3 was sprayed, which was significantly superior over the rest of the treatments. The declining order of next best insecticides were T_2 (2.18 whitefly plant^{-1}), T_4 (3.61 whitefly plant^{-1}), T_1 (3.88 whitefly plant^{-1}), T_6 (4.01 whitefly plant^{-1}), T_7 (4.21 whitefly plant^{-1}) and T_5 (4.48 whitefly plant^{-1}).

At 5th day after 2nd spray, all the treatments were recorded to have a significantly lower population of whitefly than untreated control (8.62 larvae plant^{-1}). The population of whitefly was lowest (1.51 whitefly plant^{-1}) in the check where T_3 was sprayed, which was significantly superior over the rest of the treatments. The declining order of next best insecticides were T_2 (1.99 whitefly plant^{-1}), T_4 (2.98 whitefly plant^{-1}), T_1 (3.31 whitefly plant^{-1}), T_6 (3.39 whitefly plant^{-1}), T_5 (4.08 whitefly plant^{-1}) and T_7 (3.94 whitefly plant^{-1}).

Table 4.6: Effect of newer molecules of insecticides against the population of whitefly, *B. tabaci* in tomato after second application during 2020-21

Treatments	Dose a.i (g)	Formulation (ml)/h.	Mean no. of whiteflies per plant and percent field efficacy												
			DBS	1 DAS	PFE	3 DAS	PFE	5 DAS	PFE	7 DAS	PFE	10 DAS	PFE	Over all mean	Over all mean PFE
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	30+60	250	6.45 (2.72)	4.2 (2.27)	35.6598	3.88 (2.20)	41.7607	3.31 (2.07)	51.2988	2.02 (1.73)	71.0032	1.92 (1.70)	73.3844	3.63	49.93061 53
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	37.5+75	312.5	6.87 (2.80)	3.68 (2.16)	47.0722	2.18 (1.78)	69.2784	1.99 (1.72)	72.5104	1.48 (1.57)	80.0536	0.94 (1.39)	87.7661	2.85667	67.22866 172
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	45+90	375	6.54 (2.74)	3.14 (2.03)	52.56	1.98 (1.72)	70.6889	1.51 (1.58)	78.0886	0.87 (1.36)	87.6831	0.61 (1.26)	91.6604	2.44167	72.25515 539
Tetraniliprole 200 g/L SC (Tetraniliprole 18.18% w/w SC)	45	225	6.59 (2.75)	4.28 (2.29)	35.8271	3.61 (2.14)	46.9646	2.98 (1.99)	57.0857	1.79 (1.67)	74.8507	1.81 (1.67)	75.4423	3.51	53.68202 399
Spirotetramat 150 g/L OD (Spirotetramat 15.31% w/w OD)	90	600	6.68 (2.77)	4.61 (2.36)	31.8105	4.48 (2.34)	35.07	4.08 (2.25)	42.0364	3.81 (2.19)	47.1911	2.41 (1.82)	67.7422	4.03167	44.57739 286
Cyantriniliprole 10.26% OD	90	900	6.59 (2.75)	4.78 (2.40)	28.3303	4.01 (2.23)	41.0881	3.39 (2.09)	51.1814	3.01 (2.00)	57.7098	2.41 (1.84)	67.3016	4.345	38.11402 878
Spiromesifen 22.9% SC	150	625	6.39 (2.71)	4.52 (2.34)	30.1075	4.21 (2.28)	36.214	3.94 (2.22)	41.4851	3.82 (2.19)	44.6496	2.03 (1.74)	71.5953	4.15167	39.02699 982
Control			11.5 (3.55)	10.3 (3.36)		9.83 (3.29)		8.62 (3.10)		7.54 (2.92)		6.34 (2.71)		9.02167	
CD			0.081	0.055		0.012		0.015		0.019		0.02			
SE(m)			0.027	0.018		0.004		0.005		0.006		0.006			

(DBS-Days before spray; DAS-Days after spray; PFE-Percentage field efficacy)
Values in parenthesis are Square root transformed values



x-axis:Treatments y-axis: Whitefly population per plant

T1 = Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 30+60 g a.i./250 ml, T2 = Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml, T3= Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i. /375 ml., T4 Tetraniliprole 200 g/L SC, T5 = Spiromesifan 22.9%SC, T6 = Cyantriniliprole 10.26 % OD, T7 = Spiromesifan 22.9%SC, T8 = Control

Fig. 4.3: Efficacy of some newer insecticides against the population of whitefly, *B. tabaci* in tomato during 2020-21

At 7th day after 2nd spray, all the treatments were recorded to have a significantly lower population of whitefly than untreated control (7.54 larvae $plant^{-1}$). The population of whitefly was lowest (0.87 whitefly $plant^{-1}$) in the check where T_3 was sprayed, which was significantly superior over the rest of the treatments. The declining order of next best insecticides were T_2 (1.48 whitefly $plant^{-1}$), T_4 (1.79 whitefly $plant^{-1}$), T_1 (2.02 whitefly $plant^{-1}$), T_6 (3.01 whitefly $plant^{-1}$), T_5 (3.81 whitefly $plant^{-1}$) and T_7 (3.82 whitefly $plant^{-1}$).

At 10th day after 2nd spray, all the treatments were recorded to have a significantly lower population of whitefly than untreated control (6.34 larvae $plant^{-1}$). The population of whitefly was lowest (0.61 whitefly $plant^{-1}$) in the check where T_3 was sprayed, which was significantly superior over the rest of the treatments. The declining order of next best insecticides were T_2 (0.94 whitefly $plant^{-1}$), T_4 (1.81 whitefly $plant^{-1}$), T_1 (1.92 whitefly $plant^{-1}$), T_7 (2.03 whitefly $plant^{-1}$) and T_5 (2.34 whitefly $plant^{-1}$) and T_6 (2.41 whitefly $plant^{-1}$).

Based on the overall mean population of whitefly, the order of efficacy of different treatments during the crop season 2020-21 was as follows: **T_3 > T_2 > T_4 > T_1 > T_5 > T_7 > T_6 >T_8 untreated check untreated check (Fig 4.6).**

The Percentage field efficacy (PFE) of the insecticides are also found to be in the following order: **T3 (72.25%)> T2 (67.22%) > T_4 (53.68%) > T_1 (49.93%)> T_5 (44.57%)> T_7 (39.02%)> T_6 (38.11%)>T_8 untreated check.**

4.3.3 Effect of newer insecticides against the population of leafminer, *L. trifolii* in tomato during 2020-21

The data on the number of leafminers after various insecticidal sprays were noted one day before and 1st, 3rd, 5th, 7th and 10th days after each application during the cropping season 2020-21 are showed in **Tables 4.7 and 4.8** and graphically depicted in **Figure 4.4.**

At one day before 1st spray, the number of leaf mines in various treatments non-significantly varied from 9.59 to 10.17 leaf mines $plant^{-1}$. But, one day after 1st spray, the number of leaf mines was considerably decreased. It was minimum (2.54

leaf mines plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (2.74 leaf mines plant^{-1}), T_4 (2.94 leaf mines plant^{-1}), T_1 (3.08 leaf mines plant^{-1}), T_6 (3.34 leaf mines plant^{-1}), T_5 (3.58 leaf mines plant^{-1}), T_7 (3.89 leaf mines plant^{-1}). However, in all the treatments, the population of leaf mines was significantly less than untreated control (9.98 leaf mines plant^{-1}).

At 3rd day after 1st spray, the number of leaf mines was again decreased. It was minimum (2.28 leaf mines plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (2.34 leaf mines plant^{-1}), T_1 (2.53 leaf mines plant^{-1}), T_4 (2.74 leaf mines plant^{-1}), T_6 (2.74 leaf mines plant^{-1}), T_5 (2.94 leaf mines plant^{-1}), T_7 (3.21 leaf mines plant^{-1}). However, in all the treatments, the population of leaf mines was significantly less than untreated control (10.16 leaf mines plant^{-1}).

At 5th day after 1st spray, the number of leaf mines was found minimum (1.48 leaf mines plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (1.61 leaf mines plant^{-1}), T_4 (1.81 leaf mines plant^{-1}), T_1 (2.01 leaf mines plant^{-1}), T_6 (1.88 leaf mines plant^{-1}), T_5 (2.14 leaf mines plant^{-1}), T_7 (2.28 leaf mines plant^{-1}). However, in all the treatments, the population of leaf mines was significantly less than untreated control (10.38 leaf mines plant^{-1}).

At 7th day after 1st spray, the number of leaf mines was found minimum (2.01 leaf mines plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (2.21 leaf mines plant^{-1}), T_4 (2.28 leaf mines plant^{-1}), T_1 (2.54 leaf mines plant^{-1}), T_6 (2.48 leaf mines plant^{-1}), T_5 (2.68 leaf mines plant^{-1}), T_7 (2.81 leaf mines plant^{-1}). However, in all the treatments, the population of leaf mines was significantly less than untreated control (10.41 leaf mines plant^{-1}).

At 10th day after 1st spray, the number of leaf mines was found minimum (2.68 leaf mines plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (2.81 leaf mines plant^{-1}), T_4 (2.80 leaf mines plant^{-1}), T_1 (2.94 leaf mines plant^{-1}), T_6 (3.12 leaf mines plant^{-1}), T_5 (3.01 leaf mines plant^{-1}), T_7 (3.41 leaf mines plant^{-1}). However, in all the treatments, the population of leaf mines was significantly less than untreated control (10.65 leaf mines plant^{-1}).

Table 4.7: Effect of newer molecules of insecticides against the population of leafminer, *L. trifolii* in tomato after first application during 2020-21

Treatments	Dose a.i (g)	Formulation (ml)/h.	Mean no. of mines per plant and percent field efficacy											
			DBS	1 DAS	PFE	3 DAS	PFE	5 DAS	PFE	7 DAS	PFE	10 DAS	PFE	Over all mean	Over all mean PFE
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	30+60	250	9.93 (3.31)	3.08 (2.02)	69.3525	2.53 (1.88)	75.3331	2.01 (1.73)	80.7904	2.54 (1.88)	76.3167	2.94 (1.98)	73.5276	3.83833	75.4481628
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	37.5+75	312.5	10.07 (3.32)	2.74 (1.93)	73.1147	2.34 (1.83)	77.5027	1.61 (1.62)	84.8271	2.21 (1.79)	79.6801	2.81 (1.95)	75.0499	3.63	78.7811694
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	45+90	375	10.17 (3.34)	2.54 (1.88)	75.3222	2.28 (1.81)	78.2951	1.48 (1.57)	86.1894	2.01 (1.73)	81.7007	2.68 (1.92)	76.4382	3.52667	80.3768678
Tetraniliprole 200 g/L SC (Tetraniliprole 18.18% w/w SC)	45	225	10.04 (3.32)	2.94 (1.98)	71.0661	2.74 (1.93)	73.5783	1.81 (1.68)	82.8913	2.28 (1.81)	78.9739	2.8 (1.95)	75.0644	3.76833	76.6273978
Spirotetramat 150 g/L OD (Spirotetramat 15.31% w/w OD)	90	600	9.82 (3.29)	3.58 (2.14)	63.9783	2.94 (1.98)	71.0146	2.14 (1.77)	79.3189	2.68 (1.92)	74.7314	3.01 (2.00)	72.5937	4.02833	72.2607703
Cyantriniliprole 10.26% OD	90	900	9.83 (3.29)	3.34 (2.08)	66.4273	2.74 (1.93)	73.0138	1.88 (1.69)	81.85	2.48 (1.86)	76.6409	3.12 (2.03)	71.6211	3.89833	74.4830151
Spiromesifen 22.9% SC	150	625	9.59 (3.25)	3.89 (2.21)	59.9203	3.21 (2.05)	67.5936	2.28 (1.81)	77.4375	2.81 (1.95)	72.8702	3.41 (2.10)	68.2071	4.19833	69.4554137
Control			9.81 (3.29)	9.98 (3.13)		10.16 (3.34)		10.38 (3.37)		10.41 (3.38)		10.65 (3.41)		10.2317	
CD			NS	0.053		0.017		0.02		0.016		0.025			
SE(m)			0.023	0.017		0.006		0.007		0.005		0.008			

(DBS-Days before spray; DAS-Days after spray; PFE-Percentage field efficacy;NS-Non significant)
Values in parenthesis are Square root transformed values

Thus, on the basis of overall mean population of leafminer, the order of efficacy of different insecticides in the present study was as follows: **T3 > T2 > T_4 > T_1 > T_6 > T_5 > T_7 >T_8 untreated check (Table-4.7).**

The Percentage field efficacy (PFE) of the insecticides are also found to be in the following order: **T3 (80.37%)> T2 (78.78%) > T_4 (76.62%) > T_1 (75.44%)> T_6 (74.48%)> T_5 (72.26%)> T_7 (69.45%)>T_8 untreated check.**

At one day before 2nd spray, the number of leaf mines in various treatments non-significantly varied from 4.53 to 10.72 leaf mines plant^{-1}. But, one day after 2nd spray, the number of leaf mines was considerably decreased. It was minimum (1.74 leaf mines plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (2.36 leaf mines plant^{-1}), T_4 (2.41 leaf mines plant^{-1}), T_1 (2.46 leaf mines plant^{-1}), T_6 (2.64 leaf mines plant^{-1}), T_5 (2.66 leaf mines plant^{-1}), T_7 (3.14 leaf mines plant^{-1}). However, in all the treatments, the population of leaf mines was significantly less than untreated control (10.16 leaf mines plant^{-1}).

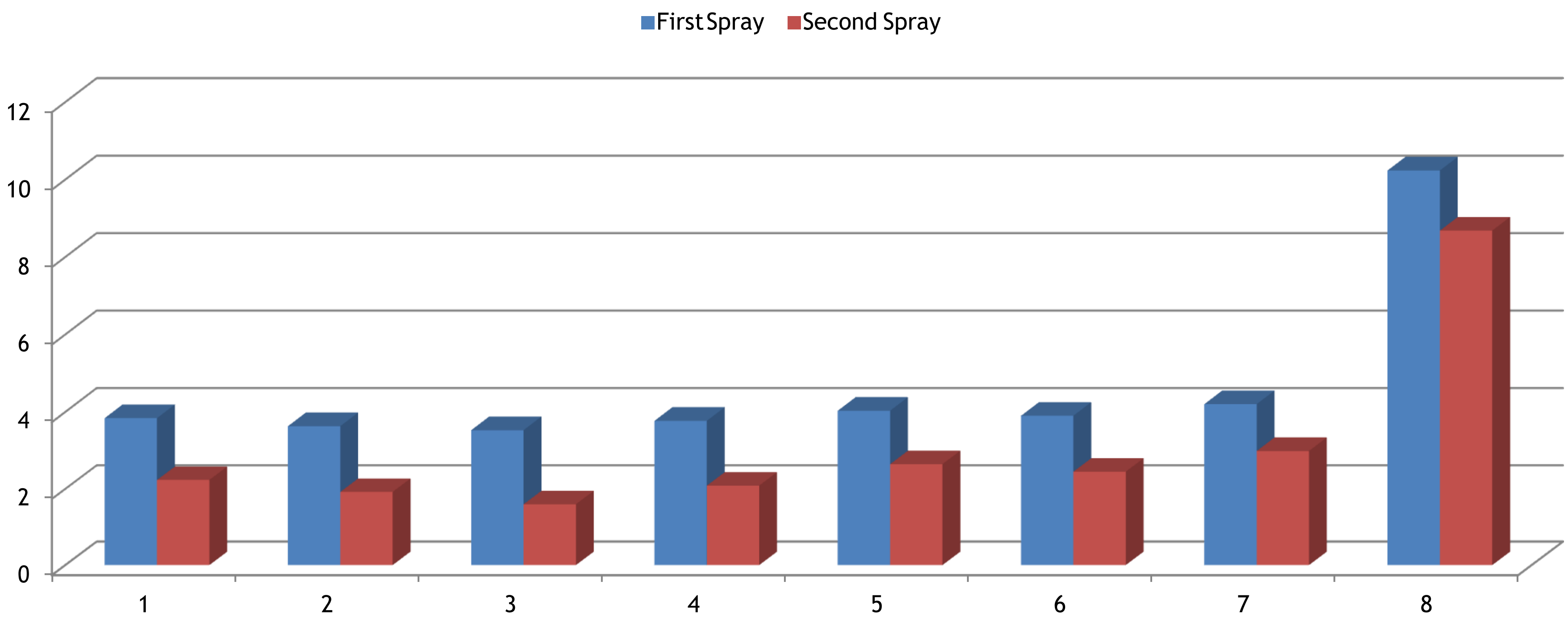
At 3rd day after 2nd spray, the number of leaf mines was again decreased. It was minimum (1.14 leaf mines plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (1.66 leaf mines plant^{-1}), T_4 (2.01 leaf mines plant^{-1}), T_1 (2.08 leaf mines plant^{-1}), T_6 (2.28 leaf mines plant^{-1}), T_5 (2.41 leaf mines plant^{-1}), T_7 (2.88 leaf mines plant^{-1}). However, in all the treatments, the population of leaf mines was significantly less than untreated control (9.52 leaf mines plant^{-1}).

At 5th day after 2nd spray, the number of leaf mines was found minimum (0.88 leaf mines plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (1.28 leaf mines plant^{-1}), T_1 (1.54 leaf mines plant^{-1}), T_4 (1.54 leaf mines plant^{-1}), T_6 (1.94 leaf mines plant^{-1}), T_5 (2.21 leaf mines plant^{-1}), T_7 (2.54 leaf mines plant^{-1}). However, in all the treatments, the population of leaf mines was significantly less than untreated control (8.86 leaf mines plant^{-1}).

Table 4.8: Effect of newer molecules of insecticides against the population of leafminer, *L. trifolii* in tomato after second application during 2020-21

Treatments	Dose a.i (g)	Formulation (ml)/h.	Mean no. of mines per plant and percent field efficacy												
			DBS	1 DAS	PFE	3 DAS	PFE	5 DAS	PFE	7 DAS	PFE	10 DAS	PFE	Over all mean	Over all mean PFE
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	30+60	250	4.76 (2.40)	2.46 (1.86)	48.9352	2.08 (1.75)	57.6942	1.54 (1.59)	69.2967	1.34 (1.53)	73.9351	1.21 (1.49)	77.2714	2.23167	62.4652914
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	37.5+75	312.5	4.67 (2.38)	2.34 (1.83)	50.4901	1.66 (1.63)	65.586	1.28 (1.51)	73.9886	0.88 (1.37)	82.5529	0.68 (1.29)	86.9807	1.91833	68.1543746
Tetraniliprole 120 g/L + Spirotetramat 240 g/L SC	45+90	375	4.53 (2.35)	1.74 (1.65)	62.0472	1.14 (1.46)	75.6359	0.88 (1.37)	81.5645	0.74 (1.32)	84.8751	0.54 (1.24)	89.3416	1.595	76.0306568
Tetraniliprole 200 g/L SC (Tetraniliprole 18.18% w/w SC)	45	225	4.72 (2.39)	2.41 (1.85)	49.5492	2.01 (1.73)	58.7715	1.54 (1.59)	69.0365	1.14 (1.46)	77.6374	0.68 (1.29)	87.1186	2.08333	63.7486439
Spirotetramat 150 g/L OD (Spirotetramat 15.31% w/w OD)	90	600	4.91 (2.43)	2.66 (1.91)	46.4705	2.41 (1.85)	52.4797	2.21 (1.79)	57.2848	1.88 (1.69)	64.5485	1.81 (1.68)	67.0397	2.64667	55.1958616
Cyantriniliprole 10.26% OD	90	900	4.88 (2.42)	2.64 (1.91)	46.5464	2.28 (1.81)	54.7666	1.94 (1.71)	62.2729	1.54 (1.59)	70.7814	1.41 (1.55)	74.1659	2.44833	58.5918230
Spiromesifen 22.9% SC	150	625	5.01 (2.45)	3.14 (2.03)	38.0723	2.88 (1.97)	44.3457	2.54 (1.88)	51.8864	2.28 (1.81)	57.8638	2.08 (1.75)	62.8789	2.98833	48.0420496
Control			10.72 (3.42)	10.16 (3.34)		9.52 (3.24)		8.86 (3.14)		7.14 (2.85)		5.68 (2.58)		8.68	
CD			0.019	0.022		0.022		0.018		0.019		0.02			
SE(m)			0.006	0.007		0.007		0.006		0.006		0.007			

(DBS-Days before spray; DAS-Days after spray; PFE-Percentage field efficacy)
Values in parenthesis are Square root transformed values



x-axis:Treatments y-axis: Leafminer population per plant

T1 = Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 30+60 g a.i./250 ml, T2 = Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml, T3= Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i. /375 ml., T4 Tetraniliprole 200 g/L SC, T5 = Spiromesifan 22.9%SC, T6 = Cyantriniliprole 10.26 % OD, T7 = Spiromesifan 22.9%SC, T8 = Control

Fig. 4.5: Efficacy of some newer insecticides against the population of leafminer, *L. trifolii* in tomato during 2020-21

At 7th day after 2nd spray, the number of leaf mines was found minimum (0.74 leaf mines plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (0.88 leaf mines plant^{-1}), T_4 (1.14 leaf mines plant^{-1}), T_1 (1.34 leaf mines plant^{-1}), T_6 (1.54 leaf mines plant^{-1}), T_5 (1.88 leaf mines plant^{-1}), T_7 (2.28 leaf mines plant^{-1}). However, in all the treatments, the population of leaf mines was significantly less than untreated control (7.14 leaf mines plant^{-1}).

At 10th day after 2nd spray, the number of leaf mines was found minimum (0.54 leaf mines plant^{-1}) with T_3 (with a significant difference from all other treatments) followed by T_2 (0.68 leaf mines plant^{-1}), T_4 (0.68 leaf mines plant^{-1}), T_1 (1.21 leaf mines plant^{-1}), T_6 (1.41 leaf mines plant^{-1}), T_5 (1.81 leaf mines plant^{-1}), T_7 (2.08 leaf mines plant^{-1}). However, in all the treatments, the population of leaf mines was significantly less than untreated control (5.68 leaf mines plant^{-1}).

Thus, on the basis of overall mean population of leafminer, the order of efficacy of different insecticides in the present study was as follows: **T3 > T2 > T_4 > T_1 > T_6 > T_5 > T_7 >T_8 untreated check (Table-4.7).**

The Percentage field efficacy (PFE) of the insecticides are also found to be in the following order: **T3 (76.03%)> T2 (68.15%) > T_4 (63.74%) > T_1 (62.46%)> T_6 (58.59%)> T_5 (55.19%)> T_7 (48.04%)>T_8 untreated check.**

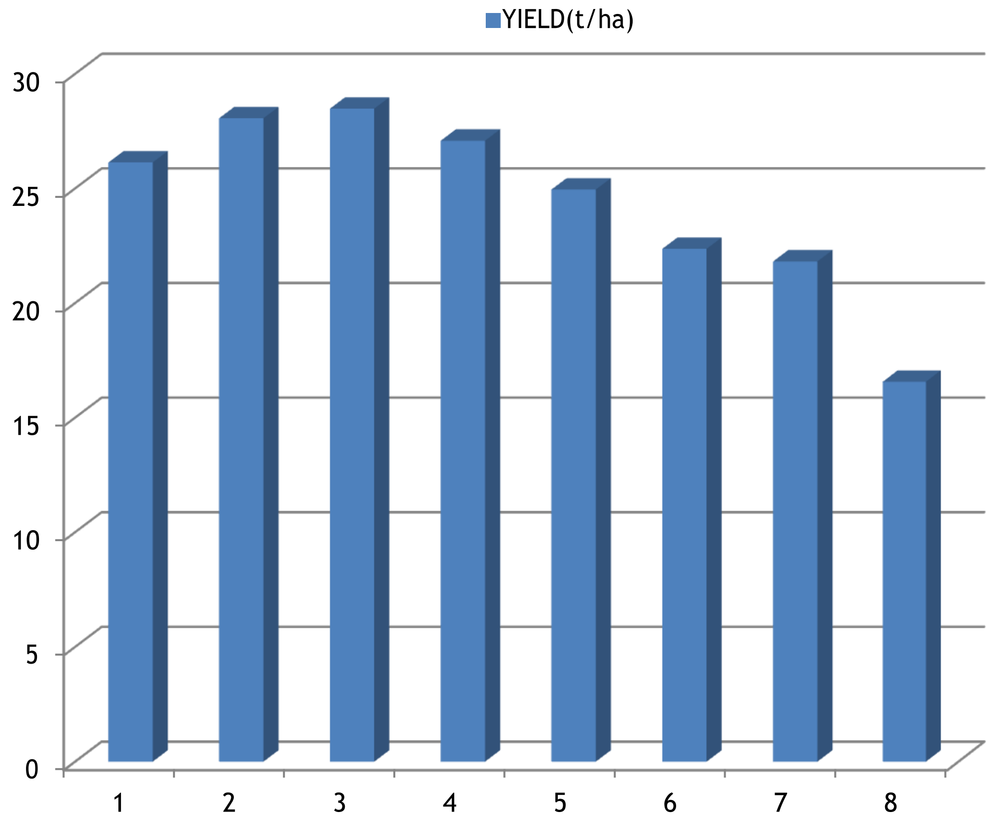
4.4 EFFECT OF NEWER MOLECULES OF INSECTICIDES ON THE YIELD OF TOMATO

The data collected during the cropping period of 2020-21 **(Fig 4.5)** showed that the yield varied from 16.56 to 28.48 t ha^{-1} in different insecticidal treatments. The treatments with T_3 produced the highest yield (28.48 t ha^{-1}) which significantly differed from all other treatments. This was followed by T_2 (28.06 t ha^{-1}), T_4 (27.08 t ha^{-1}), T_1 (26.13 t ha^{-1}), T_5 (24.95 t ha^{-1}), T_6 (22.36 t ha^{-1}), T_7 (21.81 t ha^{-1}) and control plot (16.56 t ha^{-1}). T_3 was noted highest % increase in yield over control (71.87%) **(Table 4.9).**

The above results revealed that T_3 recorded the maximum yield and appeared to be due to higher efficacy and unique mode of insecticidal action resulted in the highest reduction of insects.

Table 4.9: Effect of newer molecules of insecticides on the yield of tomato during 2020-21

Treatment No.	Treatments	Dosage/ha		YIELD		
		a.i.(g)	a.i.(g)	Kg per plot	Tons per ha	% Increase over Control
T_1	Tetraniliprole 120g/L + Spirotetramat 240g/L SC	30+60	250	15.68 (4.08)	26.13	57.70
T_2	Tetraniliprole 120g/L + Spirotetramat 240g/L SC	37.5+75	312.5	16.83 (4.22)	28.06	69.34
T_3	Tetraniliprole 120g/L + Spirotetramat 240g/L SC	45+90	375	17.08 (4.25)	28.48	71.87
T_4	Tetraniliprole 200g/L SC	45	225	16.26 (4.15)	27.08	63.43
T_5	Spirotetramat 150g/L OD	90	600	14.98 (3.99)	24.95	50.59
T_6	Cyantraniliprole 10.26% SC	90	900	13.42 (3.79)	22.36	34.97
T_7	Spiromesifen 22.9% SC	150	625	13.07 (3.75)	21.81	31.65
T_8	Control			9.96 (3.31)	16.56	
C.D.				0.009		
S.E.(m)				0.003		



x-axis:Treatments y-axis: Yield of the plots(t/ha)

T1 = Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 30+60 g a.i./250 ml, T2 = Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml, T3= Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i. /375 ml., T4 Tetraniliprole 200 g/L SC, T5 = Spiromesifan 22.9%SC, T6 = Cyantriniliprole 10.26 % OD, T7 = Spiromesifan 22.9%SC, T8 = Control

Fig 4.5: Effect of newer molecules of insecticides on the yield of tomato during 2020-21

Chapter tf

DISCUSSION

The present experiment entitled "Study on Seasonal Incidence and Bio-efficacy of some Newer Insecticides on the Insect-Pest Complex of Tomato (*Lycopericum esculentum* L.)" was conducted in the year of 2020-21 at Vegetable Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh to study pest complex, population dynamics, and bio-efficacy of some newer insecticides against major insect pests of tomato and their impact on yield of tomato.

A total of seven species of insect pest have been recorded to attack tomato crop. Of these, one species of borers, *Helicoverpa armigera* (Hub.), three species of defoliators viz., *Spodoptera litura* (Fab.), *Liriomyza trifolii* (Burgess), *Hieroglyphus banian* (Fab.) and three species of sapsuckers viz., *Bemisia tabaci* (Gennadius), *Thrips tabaci* (Lindman), *Aphis gossypii* (Glover) are recorded. Among the various insect pests of tomato *Helicoverpa armigera* (Hbn.), *Bemisia tabaci* (Gennadius) and *Liriomyza trifolii* (Burgess) were found to exhibit relatively higher abundance as compared to other species in both the years and therefore, considered as the pest of major importance.

The present studies deal with the seasonal abundance of major insect pests of tomato and impact of abiotic factors on their population and bioefficacy of some newer insecticides on major insect pest of tomato crop and also studied the impact of insecticidal treatments on tomato yield.The results obtained in present studies were discussed in the light of available literature and are presented below:

5.1 POPULATION DYNAMICS OF MAJOR INSECT-PESTS OF TOMATO AND THEIR CORRELATION WITH ABIOTIC FACTORS

5.1.1 Fruit borer, *Helicoverpa armigera* (Hbn.)

The first presence of larva with a mean number of 0.09 larvae per plant in the 47th SMW(of 2020).Then the no of larva became negligible due to weather condition and it becomes visible in 50th SMW(0.24 larvae per plant).The number of larvae steadily increased and reached its peak(4.38 larvae/plant) in the 10th SMW(of 2021) followed by a steady decrease in the number. However, no larvae were found from 43^{rd} to 46^{th} SMW(of 2020). **Reddy and Kumar (2004)** observed similar kind of results and concluded that in March-April it reached a topmost level, and in October-November, the incidence was reduced. A related pattern of larval populations was found at different locations. **Kharpuse and Bajpai (2006)** observed similar kind of results, and they concluded that the peak number of *H. armigera* was found in the second and last week of March.

The correlation between the weather factors and number of larvae revealed a non-significantly positive correlation with maximum and average temp.,but it showed negative non-significant correlation with rainfall,minimum temperature,morn,even and avg RH. Similar result was found by **Khan *et al*. (2003).** He recorded a positive association between mean temperature and outbreak of *H. armigera*. A substantial negative correlation between the larval population and higher and lower RH.

5.2.2 Whitefly, *Bemisia Tabaci* (Genn)

The first presence of pest with a mean number of 0.001 adults per plant is seen in the 45th SMW(of 2020).Then number of adults steadily increased and reached its peak (7.880 adults/plant) in the 9th SMW(of 2021) followed by a steady decrease in the number. However, no pest was found from 43^{rd} to 44^{th} SMW(of 2020). Similar result was observed by **Mandloi *et al. (*2015)** found the maximum number of whiteflies was recorded at 7th and 9th SMW. **Chaudhuri *et al.* (2001)** recorded the peak density of *Bemisia tabaci* (Genn) during mid-February in West Bengal, India. High rates of infestation were sustained from mid-February to mid-March. Both these observations support the results obtained in the present experiment.

The correlation between the weather factors and number of adults revealed a non-significantly positive correlation with morning and avg. RH,but it showed negative non-significant correlation with rainfall,maximum,minimum,average temperature and evening RH. An equivalent finding has supported this study concluded by **Mathur *et al.* (2012)**, where they stated the incidence of jassids and whitefly shown a substantial negative correlation with wind speed and both max. and min. temp. Whereas, positive correlation with mean RH.

5.2.3 Leafminer, *Liriomyza trifolii* (Burgess)

The first presence of mined leaves in plant with a mean number 0.02 mine per plant were recorded in the 47th SMW(of 2020).Then the mined leaves become negligible due to weather parameters and was seen again during the 50th SMW of 2020.The number of mines per plant steadily increased and reached its peak in the 10th SMW(of 2021)followed by a steady decrease in the number. However, no mined leaves were found from 43rd to 46th SMW(of 2020). . **Mandloi *et al.* (2015)** also reported the incidence of leafminer at 43rd SMW to 12th SMW. Also **Chaudhuri and Senapati (2004)** elucidated that the leaf miner population was initiated at about 46th standard meteorological week (SMW), increased at first slowly up to 01st SMW and then steadily up to 6th SMW attaining the maximum at about 8th SMW which was maintained up to 13th SMW. These are very similar with the present experimental conclusion.

The correlation between the weather factors and number of mines revealed a non-significantly positive correlation with morning and average RH,but it showed negative non-significant correlation with rainfall,maximum,minimum,average temperature and evening RH. **Chaudhuri and Senapati (2004)** also observed that abiotic conditions such as maximum temperature, minimum temperature, temperature gradient, average temperatue and sunshine hours had a significant negative influence on *L. trifoli* population. In case of relative humidity gradient, a positive influence was observed.

5.2 BIOEFFICACY OF SOME NEWER INSECTICIDES AGAINST MAJOR INSECT PESTS OF TOMATO UNDER FIELD CONDITION

5.2.1 Impacts of newer insecticides against the population of fruit borer, *H. armigera*

The relative bio-efficacy of certain new insecticides was evaluated under field conditions for management of fruit borers during 2020-21 and discussed below. In present study, Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i. /375 ml. was found most effective and superior over the insecticidal treatments after 1st and 2nd spray followed by Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml,Spirotetramat 150 g/L,Tetraniliprole 200 g/L SC,Spiromesifan 22.9%SC, Cyantriniliprole 10.26 % OD and Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 30+60 g a.i./250 ml. **Mandal (2012)** reported that cyantraniliprole 10% OD @ 90 and 105 g *a.i.*ha-1 dosage were more effective against the fruit borer *H.armigera* than the standard checks of imidacloprid 17.8% SL and fipronil 5% SC. Highest yield is also obtained with the same treatments.The results from an expt conducted by **Ramesh Babu (2013)** revealed that tetraniliprole SC 200 w/v was most effective in reducing semilooper larval population in Soybean.

5.2.2 Effect of newer molecules of insecticides against the population of Whitefly, *B.tabaci*

The relative bio-efficacy of certain new insecticides was evaluated under field conditions for management of fruit borers during 2020-21 and discussed below. In present study, Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i. /375 ml. was found most effective and superior over the insecticidal treatments after 1st and 2nd spray followed by Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml, Tetraniliprole 200 g/L SC, Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 30+60 g a.i./250 ml, Spirotetramat 150 g/L, Spiromesifan 22.9%SC, Cyantriniliprole 10.26 % OD. **Mann *et al.* (2012)** stated that Spiromesifen could be a valuable resource for the reduction of *B. tabaci*ingrown vegetables. Spiromesifen compounds have a unique mode of action which inhibits lipid metabolism, leading to decreased in adult fecundity and reduce insect growth. **Mandal (2012)** reported that cyantraniliprole 10% OD @ 90 and 105 g *a.i.*ha-1was highly effective in controlling the fruit borer, *H. armigera*, aphid, *Aphis gossypii* and white fly, *Bemisiatabaci*in tomato crop. They were tested along with the standard checks of imidacloprid 17.8% SL and fipronil 5% SC and the results showed that they were comparatively more than standard checks.These reports are similar to the present experimental results.

5.2.3 Effect of newer molecules of insecticides against the population of leaf miner. *L. trifolii*

The relative bio-efficacy of certain new insecticides was evaluated under field conditions for management of fruit borers during 2020-21 and discussed below. In present study, Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i. /375 ml.

was found most effective and superior over the insecticidal treatments after 1st and 2nd spray followed by Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml, Tetraniliprole 200 g/L SC, Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 30+60 g a.i./250 ml, Spirotetramat 150 g/L, Cyantriniliprole 10.26 % OD, Spiromesifan 22.9%SC. From an expt conducted by **MK Mahla et.al.(2013**)in Rajasthan college of Agriculture,Udaipur we got the similar findings. He concluded that Tetraniliprole SC 200 w/v along with Coragen after two spray caused highest reduction in leaf minor population and damage. **Sapkal*et al.* (2018)** reported that among spinosad 45% SC, chlorantraniliprole 18.5% SC, emamectin benzoate 5% SG, indoxacarb 14.5% SC, cyantraniliprole 10.26% OD, spinatoram 11.7% SC and flubendiamide 39.35% SG insecticides chlorantraniliprole 18.5% SC found most effective than all other treatment on spraying thrice followed by emamectin benzoate 5% SG >spinatoram 11.7% SC >spinosad 45% SC >flubendiamide 39.35% SG > indoxacarb 14.5% SC > cyantraniliprole 10.26% OD which is similar to the present experimental findings.

5.3 EFFECT OF INSECTICIDAL TREATMENTS ON THE YIELD OF TOMATO

The data collected during the cropping period of 2020-21 showed that the treatments with T_3 produced the highest yield (28.48 t ha-1) which significantly differed from all other treatments. This was followed by T_2 (28.06 t ha-1), T_4 (27.08 t ha-1), T_1 (26.13 t ha-1), T_5 (24.95 t ha-1), T_6 (22.36 t ha-1), T_7 (21.81 t ha-1) and control plot (16.56 t ha-1). T_3 was noted highest % increase in yield over control (71.87%).In 2013, **Ramesh Babu (year?)** also found Tetraniliprole @ 50 and 60 g a.i./ha was found to be very effective in reducing pest population and in getting highest mean yield. **Sharma** (2004) concluded from the experiment that Spiromesifen residues were found below the LOQ of 0.05 mg/kg and also are detectable in soil after 15 days of treatment,hence less suitable for qualitative yield.

SUMMARY AND CONCLUSION

The insect pest problems in agriculture are probably as old as agriculture itself. In past days, the pest problems were managed by various means of eco-friendly approaches, and many of the pests which have gained severe pest status at present were not considered to be important in the past. With the scientific advancement and research in various sector of agriculture with the purpose to increase the yield, several newer technologies have been developed, and some of them were revolutionary. The development of various synthetic chemical toxicants to overcome the pest problem was one of them. But, the unscientific and indiscriminate use of those scientific discoveries has created numerous problems in various field of agriculture which includes persistence, bioaccumulation, biomagnification, mammalian hazard, pest resistance, resurgence, secondary pest outbreak and the most important one, destruction of natural enemies. Though it was late, people felt inclined about those hazardous effects and have taken many measures to overcome it and consequently, many of the revolutionary chemicals had been banned which results in an increasing demand for safer, biodegradable, specific and environment-friendly insecticides for controlling pest problems and this led to the development of newer pesticides.

Taking all the matters into consideration, the present research was carried out, and the findings can be summarized as follow:

The objective of the experiment were

(1) To study the population dynamics of major tomato insects pests and their correlation with abiotic factors,

(2) To study the bioefficacy of some newer insecticides against major insect pests of tomato under field condition,

(3) To study the effect of some newer insecticides on the yield of tomato crop.

- During the present experiment, total 7 species of insect-pests were reported to exist in the ecosystem of the crop. Among which three species were major and the remaining four species being minor.
- All the major pests of tomato shown their maximum abundance in between 7th to 10th SMW.
- The correlation between the weather factors and number of larvae revealed a non-significantly positive correlation with maximum and average temp., but it showed negative non-significant correlation with rainfall, minimum temperature, morn, even and avg RH.
- The correlation between the weather factors and number of adults revealed a non-significantly positive correlation with morning and avg. RH, but it showed negative non-significant correlation with rainfall, maximum, minimum, average temperature and evening RH.
- The correlation between the weather factors and number of mines revealed a non-significantly positive correlation with morning and average RH,but it showed negative non-significant correlation with rainfall, maximum, minimum, average temperature and evening RH.
- In the field, the efficacy of seven Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 30+60 g a.i./250 ml, Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml, Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90 g a.i. g/375 ml, Tetraniliprole 200 g/L SC, Spirotetramat 150 g/L, Cyantriniliprole 10.26 % OD, Spiromesifan 22.9%SC insecticides were tested based on per cent reduction of mean pest population after two consecutive sprays at 15 days interval.
- In comparison with the untreated plot, all the treatments exhibited better result in controlling *H. armigera,Bemisia tabaci and Liriomyza trifolii.*
- In case of a reduction of fruit damage by *H. armigera*, , Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i. /375 ml. was found most effective and superior over the insecticidal treatments after 1st and 2nd spray followed by

Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml, Spirotetramat 150 g/L, Tetraniliprole 200 g/L SC, Spiromesifan 22.9%SC.

- In case of reduction of damage by whitefly Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i. /375 ml. was found most effective and superior over the insecticidal treatments after 1st and 2nd spray followed by Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml, Tetraniliprole 200 g/L SC.
- In case of reduction of damage by leaf minor, Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i./375 ml. was found most effective and superior over the insecticidal treatments after 1st and 2nd spray followed by Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 37.5+75 g a.i./312.5 ml, Tetraniliprole 200 g/L SC.
- In case of yield, the treatments with T_3 produced the highest yield (28.48 t ha^{-1}) followed by T_2 (28.06 t ha^{-1}), T_4 (27.08 t ha^{-1}), T_1 (26.13 t ha^{-1}), T_5 (24.95 t ha^{-1}), T_6 (22.36 t ha^{-1}), T_7 (21.81 t ha^{-1}) and control plot (16.56 t ha^{-1}). T_3 was noted highest % increase in yield over control (71.87%).

CONCLUSION

As tomato is consumed raw (not in a processed form generally), it is highly required to be free from insecticidal residue. The newer molecules of insecticide have a quick biodegradable property to get a higher yield without having any pesticidal residue on the desired crop or having significantly less of it. The overall findings from the present investigation in the field revealed that the pesticides of newer molecules performed very well in minimizing the pest population and increase the marketable yield over control. The current research findings show that all the insecticides are giving superior result over control, and they are less toxicity upon the non-target pests. Being short persistent, biodegradable and target specific, they are supremely environment friendly.

The present research would also benefit the farmers of Eastern region of U.P to recognize the variation of insect pests of tomato. According to the observations of the current experiment, the newer insecticides viz. Tetraniliprole 120 g/L+Spiotetramat 240 g/L SC 45+90g a.i. /375 ml was found to be the most effective in reducing of *H. armigera*, Whitefly and Leafminer. It is also quite evident that for accomplishing the faster reduction of insect pests, it can be an excellent substitute chemical against the monotonous insecticides.

Thus, it is the crucial time to take a revolutionary decision and essential steps to shift from traditional synthetic insecticides to eco-friendly newer insecticides for managing the different pests of tomato. The recent research may serve as a legitimate pathfinder for imminent research.

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