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Population dynamics and development of suitable pest management module against major insect pests of tomato (*Solanum lycopersicum*)

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Abstract

Investigation on the population dynamics and evaluation of pest management modules against major insect pests of tomato were carried out at Navsari Agricultural University, Navsari, south Gujarat in *rabi,* 2007-08. Results revealed that aphid and whitefly population commenced from transplanting with 1.35 aphids leaf^{-1} and 0.37 whiteflies leaf^{-1}, reached to peak level (7.31 aphids leaf^{-1}and 6.01 whiteflies leaf^{-1}) at 11 WAT. Peak level of percent infested leaves by leaf miner was 31.75 % at 10th WAT. The higher population of *Helicoverpa* on foliage (2.80-3.40 plant^{-1}) was noticed during third week of January to end of February (10-16 WAT). The population of mirid bug, which acts as a potential predator of sucking pests reached peak (1.90-2.05 plant^{-1}) when population of aphid and whitefly reached maximum. Correlation studies between insect pest population/damage and weather parameters showed that there was significant negative correlation of aphid (r=-0.491) and whitefly (r=-0.449) with maximum temperature and negative significant correlation with minimum temperature (r=-0.645, r=-0.599). Further, the wind velocity showed significantly positive correlation with aphid (r=0.574) and whitefly (r=0.534) population. The wind velocity gave positive and significant correlation with the population of mirid bug as natural enemies. The IPM module was found most promising in reducing the population of aphids (2.1 leaf^{-1}), whitefly (2.4 leaf^{-1}), *Helicoverpa* larva (1.0 plant^{-1}) on foliage. Besides, it reduced leaf infestation by leaf miner (17.8 %) and fruit infestation by *Helicoverpa* (15.4 %) and increased yield (36445 kg ha^{-1}). The sole insecticidal module was equally effective as IPM module in recording low population of aphids (2.2 leaf^{-1}), whitefly (2.5 leaf^{-1}), *Helicoverpa* (1.1 plant^{-1}), leaf infestation (18.3 %), fruits infestation (16.3 %) and also increased fruit yield (34684 kg ha^{-1}). The biological module and botanical module ranked third and fourth in efficacy with respect to pest control. Besides pest management, population of mirid bugs (0.8 plant^{-1}) as natural enemy was also conserved in IPM module. The net ICBR obtained in IPM module was 1:9.45 which was comparable to the insecticidal module (1:15.92).

Key words: Aphid, *Chrysoperla, Helicoverpa,* IPM, leaf miner, mirid bug, population dynamics, tomato, *Trichogramma,w*hitefly

Introduction

Tomato (*Solanum lycopersicum*) is grown in India over an area of 6.34 lakh ha with a total production of 12433.2 thousand MT and total productivity of 19.6 MT ha^{-1} (Kumar, 2010). In India, about 16 pests reportedly feed on tomato, commencing from germination to harvesting stage which reduce its yield and also spoil quality (Butani, 1977). The farmers therefore follow plant protection schedule based on plant growth and time of pest appearance. The important insect pests identified on tomato in Gujarat and also other parts of the country are aphid (*Aphis gossypii* Glover and *Myzus persicae* Sulzer), jassid (*Amrasca biguttula biguttula* Ishida), whitefly (*Bemisia tabaci* Genn.), leaf miner (*Liriomyza trifoli* Burgess), fruit borer (*Helicoverpa armigera* Hubner), tobacco leaf eating caterpillar (*Spodoptara litura* Fab.), mealy bug (*Ferrisia virgata* Cockerell) (Reddy and Kumar 2004; Jamadar, 2006). Amongst these, *A. gossypii* and *M. persicae* caused significant reduction in yield ranging from 25 to 80 % (Kishore and Parihar, 2002).

It is recognized that the estimation of population is a basic necessity for measuring the intensity of a pest population, determining the influence of natural enemies on the populations, assessing the crop losses, monitoring the appearance of the pest and making decisions on the methods of control to be used. Establishment of the relationships between the populations of a given insect pest, time of its appearance and duration for which it is likely to cause damage to the crop at a vital growth stage and the consequent loss in yield by the pest are of vital importance for working out the economic threshold. Before developing insect pest management programme for specific agro ecosystem, it is necessary to have basic information on abundance and distribution of pest in relation to weather parameters, as it helps in determining appropriate time of action and suitable effective method of control.

Against major insect pests of tomato, Trichogrammatids, NPV, one row of marigold after 16 rows of tomato, azadirachtin, NSKE, endosulfan, cypermethrin+ profenophos, profenofos and indoxacarb have been found effective (Parminder Kumar *et al*., 2004; Yadav *et al*., 2006; Singh *et al*., 2004; Senguttuvan *et al*.; 2005; Shivalingaswamy *et al*., 2008). But reports on integration of all such components and their efficacy against target insect pests of tomato are lacking. Keeping this in consideration, the present investigation was, therefore, undertaken to study population dynamics in relation to weather parameters and to evaluate efficacy and economics of various pest management modules for management of major insect pests of tomato in south Gujarat.

Materials and methods

To study the population dynamics of major insect pests of tomato, a field experiment was conducted at College Farm, N.M. College of Agriculture, Navsari Agricultural University, Navsari during *rabi* season of 2007-08. A variety, Gujarat Tomato-2 (GT-2) was grown in 400 m^2. The experimental area was kept free from insecticidal spray throughout the crop season in order to record the incidence of insect pests. To study incidence of major insect pests on tomato, 30 plants were selected randomly and weekly observations were recorded throughout the crop season. In case of aphid, number of nymphs and adults, while in case of whitefly, number of adults were recorded during early morning on selected plant. For recording leaf miner infestation, pernectage of damaged leaves was worked out. In case of vegetative stage of the tomato crop, population of fruit borer was counted from selected plants, whereas during fruiting stage, perncetage of damaged fruits were worked out. Besides insect pests population, the population of mirid bug plant^{-1} as natural enemy were also recorded. In order to study the influence of weather parameters *viz*., maximum temperature, minimum temperature, average temperature, maximum relative humidity, minimum relative humidity, average relative humidity, rainy days, sunshine hours, wind velocity and rainfall on population of insect pest of tomato and there natural enemy, the simple correlation coefficient was worked out. Weekly meteorological data recorded at the meteorological observatory, N.M. College of Agriculture, Navsari Agricultural University, Navsari were used for this purpose (Fig.1).

To assess feasibility of pest management module against major insect pests of tomato, the Integrated Pest Management (IPM) module (M_5) was compared with four modules *viz*; Non-Pesticidal Pest Management (NPM) module (M_1), botanical pest management module (M_2), biological pest management module (M_3), insecticide based pest management module (M_4) and untreated control (C) (Table 3). The experiment was conducted in a randomized block design (RBD) with a plot size of 3.6 x 2.7 m with each treatment replicated four times. Tomato variety GT-2 was transplanted on 5 Nov, 2007. Five days after transplanting of tomato seedlings, 40 days old seedlings of marigold were also transplanted (marigold 2 rows per 5 rows of tomato) in non pesticidal and IPM based pest management modules. Weekly observations on insect pest population and their damage were

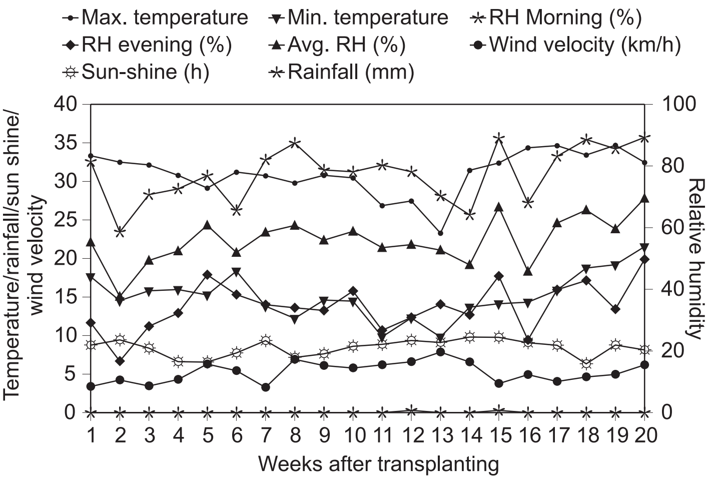

Fig. 1. Weekly meteorological data during the investigation period.

recorded same as in case of population dynamic study throughout the crop season on 5 randomly selected plants in each replication. Total ten pickings were carried out commencing from 90 days after transplanting and at every picking, damaged and healthy marketable fruits obtained from all the plants of each treatment plot were separated and percent damaged fruits was worked out.

Results and discussion

Population dynamics of major insect pests of tomato and natural enemy: In the present investigation, *A. gossypii* population commenced from 1st week after transplanting (WAT) *i.e.* second week of November with 1.35 aphids leaf^{-1}. Further, the mean population indicated that the activity of this pest increased steadily and reached peak level of 7.31 aphids leaf^{-1} at 11th WAT coinciding with third week of January, then aphid population gradually decreased. Low aphid population was noticed from last week of February to last week of March (5.43-2.83 leaf^{-1}) coinciding with 16-20 WAT (Table 1). Hath and Das (2004) found low population of aphid from third week of February to the last week of March, whereas Reddy and Kumar (2004) reported peak population of two aphid species (*A. gossypii* and *M. persicae*) during November and February on tomato at Bangalore, Karnataka. Reddy and Kumar (2004) recorded highest white fly population during November and December. In the present investigation higher white fly population (5.28-6.01 leaf^{-1}) was noticed during last week of December to third week of January (8-11 WAT) (Table 1). Thereafter, population steadily declined, which indicates almost the same trend as reported by earlier workers.

The similar trend was noticed in case of leaf miner, *Liriomyza trifolii,* Burgess infestation which commenced from transplanting and continued up to end of the crop season. Peak level of percent infested leaves were 31.75 % at 10th WAT coinciding with second week of January, then it gradually decreased at the time of last harvesting (Table 1). Reports of Hath and Das (2004) and Reddy and Kumar (2004) indicated peak infestation of leaf miner (*L. trifoli*) during March to April and thereafter population declined. The slight different trend in the present investigation could be due to different sowing periods as well as different agro-ecological conditions where the crop was raised.

The larval population of *H. armigera*, Hubner on foliage started from 2nd WAT *i.e.* third week of November (0.25 larvae plant^{-1}) and gradually increased and reached the peak population level (3.40 larvae plant^{-1}) during 16 WAT *i.e.*, second week of February (Table 1). The data on percent infested fruits by *Helicoverpa* revealed that at all pickings, the infestation was observed. However, the highest percent infested fruits were observed during eighth picking (28.96 %). The mirid bugs are important predators of sucking pests of tomato. Their population in the form of adult bugs appeared along with population of sucking pests. The peak population of mirid bug (1.90-2.05 plant^{-1}) was observed when population of aphid and whitefly reached at maximum level.

Correlation of insect pest population/damage and mirid bug with weather parameters: The data on different insect-pest population/damage during 2007-08 were correlated with weather parameter and presented in Table 2. It was revealed from the

Table 1. Mean population of aphids, whitefly per leaf, *Helicoverpa* larvae per plant and per plant percent infested leaves by L. *trifoli*

WAT	Date	Mean population				Infested leaves by leaf miner (mean %)
		Aphids leaf^{-1} (nymph+ adults)	Whitefly leaf^{-1}	*Helicoverpa* plant^{-1}	Mirid bug plant^{-1}	
1	12.11.07	1.35	0.37	0.00	0.05	14.67
2	19.11.07	1.35	1.40	0.25	0.10	15.03
3	26.11.07	1.66	1.96	0.25	0.05	13.56
4	03.12.07	3.19	3.53	0.35	0.25	24.96
5	10.12.07	3.99	3.45	0.80	0.50	23.67
6	17.12.07	4.14	4.18	1.75	0.45	26.17
7	24.12.07	5.18	4.96	1.90	0.60	27.22
8	31.12.07	6.21	5.28	2.05	1.05	28.91
9	07.01.08	6.70	6.00	2.20	0.95	28.55
10	14.01.08	7.20	5.75	2.80	1.35	31.75
11	21.01.08	7.31	6.01	2.80	1.30	29.35
12	28.01.08	5.13	5.94	3.05	1.70	14.67
13	04.02.08	6.51	5.05	3.15	1.95	15.03
14	11.02.08	7.11	5.60	2.95	2.05	13.56
15	18.02.08	6.43	5.04	3.15	1.90	24.96
16	25.02.08	5.43	5.00	3.40	1.90	23.67
17	03.03.08	3.94	4.55	2.90	1.75	26.17
18	10.03.08	3.58	3.69	3.15	1.45	27.22
19	17.03.08	3.31	2.96	2.45	1.20	28.91
20	25.03.08	2.83	2.68	2.45	1.10	28.55

data that, there was significant negative correlation of aphid (r=-0.491) and whitefly (r=-0.449) with maximum temperature and negative significant correlation with minimum temperature (r=-0.645, r=-0.599, respectively). Further, the wind velocity showed significantly positive correlation with aphid (r=0.574) and whitefly (r=0.534) population. The morning relative humidity, evening and average relative humidity showed positive correlation with the entire insect pest population/damage but found to be non-significant. Sunshine hours and rainfall also gave positive correlation with insect pest population except percent damaged leaves by leaf miner which was negatively correlated. There was no any impact of abiotic factors on percent damaged leaves by leaf miner and larval population of *Helicoverpa.* The wind velocity gave positive and significant correlation with the population of mirid bug as natural enemies. Sarangdevot *et al.* (2010) reported that aphid population was significantly negatively correlated with mean temperature and positively correlated with relative humidity which supports the present investigation.

Efficacy of pest management modules against sucking insect-pests of tomato: The IPM module played significant role in controlling population of aphid (2.1 leaf^{-1}), and whitefly (2.4 leaf^{-1}). Besides pest management, population of mirid bug (0.8 plant^{-1}) as natural enemy also flourished in IPM module (Fig. 2). Though, sole application of insecticides was equally effective (2.20 aphids leaf^{-1} and 2.48 whitefly leaf^{-1}) as compared to IPM module. It drastically

Table 2. Correlation of insect pest population/damage of tomato in relation to weather parameters

Weather Parameters	Aphid	Whitefly	Leaf miner	*Helicoverpa*	Mirid bug
Maximum Temp	-0.491*	-0.449*	-0.013	-0.175	-0.152
Minimum Temp	-0.645**	-0.599**	0.136	-0.328	-0.333
Morning RH (%)	0.095	0.095	0.403	0.287	0.202
Evening RH (%)	0.140	0.144	0.279	0.281	0.238
Average RH (%)	0.128	0.130	0.382	0.315	0.243
Wind velocity (km/h)	0.574**	0.533*	0.274	0.429	0.451*
Sunshine hours	0.211	0.137	-0.421	0.378	0.372
Rainfall (mm)	0.199	0.277	-0.200	0.370	0.358

* Significant at P=0.05 (r = ± 0.443), ** Highly Significant at P=0.05 (r = ± 0.561), RH=Relative humidity, Temp.= temperature

reduced population of mirid bug (0.6 plant^{-1}) which played its role as an effective natural enemy of aphid and whitefly. Next to insecticidal module, botanical insecticide module in vegetative phase also gave effective control of aphid (2.3 leaf^{-1}) and whitefly (1.6 leaf^{-1}). The biological module was found moderately effective in combating sucking pest population, whereas non-pesticidal module did not exert any effective control of sucking pests.

The biological control through release of trichocards having 300 parasitized eggs in combination with *Chrysoperla* larvae and neem extract played an important role in management of *Helicoverpa* (Usman *et al*., 2012). Senguttuvan *et al*. (2005) reported that NSKE were found effective against white fly. Thus, in all the above reports, efficacy of bio-agents, neem and their products have been successfully demonstrated. In present investigation, the use of neem as a component of IPM module as well as its sole use in botanical module has proved its significance over remaining modules besides control. Sharma and Lal (2002) indicated highest reduction of white fly, *B. tabaci* population (94.8 %) when thiamethoxam was used. Similarly, Leeuwen *et al*. (2005) found spinosad at 5 mg as most effective against the tomato whitefly. In the present experiment, thiamethoxam and spinosad were incorporated as a component of chemical insecticidal module (M_4), wherein the sucking pest population was significantly lower than any other module or treatment except M_5, *i.e.* IPM module which in turn did not differ significantly with chemical insecticidal module (M_4).

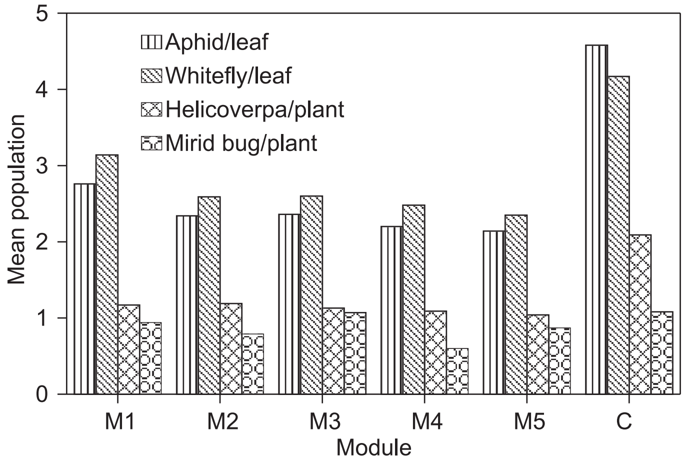

Fig. 2. Mean population of insect pest of tomato in diffrenet treatments/ modules. LSD (P=0.05) valued for aphid, whitefly, *Helicoverpa* and Leaf miner, mirid bug are 0.06, 0.15, 0.05, 0.04, respectively.

Table 3. Details of pest management modules used for the management of major insect pests of tomato

Module	Components and practices of respective modules	Concentration used	Time of application	Source
M_1	1. Trap crop (marigold 2 rows/5 rows of tomato) 2. Collection and disposal of immature stages of *Helicoverpa armigera* Hubner and infested tomato fruits		25 days old seedlings of marigold and 40 days old seedling of tomato were transplanted together At weekly intervals commencing from transplanting	Hath and Das (2005); Sushil *et al.* (2006)
M_2	1. Neemazal (two applications). 2. Ginger rhizome extract (two applications) 3. Garlic bulb extract (one application)	5 % 5 % 5 %	One pre-flowering + one post-flowering One pre-flowering + one post-flowering One pre-flowering	Singh *et al.* (2006)
M_3	1. Release of *Chrysoperla carnea* larvae (2 applications) 2. Spraying of *Ha*NPV @ (two applications) 3. Release of *Trichogramma chilonis* Ishii adults	10000 ha^{-1} 250 LE ha^{-1} 160000 ha^{-1}	Two pre-flowering One pre-flowering + one post-flowering One post-flowering	Liu and Chen (2001) Sharma *et al.* (1997) Parminder kumar *et al.* (2004); Yadav *et al.* (2006)
M_4	1. Thiomethoxam 25 % WG (two applications) 2. Spinosad 45 % SC (one applications) 3. Indoxacarb 15 % SC (two applications)	0.005 % 0.002 % 0.01 %	One pre-flowering + one post-flowering One pre-flowering Two post-flowering	Sharma and Lal (2002) Leeuwen *et al.* (2005) Kuttalam *et al.* (2008); Singh *et al.*(2005)
M_5	1. Collection and disposal of immature stages of *H. armigera a*nd infested fruits 2. Marigold as trap crop 3. Release *Chrysoperla* larvae 4. Spray NSKE 5. Spray endosulfan 35 EC 6. Release of *Trichogramma chilonis* adults 7. Spray profenofos 40 % + cypermethrin 4 % 44 EC	 10000 ha^{-1} 5 % 0.07 % 160000 ha^{-1} 0.044 %	At weekly intervals commencing from transplanting same as in treat. T1 One pre-flowering One pre-flowering + one post-flowering One pre-flowering One post-flowering One post-flowering	Praveen and Dhandapani (2003) Liu and Chen (2001) Senguttuvan *et al.* (2005) Yadav *et al.* (2006) Thakor and Patel (2008)
C	Control	Water spray	-	

M_1 - Non-pesticidal pest management module; M_2 - Botanical pest management module; M_3 - Biological pest management module; M_4 - Insecticidal pest management module; M_5 - Integrated pest management module; C- Untreated control
(Note: M-Module, LE- Larval Equivalent, *Ha*NPV- *Helicoverpa armigera* Nuclear Polyhydrosis Virus, NSKE-Neem Seed Kernel Extract)

The component and package of practices selected in various integrated pest management modules developed in India and abroad vary from area to area and region depending upon the requirement, however perusal of the available literature on white fly with respect to components of the current IPM package with that of earlier workers revealed a non-significant impact of marigold as trap crop on white fly reduction (Bandyopadhyay *et al*., 2005). In the present investigation, when marigold was exclusively used as trap crop in non-pesticidal module (M_1), it had no impact on white fly population reduction resulting in highest white fly population (3.14 $leaf^{-1}$) which was found significantly higher than most effective IPM module (M_5) (2.35) (Fig. 2).

Efficacy of pest management modules against tomato leaf miner, *L. trifolii*: Out of the five treatment modules, IPM module was effective in reducing leaf infestation (17.8 %) followed by insecticidal module (18.3 %) and botanical module (18.4 %) (Fig. 3). The practices in non-pesticidal module proved less effective against leaf miner indicating as high as 19.12 per cent leaf damage followed by 23.34 per cent leaf damage in biological pest management module (Fig. 3). Earlier workers have proved Chlopyriphos + cypermethrin (0.05 %) was effective in controlling *L. trifoli* (Galande, 2001). In the present study, instead of chlopyriphos + cypermethrin, profenofos + cypermethrin was used which supports the IPM module in recording comparatively lower leaf miner infestation. The insecticides *viz,* spinosad and indoxacarb included in insecticide module reduced leaf infestation by *L. trifoli* which was comparable with the IPM module.

Efficacy of pest management modules against tomato fruit borer, *H. armigera*: The overall order of effectiveness of various treatment modules in reducing *Helicoverpa* larval population and fruit infestation was: M5 > M4 > M3 > M1 > M2 > Control (Fig. 3). IPM module consistently suppressed the *Helicoverpa* population both during vegetative and reproductive stages of the crop and recorded minimum percent fruit infestation. Hussain and Bilal (2007) proved that growing of tomato with marigold (3:1) effectively manages population of *H. armigera.* From the results, it was also evident that application of 5 % NSKE, an essential component of botanical module as well as one of the components of IPM assisted in lowering larval population and fruit damage by *Helicoverpa*. Devraj and Nandihalli (2002) showed that 60 % NSKE recorded higher pupal mortality and lowest adult emergence of *H. armigera.* In the present investigation, though the botanical module was not very effective, but use of NSKE in IPM module assisted in the management of pest effectively. This is more or less in line with the earlier reports.

Insecticidal module was effective for the control of *H. armigera* and was comparable with IPM module. These findings are in agreement with Thakor and Patel (2008) who demonstrated effectiveness of spinosad 0.009 %, indoxacarb 0.014 % and profenophos + cypermethrin (Polytrin-C) 0.066 % in killing eggs of *H. armigera*.

Economics of pest management modules against insect-pests of tomato: As far as yield and economics is concerned, the IPM module recorded higher fruit yield (36445 kg ha^{-1}) and net gain

Table 4. Yield and economics of different treatments / modules

Treatments (modules)	Yield (kg ha^{-1})	Increased yield over control (kg ha^{-1})	Cost of** Treatment (Rs ha^{-1})	Gross* realization over control (Rs ha^{-1})	Net gain over control (Rs ha^{-1})	I.C.B.R.	Net I.C.B.R.	Rank
Non-pesticidal pest management module (M_1)	23598^c	2019	4500	14133	9633	1: 2.14	1: 1.14	5
Botanical pest management module (M_2)	30350^b	8771	5955	61397	55442	1: 9.31	1: 8.31	3
Biological pest management module (M_3)	30813^b	9234	7450	64638	57188	1: 7.68	1: 6.68	4
Insecticidal pest management module (M_4)	34684^a	13105	5120	91735	86615	1: 16.92	1: 15.92	1
Integrated pest management module (M_5)	36445^a	14866	9085	104062	94977	1: 10.45	1: 9.45	2
Untreated control	21579^c	-	-	-	-	-	-	6
LSD (P=0.05)	3371.61							

Treatment means followed by same alphabets are not significantly different.
Total cost of insecticides used including two labours per hectare for each spray @ Rs. 50 per day.
*Prevailing market price of tomato= Rs.7 /kg
**Thiamethoxam @ Rs. 4450/l, Spinosad @ Rs. 2000/l, Indoxacarb @ Rs. 3700/l, Endosulfan @ Rs. 350/l, Polytrin-C @ Rs 400/l, NSKE 5% @ Rs. 15/Kg, *Ha*NPV@ Rs. 250/100LE, Neemazal @ Rs. 450/l, *C. carnea*@ Rs. 30/100 eggs card, *Trichocards* @ Rs. 25/card, Marigold @ Rs. 0.50/ seedling, Ginger @ Rs. 63/kg,Garlic @ Rs. 60/kg
Note: M- Module, I.C.B.R.-Incremental Cost Benefit Ratio,

(94977 Rs ha^{-1}), followed by insecticidal module in terms of fruit yield (34684 kg ha^{-1}) and net gain (86615 Rs. ha^{-1}) (Table 4). The IPM module recorded lower net ICBR (1:9.45) than insecticidal module (1:15.92). This was attributed to higher cost of treatments involved in IPM. However, on the basis of overall ranking (based on various parameters), IPM module was best and most effective as it involved eco-friendly approach to control tomato insect-pest which was evident from higher population of mirid bug as natural enemy, than insecticidal module. These findings are more or less similar to results obtained by Praveen and Dhandapani (2003) wherein combined use of *T. chilonis, C. carnea, B.t.* and *Ha*NPV effectively controlled *H. armigera* coupled with increase in fruit yield (23.29 t ha^{-1}).

Looking to the relationship of abiotic factors on overall population/damage of insect pest of tomato, it may be concluded that aphid and whitefly population showed negative bearing on its abundance. This implies that the increase in maximum temperature decreases the aphid and whitefly population and vice-versa. The overall order of effectiveness of various treatment modules in terms of efficacy and economics against management of insect-pest of tomato was IPM module > insecticidal module > biological module > botanical module > non-pesticidal module > untreated control. The study revealed that, IPM was the most promising module (economical) for management of major insect-pests of tomato.

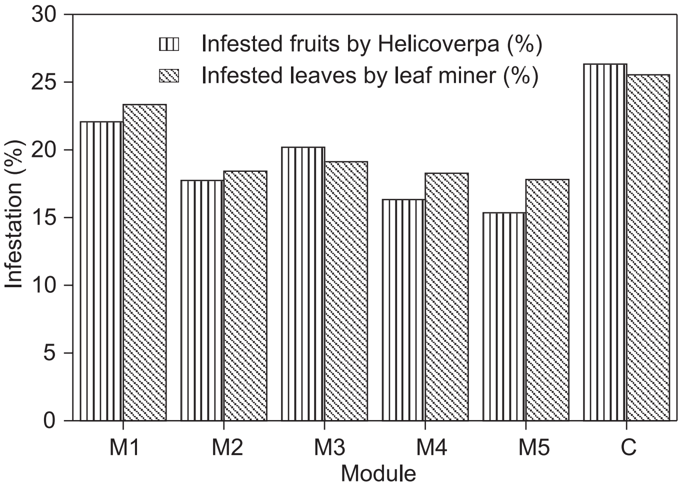

Fig. 3. Per cent infested fruits and leaves by *H. armigera* and *L. trifoli* in diffrenet treatments. LSD (P=0.05) value for infested fruits by *Helicoverpa* and infested leaves by leaf miner are 1.23 and 7.59, respectively

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