The Pharma Innovation Journal 2022; SP-11(5): 1098-1104

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(5): 1098-1104

www.thepharmajournal.com
Received: 08-02-2022
Accepted: 18-04-2022

Swathi H Dibbad
Department of Entomology, College of Horticulture, Mudigere, Karnataka, Keladi Shivappanayaka University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

Dr. L Hanumatharaya
Department of Entomology, College of Horticulture, Mudigere, Karnataka, Keladi Shivappanayaka University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

Dr. M Hanumanthappa
Directorate of Research, Keladi Shivappanayaka University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

Dr. Suchithra Kumari MH
Department of Entomology, College of Horticulture, Mudigere, Karnataka, Keladi Shivappanayaka University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

Corresponding Author
Swathi H Dibbad
Department of Entomology, College of Horticulture, Mudigere, Karnataka, Keladi Shivappanayaka University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India

Evaluation of different modules for the management of major insect pests of tomato

Swathi H Dibbad, Dr. L Hanumatharaya, Dr. M Hanumanthappa and Dr. Suchithra Kumari MH

Abstract

Investigation on "Evaluation of different modules for the management of major insect pests of tomato" was carried out under polyhouse condition at College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India. Among insecticide scheduling, T_4 (seed treatment with imidacloprid, seedling root dip with imidacloprid, fipronil 5 SC (48 DAT) + imidacloprid 17.8 SL (73 DAT) + chlorantraniliprole 18.5 SC (98 DAT) + dinotefuron 20 SG (123 DAT) insecticide schedule was proved to be better in reducing whitefly, leaf miner and tomato pinworm population on tomato under naturally ventilated polyhouse condition.

Keywords: Insecticide, whitefly, leaf miner, tomato pin worm, management

Introduction

The major insect pests of tomato includes whitefly, *Trialeurodes vaporariorum* (Westwood), serpentine leaf miner, *Liriomyza trifolii* (Burgess), South American leaf miner *Tuta absoluta* (Meyrick), thrips, *Scirtothrips dorsalis* (Hood), aphid *Aphis gossypii* (Glover), jassid, *Amrasca devastans* (Distant) and fruit borer, *Helicoverpa armigera* (Hub.) are major species according to (Mandloi *et al.*, 2015) [9]. Among the key insect pests the most dangerous pests having a pandemic distribution are whitefly (*T. vaporariorum*), leaf miner (*L. trifolii*) and tomato pin worm (*T. absoluta*) which are found to damage many vital crops including vegetables, tubers, fiber crops and ornamentals from tropics and sub-tropics to temperate climates in crops grown under open and protected environment (Anu *et al.*, 2020) [1]. The wide range of geographical distribution with varieties of host range make them difficult to control. The larvae of *L. trifolii* feed on mesophyll and reduce chlorophyll content of leaves. Adults puncture leaves to feed and oviposit *T. vaporariorum*, which sucks the phloem sap of growing tomato plant, also transmits tomato yellow curl viruses (Zhang *et al.*, 2017) [15]. Tomato pin worm has been responsible for losses of 80-100 per cent in tomato under both protected cultivation and open fields. Yield and fruit quality are both considerably impacted by direct feeding of the pest as well as secondary pathogens entering host plants through wounds made by the pest (Michailidis *et al.*, 2019) [11]. To overcome the above problems, the present study was undertaken for the management of major insect pests of tomato.

Materials and Method

An experiment was conducted during 2019-20 under polyhouse condition at College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India**.** The experiment was laid out in Randomized Complete Block Design (RCBD). There were five treatments with five replications. Tomato cultivar Arka Samrat seedlings, were transplanted in the main field with a plot size of 6.5 m × 1.5 m and spacing of about 65 × 60 cm on 18th December 2019. Irrigation was provided through drip immediately after transplanting. Seedling root dip was imposed while transplanting and the other treatments were imposed according to the schedule. Treatment details given in table 1**.**

Table 1: Treatment details of biopesticides and insecticides used against major insect pests of tomato

Sl. No	Seed treatment (at sowing)	Seedling root dip (at transplanting)	48DAT	73DAT	98DAT	123DAT
T1	Seed treatment with azadirachtin 10,000ppm @ 5ml/l	Seedling root dip with azadirachtin 10,000ppm @ 5ml/l	*Lecanicillium lecani* (1×10⁸cfu/g) @ 5g/l	Spinosad 45SC @ 0.25ml/l	Azadirachtin 10,000ppm 2ml/l	Abamectin 1.9w/w @ 0.25ml/l
T2	Seed treatment with imidacloprid @ 5g/kg of seeds	Seedling root dip with imidacloprid 17.8SL @ 1ml/l	*Lecanicillium lecani* (1×10⁸cfu/g) @ 5g/l	Buprofezin 25% SC @ 1ml/l	Cyantraniliprole 10.26% OD @ 1.8 ml/l	Azadirachtin 10,000ppm @ 2ml/l
T3	Seed treatment with imidacloprid @ 5g/kg of seeds	Seedling root dip with imidacloprid 17.8SL @ 1ml/l	Chlorfenapyr 10% SC @ 1.5ml/l	Emamectin benzoate 5% SG @ 0.25g/l	Thiamethoxam 25% WG @ 0.25g/l	Spinosad 45SC @ 0.25ml/l
T4	Seed treatment with imidacloprid @ 5g/kg of seeds	Seedling root dip with imidacloprid 17.8SL @ 1ml/l	Fipronil 5SC @ 1ml/l	Imidacloprid 17.8% SL @ 0.3ml/l	Chlorantraniliprole 18.5 SC @ 1.8ml/ l	Dinotefuron 20% SG @ 0.5-1ml/l
T5 (RPP)	-	-	Imidacloprid 17.8% SL @ 0.3ml/l	Dimethoate 30% EC @ 1.7ml/l	Imidacloprid 17.8% SL @ 0.3ml/l	Dimethoate 30% EC @1.7ml/l

DAT- Days After Transplanting

Incidence of whitefly, leaf miner and tomato pin worm

The observations were recorded on five randomly selected plants from each plot at twenty five days intervals along with one observation which was taken between the intervals, starting from 50 to 125 DAT (days after transplanting) after the imposition of treatments. Both nymphs and adults of whitefly was counted on fully opened randomly selected top, three leaves. Observation on whitefly adults were recorded in early morning hours, whereas, the nymphal population was counted per unit area (2 cm^2) under a stereo-zoom binocular microscope at 10 X magnification (marques *et al*., 1990) [10]. In case of leaf miner and tomato pin worm, from each treatment and replication, five plants were selected randomly from each plot and number of mines per leaf was counted on fully opened, randomly selected three leaves (Christopher *et al*., 2018) [4]. Per cent fruit damage due to pin worm infestation was calculated by using the following formula.

$$\text{Per cent fruit damage (\%)} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits observed}} \times 100$$

Fruit yield (tons/ 500 m. sq. area) and Cost economics

Marketable fruit yield was recorded at the time of each picking from each cultivar separately. The yield was expressed in a tons of fruits per 500 m. sq.

Cost effectiveness of each treatment was assessed based on net returns. Net returns of each treatment were worked out by deducting total cost of the treatment from the gross returns. Total cost of production includes both cultivation as well as plant protection cost. Further, gross returns, net returns and B: C ratio was calculated by using formulas as given below.

Gross returns = Marketable fruit yield × Market price
Net returns = Gross returns – Total cost

$$\text{C : B ratio} = \frac{\text{Net returns}}{\text{Total cost}}$$

Statistical analysis of the experimental data

The data obtained from each treatments in the present investigation for various parameters such as number of adults and nymphs of whitefly, number of mines per leaf, per cent leaf miner infestation and per cent pin worm/ blotch miner infestation per plant were subjected to ANOVA for a Randomized Complete Block Design (RCBD), with appropriate statistical transformation (Square root and Angular), wherever necessary. After analysis, data was suitably interpreted by using the critical difference value calculated at 0.05 level of probability. The calculations were done at five per cent level of significance.

Results and Discussion

Influence of treatments on the population density of whitefly nymphs

At 50 DAT, significantly lower whitefly nymphs were recorded in T_4 (0.00 / 2cm^2) and T_3 (0.11 / 2cm^2) which were statistically on par with each other but significantly lower than T_5 (0.22 nymphs/ 2cm^2). Further, significantly higher whitefly nymphs were recorded in T_1 (0.97 / 2cm^2) and T_2 (0.80 nymphs/ 2cm^2) and they were on par with each other. At 63 DAT, significantly lowest whitefly nymphs were recorded in T_4 (0.12 / 2cm^2), T_3 (0.14 / 2cm^2) and T_5 (0.26 / 2 cm^2) being statistically on par with each other. However, T_2 (0.78 nymphs/ 2cm^2) being statistically on par with T_1 (0.90 nymphs/ 2cm^2) (Table 2).

At 75 DAT, once again T_4 and T_3 (0.19 and 0.20, respectively) recorded significantly lower nymphs per two cm^2 leaf area being at par with each other. The next best treatment, which received significantly lowest nymphs, was T_5 (0.40 / 2cm^2). Whereas, significantly higher whiteflies were recorded in T_1 and T_2 (0.86 and 0.81 nymphs/ 2cm^2, respectively) being statistically at par with each other. At 88 DAT, again confirmed same trend with slightly higher incidence of whitefly nymphs per two cm^2 leaf area. Among the treatments T_4 and T_3 (0.20 and 0.26, respectively) were statistically on par with each other. While, T_5 (0.42) had moderate density of nymphs per two cm^2 leaf area. However, significantly higher nymphs were recorded in T_1 and T_2 (0.90 and 0.84 / 2cm^2, respectively) being on par with each other (Table 2).

The efficacy of different treatments at 100 DAT has recorded significantly lower nymphs per two cm^2 in T_3 and T_4 (0.30 and 0.36, respectively) which are statistically on par with each other. The next best treatment, which received lowest nymphs load, was in T_5 (0.60 / 2cm^2). However, T_2 and T_1 (0.79 and 0.78, respectively) recorded significantly higher whitefly nymphs per two cm^2 leaf area and they were statistically on par with each other. At 113 DAT, again T_3 and T_4 (0.44 and 0.46 nymphs/ 2cm^2, respectively) stand superior in recording lower nymphal density per two cm^2.

Further, T_5, T_1 and T_2 (0.80, 0.80 and 0.85, respectively) recorded significantly higher nymph density per two cm^2 leaf area being on par with each other. At 125 DAT, T_4 and T_3 (0.28 and 0.30 / 2cm^2, respectively) recorded significantly lower whitefly nymphs density being on par with each other. The treatment received moderate nymphal load were T_5 (0.56 / 2cm^2) being on par with T_1 and T_2 (0.73 and 0.74 nymphs/ 2cm^2, respectively).

The overall mean indicated that among the treatments, T_4 and T_3 (0.23 and 0.25, respectively) recorded significantly lower density of whitefly nymphs per two cm^2. The next best treatment that received lowest nymphs population per two cm^2 leaf area in T_5 (0.47). However, higher whitefly nymphal load were recorded in T_1 and T_2 (0.85 and 0.80 / 2cm^2, respectively) being statistically on par with each other (Table 2).

The present investigation is in line with (Magsi *et al.*, 2017) [8] who revealed that T_3 (confidor 200 ml/ acre) brought the highest reduction (93.24%) in whitefly population within 72 hrs of post-treatment interval, followed by T_4 (Agrovista 100 g/ acre) which gave 89.86% reduction and T_2 (Polo 200 ml/ acre) with efficacy percentage of 86.79%, respectively. The almost same trend of effectiveness was recorded during the second and third spray, respectively.

Influence of treatments on the population density of adult whitefly

At 50 DAT, the whitefly adults were significantly lower in T_3 and T_4 (0.00 and 0.00 adults/ leaf, respectively) which were statistically on par with each other, followed by T_5 (0.30 adults/ leaf). Whereas, significantly higher adult whiteflies per leaf were recorded in T_1 and T_2 (1.10 and 1.00, respectively) being on par with each other. At 63 DAT, once again T_4 and T_3 (0.20 and 0.28, respectively) recorded significantly lower adults per leaf being on par with each other. The next best treatment which received significantly least adults whiteflies were T_5 (0.54). However, significantly higher adults per leaf were recorded in T_2 and T_1 (1.40 and 1.20, respectively) and they were statistically on par with each other (Table 2).

Further, at 75 DAT, significantly minimum number of whitefly adults were recorded in T_4 (0.28) being statistically on par with T_3 and T_5 (0.30 and 0.60 adults/ leaf, respectively). However, significantly higher adults per leaf were recorded in T_2 and T_1 (1.24 and 1.18, respectively) and they were on par with each other. At 88 DAT, T_3, T_4 and T_5 had significantly lower whitefly adults per leaf (0.54, 0.60 and 0.62, respectively). Further, significantly more whitefly adults were recorded in T_2 (1.60 adults/ leaf) but significantly lower than T_1 (1.80 adults/ leaf).

The efficacy of different treatments again at 100 DAT recorded significantly least adults load in T_3 (0.58 adults/ leaf) being on par with T_4 and T_5 (0.60 and 0.98 adults/ leaf, respectively). However, significantly more number of whitefly adults per leaf were observed in T_1 and T_2 (1.60 and 1.30, respectively). At 113 DAT, significantly least number of adult whiteflies were recorded in T_4 and T_3 (0.48 and 0.60 / leaf, respectively) followed by T_5 and T_2 (1.00 and 1.40 adults/ leaf, respectively) which were statistically on par with each other. Whereas, significantly highest number of whitefly adults per leaf were recorded in T_1 (1.82). At 125 DAT, T_4 and T_3 (0.20 and 0.30 / leaf, respectively) recorded significantly lower whitefly adults density, it was followed by T_5 and T_1 (0.80 and 1.08 adults/ leaf, respectively) being on par with T_2 (1.10 adults/ leaf) (Table 2).

The overall mean whitefly adults per leaf indicated that, T_4 and T_3 (0.33 and 0.37, respectively) recorded significantly lower number of adult whiteflies per leaf. The next best treatment that received lower adult population per leaf was in T_5 (0.69). However, higher whitefly adult load was recorded in T_1 and T_2 (1.39 and 1.29 / leaf, respectively) being statistically on par with each other.

The present study is in accordance with (Bhambania *et al.*, 2018) [2] who reported that application of three sprays of imidacloprid (0.005%), difenthiuron (0.05%), acetamiprid (0.008%) and thiacloprid (0.024%) on whitefly were found to be the most effective insecticides. The present investigation is in conformity with Jha and Kumar (2018) who reported that all the insecticidal treatments were significantly superior over control in reducing whitefly population and efficacy was maximum in imidacloprid followed by profenophos 40% + cypermethrin 4%, and it was minimum in tobacco decoction

Table 2: Effect of scheduling insecticides against whitefly (*Trialeurodes vaporariorum*) nymphs and adults on tomato

Treatments	Mean No. of whitefly nymphs/ 2cm2								Mean No. of whitefly adults/ leaf							
	50DAT	63DAT	75DAT	88DAT	100DAT	113DAT	125DAT	Overall mean	50DAT	63DAT	75DAT	88DAT	100DAT	113DAT	125DAT	Overall mean
T1	0.97 (1.21)	0.90 (1.18)	0.86 (1.16)	0.90 (1.18)	0.78 (1.13)	0.80 (1.14)	0.73 (1.10)	0.85 (1.16)	1.10 (1.26)	1.20 (1.30)	1.18 (1.29)	1.80 (1.51)	1.60 (1.44)	1.82 (1.52)	1.08 (1.25)	1.39 (1.37)
T2	0.80 (1.14)	0.78 (1.13)	0.81 (1.14)	0.84 (1.15)	0.79 (1.13)	0.85 (1.16)	0.74 (1.11)	0.80 (1.14)	1.00 (1.22)	1.40 (1.37)	1.24 (1.31)	1.60 (1.44)	1.30 (1.34)	1.40 (1.37)	1.10 (1.26)	1.29 (1.33)
T3	0.11 (0.78)	0.14 (0.80)	0.20 (0.83)	0.26 (0.87)	0.30 (0.89)	0.44 (0.96)	0.30 (0.89)	0.25 (0.86)	0.00 (0.70)	0.28 (0.88)	0.30 (0.89)	0.54 (1.01)	0.58 (1.03)	0.60 (1.04)	0.30 (0.89)	0.37 (0.93)
T4	0.00 (0.70)	0.12 (0.78)	0.19 (0.83)	0.20 (0.83)	0.36 (0.92)	0.46 (0.97)	0.28 (0.88)	0.23 (0.85)	0.00 (0.70)	0.20 (0.83)	0.28 (0.88)	0.60 (1.04)	0.60 (1.04)	0.48 (0.98)	0.20 (0.83)	0.33 (0.91)
T5	0.22 (0.84)	0.26 (0.87)	0.40 (0.94)	0.42 (0.95)	0.60 (1.04)	0.80 (1.14)	0.56 (1.02)	0.47 (0.98)	0.30 (0.89)	0.54 (1.01)	0.60 (1.04)	0.62 (1.05)	0.98 (1.21)	1.00 (1.22)	0.80 (1.14)	0.69 (1.09)
S.Em±	0.03	0.05	0.01	0.02	0.01	0.05	0.03	0.02	0.03	0.02	0.05	0.02	0.06	0.05	0.03	0.04
CD @ 5%	0.10	0.14	0.03	0.08	0.03	0.14	0.09	0.06	0.09	0.08	0.16	0.07	0.18	0.15	0.11	0.12

Note- values in the parenthesis are $\sqrt{x+0.5}$ transformed; DAT- Days After Transplanting

Influence of treatments on the population density of leaf miner, *Liriomyza trifolii*

At 50 DAT, T_4 and T_5 (0.00 and 0.26, respectively) recorded significantly lower number of live mines per leaf are being at par with each other. The next best treatment, which received significantly least number of live mines per leaf, was T_3 (0.44). Whereas, significantly higher number of mines per leaf were recorded in T_1 and T_2 (1.84 and 1.80, respectively) being statistically at par with each other. AT 63 DAT, the treatments T_4 and T_3 (0.30 and 0.52, respectively) recorded lower number of live mines per leaf being at par with each other. The next best treatment, which received significantly least number of live mines per leaf, was T_5 (0.72). Whereas, significantly higher number of live mines per leaf were recorded in T_1 and T_2 (2.05 and 2.01, respectively) being statistically at par with each other (Table 3).

At 75 DAT, once again significantly lower number of mines were recorded in T_4 (0.40 live mines/ leaf), T_5 (0.48 live mines/ leaf) and T_3 (0.50 live mines/ leaf) being statistically on par with each other. However, the treatment that received more number of live mines per leaf was T_1 (1.80), followed by T_2 (2.00). At 88 DAT, again confirmed the same trend as 75 DAT with slightly higher numbers. Significantly lower number of live mines per leaf were recorded in T_4 (0.65), T_5 (0.80) and T_3 (0.98 live mines/ leaf) being statistically on par with each other. However, T_1 and T_2 (2.20 and 1.80 live mines/ leaf, respectively) recorded significantly higher number of mines per leaf (Table 3).

The efficacy of different treatments at 100 DAT showed that T_3 and T_4 (0.20 and 0.50, respectively) recorded lower density of live mines per leaf being on par with each other. The treatment that received moderate live mines per leaf were T_5 and T_2 (0.62 and 1.30, respectively) being on par with each other. Further, T_1 (2.10 / leaf) recorded highest number of live mines and differed statistically from other treatments. At 113 DAT, again T_3 and T_4 (0.54 and 0.59, respectively) recorded significantly lower density of live mines per leaf being at par with each other. The next best treatment, which received significantly least live mines were T_5 (0.80 / leaf). Whereas, significantly higher live mines per leaf were recorded in T_1 and T_2 (2.30 and 1.48, respectively) being statistically at par with each other. At 125 DAT, T_4, T_3 and T_5 (0.40, 0.50 and 0.60, respectively) recorded significantly lower density of live mines per leaf being at par with each other. Whereas, higher live mines per leaf were recorded in T_1 and T_2 (2.00 and 1.20, respectively) being statistically on par with each other (Table 3).

The overall mean indicated that among the treatments, significantly lower number of live mines per leaf were recorded in T_4, T_3 and T_5 (0.40, 0.52 and 0.61, respectively) being statistically on par with each other. However, T_2 (1.65 / leaf) recorded moderate number of live mines. Further, T_1 (2.04) differed statistically from other treatments by recording highest number of live mines per leaf.

The present study is in line with (Wankhede *et al.*, 2007) [14] who reported that neem oil at 1% gave the lowest leaf miner infestation (4.37%) at 14 days after second spray followed by 0.01% spinosad and 5% neem seed extract, which exhibited (4.60 and 5.07% infestation, respectively). The slight variations of the present study may be due to the fresh usage of neem based products.

The present investigation is also in line with (Mohan and Anitha 2017) [14] who reported that among the various treatments chlorantraniliprole 18.5 SC 0.006% at ten days interval was found to be the best treatment in reducing leaf damage (percentage), the number of mines /plant and number of larvae/ plant.

Table 3: Effect of scheduling insecticides against serpentine leaf miner (*Liriomyza trifolii*) on tomato

Treatments	Mean No. of live mines/ leaf							
	50DAT	63DAT	75DAT	88DAT	100DAT	113DAT	125DAT	Overall mean
T1	1.84 (1.52)	2.05 (1.59)	1.80 (1.51)	2.20 (1.64)	2.10 (1.61)	2.30 (1.67)	2.00 (1.58)	2.04 (1.59)
T2	1.80 (1.51)	2.01 (1.58)	2.00 (1.58)	1.80 (1.51)	1.30 (1.34)	1.48 (1.40)	1.20 (1.30)	1.65 (1.46)
T3	0.44 (0.96)	0.52 (1.00)	0.50 (1.00)	0.98 (1.21)	0.20 (0.83)	0.54 (1.01)	0.50 (1.00)	0.52 (1.00)
T4	0.00 (0.70)	0.30 (0.89)	0.40 (0.94)	0.65 (1.07)	0.50 (1.00)	0.59 (1.04)	0.40 (0.94)	0.40 (0.94)
T5	0.26 (0.87)	0.72 (1.10)	0.48 (0.98)	0.80 (1.14)	0.62 (1.05)	0.80 (1.14)	0.60 (1.04)	0.61 (1.05)
S.Em±	0.04	0.03	0.02	0.04	0.06	0.09	0.10	0.04
CD @ 5%	0.12	0.11	0.06	0.13	0.20	0.27	0.29	0.12

Values in the parenthesis are $\sqrt{x+0.5}$ transformed; DAT- Days After Transplanting

Influence of treatments on the population density of tomato pin worm, *Tuta absoluta*

There was no tomato pin worm infestation noticed from 50 DAT to till 63 DAT. All tomato cultivars evaluated for pin worm were free from infestation.

At 75 DAT, zero mines per leaf were recorded in the treatment T_4 (0.00 mines/ leaf). The next treatment, which received significantly lower mines per leaf, was T_5 (0.12). Further, T_1, T_2 and T_3 (0.36, 0.32 and 0.24, respectively) recorded significantly higher number of mines per leaf being on par with each other. At 88 DAT, again confirmed same trend with significantly lower incidence of number of mines per leaf in T_3 and T_4 (0.62 and 0.68, respectively) which are statistically on par with each other. The next best treatment, which received moderate number of mines per leaf, was T_5 (1.00). However, significantly higher number of mines per leaf were recorded in T_1 and T_2 (1.52 and 1.40, respectively) being on par with each other (Table 4).

The efficacy of different treatments at 100 DAT has recorded significantly lower number of mines per leaf in T_3 and T_4 (0.40 and 0.50, respectively) which are statistically on par with each other. The next treatments which received lower mines per leaf were T_2 (0.98) being on par with T_5 (1.20 mines/ leaf). However, T_1 (1.60 mines/ leaf) recorded significantly highest number of mines per leaf (Table 4).

Peak incidence was noticed at 113 DAT irrespective of the treatments imposed during the experimentation. Among the treatments again T_3 (0.75) stand superior in recording lowest number of mines per leaf. The next best treatment, which received significantly lower mines, was T_4 (0.98 mines/ leaf). However, significantly moderate density of mines per leaf were recorded in T_5 and T_2 (1.20 and 1.26, respectively) being on par with each other. Further, T_1 (1.55) recorded highest number of mines per leaf and differed significantly from other treatments. At 125 DAT, again T_4 and T_3 (0.50 and 0.59, respectively) stand superior in recording lower number of mines per leaf. Further, T_5 and T_2 (1.00 and 1.15, respectively) recorded significantly higher number of mines per leaf being on par with each other. However, T_1 (1.44 mines/ leaf) recorded highest number of mines per leaf and differed significantly from all other treatments.

The overall mean of tomato pin worm indicated that among the treatments, T_3 and T_4 (0.37 and 0.38, respectively) recorded lower number of mines per leaf. Further, T_5 and T_2 (0.64 and 0.73 / leaf, respectively) recorded significantly higher number of mines being on par with each other.

However, T_1 (0.92) recorded highest number of mines per leaf (Table 4).

The present study is line with (Gacemi and Guenaoui 2012) [14] who reported that the efficacy of foliar applications with emamectin-benzoate against *T. absoluta* larvae with mortality reaching 87%. The present study is accordance with (Braham*et al.*, 2012) [3] who reported that novel insecticides like ampligo 150 ZS (chlorantraniliprole + lambda-cyhalothrin), voliamtargo 063 SC (chlorantraniliprole + abamectin), tracer 240 SC (spinosad), nimbecidine (azadirachtin 0.03%), tutafort (plant extracts), vydate (oxamyl) and bio catch (*L. lecanii*) showed good efficacy against *T. absoluta* under greenhouse condition. The present study is also in conformity with (Hamdy and Sayed 2013) [6] who reported that spinetoram exhibited the highest toxic effect in reducing infestation of *T. absoluta*, followed by spinosad then emamectin benzoate.

Table 4: Effect of scheduling insecticides against tomato pin worm (*Tuta absoluta*) on tomato

Treatments	Mean No. of mines/ leaf							
	50DAT	63DAT	75DAT	88DAT	100DAT	113DAT	125DAT	Overall mean
T1	0.00 (0.70)	0.00 (0.70)	0.36 (0.92)	1.52 (1.42)	1.60 (1.44)	1.55 (1.43)	1.44 (1.39)	0.92 (1.19)
T2	0.00 (0.70)	0.00 (0.70)	0.32 (0.90)	1.40 (1.37)	0.98 (1.21)	1.26 (1.32)	1.15 (1.28)	0.73 (1.10)
T3	0.00 (0.70)	0.00 (0.70)	0.24 (0.86)	0.62 (1.05)	0.40 (0.94)	0.75 (1.11)	0.59 (1.04)	0.37 (0.93)
T4	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.68 (1.08)	0.50 (1.00)	0.98 (1.21)	0.50 (1.00)	0.38 (0.93)
T5	0.00 (0.70)	0.00 (0.70)	0.12 (0.78)	1.00 (1.22)	1.20 (1.30)	1.20 (1.30)	1.00 (1.22)	0.64 (1.06)
S.Em±	0.00	0.00	0.02	0.04	0.05	0.02	0.03	0.03
CD @ 5%	0.00	0.00	0.08	0.12	0.15	0.06	0.09	0.10

Values in the parenthesis are $\sqrt{x+0.5}$ transformed; DAT- Days After Transplanting

Influence of treatments on the per cent fruit damage by tomato pin worm, *Tuta absoluta*

The tomato pin worm infestation was not noticed until 60 DAT. All tomato cultivars evaluated for pin worm were free from infestation.

At 75 DAT, lowest per cent fruit infestation was recorded in T4 (1.20% fruit damage). The next best treatment, which received significantly lower per cent fruit damage was T3 and T5 (1.80 and 2.00, respectively). Whereas, T1 and T2 (4.20 and 4.00, respectively) had higher fruit damage. At 88 DAT, again confirmed same trend with slightly higher per cent fruit infestation was noticed. Among the treatments T3 and T4 (9.10 and 9.60% fruit damage, respectively) were statistically on par with each other. While, T5 (10.20) recorded moderate density of fruit damage. However, significantly higher per cent fruit damage were recorded in T1 and T2 (16.60 and 15.90, respectively) being on par with each other (Table 5).

The efficacy of different treatments at 100 DAT has recorded significantly lower per cent fruit infestation per plant in T4 and T3 (9.20 and 10.05, respectively) which are statistically on par with each other. The next best treatment which received moderate per cent fruit damage was T5 (12.40). However, T1 and T2 (20.80 and 20.00% fruit damage, respectively) recorded significantly higher per cent fruit infestation and they were statistically on par with each other (Table 5).

At 113 DAT, again T4 (10.00% fruit damage) stood superior in recording lowest per cent fruit infestation followed by T3 (12.00% fruit damage). Further, T5 recorded (20.20) moderate per cent fruit damage. Whereas, T2 and T1 (31.20 and 30.00% fruit damage, respectively) had higher density of fruit infestation which were statistically on par with each other. At 125 DAT, significantly lower per cent fruit damage was recorded in T4 and T3 (16.00 and 20.00, respectively). The next best treatment, which received significantly lower per cent fruit infestation, was T5 (29.00% fruit damage). Whereas, T1 and T2 (39.00 and 38.00% fruit damage, respectively) had higher density of fruit infestation being statistically on par with each other.

Table 5: Effect of scheduling insecticides against per cent fruit damage by tomato pin worm (*Tuta absoluta*) on tomato

Treatments	Per cent fruit damage							
	50DAT	63DAT	75DAT	88DAT	100DAT	113DAT	125DAT	Overall mean
T1	0.00 (0.00)	0.00 (0.00)	4.20 (11.83)	16.60 (24.04)	20.80 (27.13)	30.00 (33.21)	39.00 (38.65)	15.80 (23.42)
T2	0.00 (0.00)	0.00 (0.00)	4.00 (11.54)	15.90 (23.50)	20.00 (26.57)	31.20 (33.96)	38.00 (38.06)	15.58 (23.26)
T3	0.00 (0.00)	0.00 (0.00)	1.80 (7.71)	9.10 (17.56)	10.05 (18.53)	12.00 (20.27)	20.00 (26.57)	7.56 (16.00)
T4	0.00 (0.00)	0.00 (0.00)	1.20 (6.29)	9.60 (18.05)	9.20 (17.66)	10.00 (18.43)	16.00 (23.58)	6.57 (14.89)
T5	0.00 (0.00)	0.00 (0.00)	2.00 (8.13)	10.20 (18.63)	12.40 (20.62)	20.20 (26.71)	29.00 (32.58)	10.54 (18.91)
S.Em±	0.00	0.00	0.13	0.20	0.29	0.74	0.71	0.61
CD @ 5%	0.00	0.00	0.42	0.60	0.87	2.20	2.15	1.85

Values in the parenthesis are angular transformed; DAT- Days After Transplanting

The overall mean indicated that among the treatments, T4 and T3 (6.57 and 7.56, respectively) recorded significantly lower per cent fruit damage which are statistically on par with each other. The next best treatment, which received lower per cent fruit damage, was T5 (10.54). However, T1 and T2 (15.80 and 15.58, respectively) recorded significantly higher per cent fruit infestation and they were statistically on par with each other (Table 5).

Per cent fruit damage and marketable fruit yield/ $500m^2$

Significantly lower per cent fruit damage was recorded in the treatments T_4 and T_3 (10.00 and 10.90, respectively) being on par with each other. The next best treatment, which received lowest fruit damage, was T_5 (15.89). Whereas, T_1 (18.66% fruit damage) had more fruit damage than T_2 (16.00% fruit damage) and they were statistically on par with each other (Table 6).

With respect to yield, significantly higher yield were obtained in the treatments T_4 and T_3 (4.45 and 4.30 tons/ 500m^2, respectively), they were followed by T_5 (3.93 tons/ 500m^2) and T_2 (3.87 tons/ 500m^2) being statistically on par with each other. Whereas, significantly lowest yield was recorded in the treatment T_1 (3.68 tons/ 500m^2)

The present study is in line with (Usman *et al.*, 2015) [13] who reported that, all IPM modules were effective than control, in reducing fruit damage by the tomato fruit worm. The present study is also in accordance with (Kotak *et al.*, 2020) [7] who reported that, higher yield of tomato fruits were recorded in the treatments with synthetic insecticides and the moderate yield of tomato fruits were obtained from diafenthiuron 0.05% (18814.81 kg/ ha), emamectin benzoate 0.0025% (17962.96 kg/ ha) and thiodicarb 0.15% (17111.11 kg/ ha) treatments. Whereas, significantly lower yield *i.e.* 12641.98 kg/ ha was recorded from the untreated control plot.

Table 6: Performance of scheduled insecticides for tomato pin worm fruit damage and yield after imposition of the treatments

Treatments	*Per cent fruit damage	Yield (tons/ 500 m^2)	Yield (tons/ acre)
T1	18.66 (25.60)	3.68	29.44
T2	16.00 (23.58)	3.87	30.96
T3	10.90 (19.28)	4.30	34.40
T4	10.00 (18.44)	4.45	35.60
T5	15.89 (23.50)	3.93	31.44
S. Em ±	0.53	0.05	0.60
CD @ 5%	1.60	0.16	1.80

*Values in parenthesis are angular transformed

Cost economics

The highest cost of protection was recorded in T_4 (Rs. 1,388.31 / 500m^2) followed by T_2 (Rs. 803.11 / 500m^2) and T_1 (Rs. 558.58 / 500m^2). Further, lowest cost of protection was recorded in T_5 (Rs. 305.86 / 500m^2) but higher than T_3 (Rs 557.80. / 500m^2). Further, highest gross return were obtained in T_4 (Rs. 1, 24,600 / 500m^2) followed by T_3 (Rs. 1, 20,400 / 500m^2) and T_5 (Rs. 1, 10,040 / 500m^2). Further, lower gross return was obtained in T_2 (Rs. 1, 08,360 / 500m^2). However, T_1 (Rs. 1, 03,040 / 500m^2) obtained lowest gross return than rest of the treatments (Table 7).

In comparison with other treatments, highest net return was obtained in T_4 (Rs. 83,611.69 / 500m^2), followed by T_3 (Rs 80,242.20. / 500m^2) and T_5 (Rs. 70,134.14 / 500m^2). Further, lower net return was obtained in T_2 (Rs. 67,956.89 / 500m^2). However, T_1 (Rs. 62,881.42 / 500m^2) recorded lowest net return than rest of treatments (Table). Finally, the cost benefit ratio (C: B) was higher in T_4 (1: 2.03) followed by T_3 (1: 1.99) and T_5 (1: 1.75). However, lowest C: B ratio was obtained in T_1 (1: 1.56).

(Usman *et al.*, 2015) [13] who reported that IPM modules were effective than control, in reducing fruit damage. However, lowest fruit damage (5.74%) and maximum tomato yield (22013 kg/ ha) was obtained in M6, where use of chlorantraniliprole was integrated with other control strategies. The same module also revealed highest cost benefit ratio supports the present study.

Table 7: Cost economics of scheduling treatments against major insect pests of tomato under polyhouse condition

Sl. No.	Yield (tons/ 500m^2)	Cost of protection (Rs./ 500m^2)	Total cost of production(Rs./ 500m^2)	Gross returns (Rs./ 500m^2)	Net returns (Rs./ 500m^2)	C: B ratio
T_1	3.68	558.58	40,158.58	1,03,040.00	62,881.42	1:1.56
T_2	3.87	803.11	40,403.11	1,08,360.00	67,956.89	1:1.68
T_3	4.30	557.8	40,157.80	1,20,400.00	80,242.20	1:1.99
T_4	4.45	1,388.31	40,988.31	1,24,600.00	83,611.69	1:2.03
T_5	3.93	305.86	39,905.86	1,10,040.00	70,134.14	1:1.75

Gross returns = Yield x Market price (Rs. 28/kg)
Net returns = Gross returns – Total cost

Conclusion

It is concluded from the study that the treatment T_4 (seed treatment with imidacloprid, seedling root dip with imidacloprid, fipronil 5 SC (48 DAT) + imidacloprid 17.8 SL (73 DAT) + chlorantraniliprole 18.5 SC (98 DAT) + dinotefuron 20 SG (123 DAT) insecticide schedule was proved to be better in reducing whitefly, leaf miner and tomato pinworm population on tomato under naturally ventilated polyhouse condition.

Acknowledgement

The authors are thankful to the Head, Department of Entomology and Dean for providing necessary facility and encouragement during course of present investigation.

References

1. Anu BC, Saha T, Kumari SAK. Screening of tomato genotypes for tolerance or susceptibility against sucking pests under field condition. Journal of Entomological and Zoological Studies. 2020;8(2):742-745
2. Bhambania VS, Khanpara AV, Patel HN. Bio-Efficacy of insecticides against sucking pests; jassid and thrips infesting tomato. Journal of Pharmacognosy and Phytochemistry. 2018;7(3):1471-1479.
3. Braham M, Glida-Gnidez H, Hajji L. Management of the tomato borer, Tuta absoluta in Tunisia with novel insecticides and plant extracts. EPPO bulletin. 2012;42(2):291-296.
4. Christopher Ngosong, Clovis Tanyi B, Cyril Njume A, Priscilla Mfombep M, Justin Okolle N, Thomas Njock E. Importance of NPK Foliar Fertilization for Improving Performance of Tomato (*Solanum lycopersicum* L.), Managing Diseases and Leafminer. Journal of Experimental Agriculture International. 2018;5(2):1-14.
5. Gacemi A, Guenaoui Y. Efficacy of emamectin benzoate on Tuta absoluta Meyrick (Lepidoptera: Gelechiidae)

infesting a protected tomato crop in Algeria. Entomology journal. 2012;5(1):37-40.

6. Hamdy EMH, Sayed WE. Efficacy of biochemical insecticides in the control of Tuta absoluta and Helicoverpa armigera (Hubner) infesting tomato plants. Aust. Journal of Basic & Applied Sciences. 2013;7(2):943-948.
7. Kotak JN, Acharya MF, Rathod AR, Shah KD, Ghelani MK. Bio-efficacy of different insecticides against leaf miner and whitefly on tomato. International journal of chemical studies. 2020;8(3):09-15.
8. Magsi F, Hussain LK, Ahmed CM, Bhutto Z, Channa N, Ahmed JA. Effectiveness of different synthetic insecticides against Bemisia tabaci (genn) on tomato crop. India: Akinik Publications. *International Journal* of Fauna and Biological Studies. 2017;4(3):06-09.
9. Mandloi R, Pachori R, Sharma AK, Thomas M, Thakur AS. Impact of weather factors on the incidence of major insect pests of tomato (*Solanum lycopersicon* L.) cv. H-86 (Kashi Vishesh). Journal of environmental sciences. 2015;8(1):7-12.
10. Marques C, Nunes AP, Almeida ML, Godinho MC, Figueiredo E, Amaro F. A Manual de protecção integrada em culturas hortícolas protegidas. Principais pragas e auxiliares na região Oeste. – PAMAF 2034, ISA/UTL, DRARO, Lisboa 61 (1999).
11. Michaelides G, Seraphides N, Pitsillou M, Sfenthourakis S. Susceptibility of cypriot Tuta absoluta populations to four targeted insecticides and control failure likelihood. Journal of Applied Entomology. 2019;143(5):508-517.
12. Mohan M, Anitha N. Management of American serpentine leaf miner, Liriomyza trifolii (Burgess) on tomato. Pest Management in Horticulture. Ecosytem. 2017;23:(1)94-96.
13. Usman A, Khan IA, Shah M. Evaluation of some selected ipm modules for the management of tomato fruit worm (Helicoverpa armigera Hub.) Journal of Entomological and Zoological Studies. 2015;3(4):379-382.
14. Wankhede SM, Deotale VY, Undirwade DB, Mane PN, Deotale RO, Kahare RN. Performance of some insecticides and biopesticides against tomato leaf miner, Liriomyza trifolii Burgess. Journal of Soils and Crops. 2007;17(1):136-138.
15. Zhang XR, Xing ZL, Lei ZR, Gao YL. Recent status of the invasive leaf miner *Liriomyza trifolii* in China. South Western Entomologist. 2017;42(1):301-304.