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Evaluation of Combined Management Options for Managing Pests of *Lycopersicon esculentum* Mill

Nirupama Goudia[1], Rohit Raj Singh[1] and Manoj Kumar Jena[2*]
[1]PG Research Scholar, Department of Entomology,
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, (West Bengal), India.
[2]Ph.D. Research Scholar, Section of Applied Entomology, Department of Plant Protection,
Institute of Horticulture Sciences, Warsaw University of Life Sciences, Nowoursynowska Warsaw, Poland.

(Corresponding author: Manoj Kumar Jena)*
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ABSTRACT: The tomato, *Lycopersicon esculentum* Mill is susceptible to a wide range of insect pests that affect fruit quality and quantity. Continuous use of insecticides affects human health and have a negative impact on the environment. There is the need to find good agricultural pest management practices to combat the pests. Therefore, the present investigation was conducted to evaluate an effective combined management option for managing pests of *L. esculentum* Mill, at K.V.K. Instructional Farm located near College of Agriculture, Odisha University of Agriculture and Technology, Bhawanipatna, Kalahandi, Odisha during the cropping season 2020–21 from November, 2020 to May, 2021. All the treatments, T_1 – Neem oil (Multi Neem) @ 5ml/litre at an interval of 7 days, T_2 – Neem oil (Multi Neem) @ 5ml/litre + chlorphenapyr 10 EC (Ustad) @ 100g *a.i.*/ha (4 gm or ml/litre) and emamectin benzoate 5% SG (Dhanuka EM-1) @ 12g *a.i.*/ha (0.5g/litre) at an interval of 14 days in alternate sprays, T_3 – Neem oil (Multi Neem) @ 5ml/litre + chlorphenapyr 10 EC (Ustad) @ 100g *a.i.*/ha (4 gm or ml/litre) and emamectin benzoate 5% SG (Dhanuka EM-1) @ 12g *a.i.*/ha (0.5g/litre) at an interval of 14 days in alternate sprays + *Bacillus thuringiensis kurstaki* (Green Larvicide) @ 4g/litre once in every 14 days, were superior to the untreated check (T_4) and effective in managing the pests of tomato. Moreover, the Incremental Cost Benefit Ratio (ICBR) was superior in T_3 (1: 2.60) followed by T_2 (1: 1.66) and T_1 (1: 1.18) subsequently. The T_3 was the most dominant and cost-effective in managing pests of *L. esculentum*. However, natural enemies, spiders and coccinellids and pollinators, carpenter bee and honey bee were less in the T_3 treatment as compared to others.

Keywords: IPM, *Lycopersicon esculentum*, natural enemies, pests, pollinators.

INTRODUCTION

India is the second largest producer of vegetables in the world (Horticultural Statistics at a Glance, 2017). Tomatoes, *L. esculentum*, are one of the most important vegetables in the world and belong to the Solanaceae family. Historically, tomatoes originated from the Americas, particularly, Central and South, from Mexico to Peru, and Southern North America (Warnock, 1991). Due to its high nutritional value in the human diet, the tomato is widely used as the major vegetable in many countries (Alam *et al.,* 2019). Tomatoes are rich in several vitamins and minerals and beta-carotene (Huda *et al.,* 2020; Bugti, 2016; Alam *et al.,* 2019). Globally, in 2020, the tomato was found to be the second largest vegetable crop after the potato with 5,051,983 hectares of cultivable land allocated for tomato growing, and the total yield was estimated at 186,821,216 metric tons (FAOSTAT, 2022). Next to China, India is the world's second-largest tomato producer, which accounts nearly 11 per cent of global production. The total area under tomato cultivation in India is 7.89 million hectares, with an annual production of 19.76 million tonnes and a productivity of 25 MT/ha (Horticultural Statistics at a Glance, 2017). The insect pests infesting tomato include the fruit borer, *Helicoverpa armigera* (Hubner), whitefly, *Bemisia tabaci* (Genn.), jassids, *Amrasca biguttulla biguttula* (Ishida), thrips *Thrips tabaci* (Lind) and serpentine leaf miner, *Liriomyza trifolii* (Burgess) (Reddy and Kumar 2004). Many species of ladybird beetles, *Rodolia cardinalis, Cryptolaemus montrouzieri, Hippodamia variegata, Coccinella septempunctata* and *Propylea japonica* are the dominant predators of sucking pests in tomato (Suresh, 2006; Bikash, 2013; Singh, 2017). Tomato flowers are self-fertile, but pollinators are required for the increase in fruit setting. Among pollinators, carpenter bees and honey bees are the most dominant pollinators. Though carpenter bees do not efficiently vibrate greenhouse tomato flowers, some benefit from honey bee pollination has been reported (Banda and Paxton 1991; Sabara and Winston 2003; Higo *et al.,* 2004). Pesticides are the quick method for the elimination of the pest population. Excessive use of hazardous pesticides by

Smallholder farmers, has negative consequences for human health and the environment, as well as increasing pest resistance and destroying beneficial insects. Moreover, over use of insecticides has several drawbacks, including negative effects on human health, soil, and water resources, as well as the development of resistance in most pests after repeated use (Mathews, 2008). Excess usage of synthetic pesticides have several unintended consequences, including contamination and health risks, pest resistance, resurgence, and replacement, bioaccumulation and biomagnification, killing of natural enemies and pollinators, disruption of homeostasis, *etc.* (Reddy and Kumar 2004). Because of large array of problems associated with the wide use of synthetic pesticides, it is necessary for finding the safer ways of managing the pests which are cost-effective, safer and ecofriendly in nature. Keeping this rationale in mind, some safer pest management modules were designed and evaluated against the pests of tomato in the present investigation.

MATERIALS AND METHODS

The experiment was carried out at K.V.K Instructional Farm located near College of Agriculture, Odisha University of Agriculture and Technology, Bhawanipatna, Kalahandi, during the cropping season from November, 2020 to May, 2021. The field was cross ploughed with a tractor drawn cultivator. It was followed by harrowing and planking to obtain a well pulverised experimental field. The weeds and crop residues, left out from the previous sown crop, were removed. Tomato seeds of the *variety*, Pusa Hybrid-4, Pusa-120 × Chikoo, were sown in a plugged chamber in the green house on December 03, 2020, and after 21 days, seedlings were transplanted in the experimental field with a row to row and plant to plant spacing of 60 cm × 45 cm. The crop was fertilized with the recommended dose of 100:50:60 kg N, P, and K per hectare. N, P, and K were applied as a basal dose in furrows at the time of transplanting using Urea, Single Super Phosphate (SSP), and Muriate of Potash (MOP), respectively. Glyphosate (All Clear), a total weed killer, was used as a non-selective herbicide and one manual hand weeding was done at 25 days after transplanting (DAT). Need based manual weeding was done, when weeds were observed. The insecticides were applied with the help of knapsack sprayer at the economic threshold level of the pest. Harvesting was done manually 70 days after transplanting starting from 04/03/2021 to 23/04/2021. The total yield from each plot in each picking was also recorded.

The experimental set-up consisted of single tomato cropping units. A good tilth field was divided into four blocks. Each block was divided into four sub plots, each measuring about 2.5 m × 2 m with a 0.3 m border. The sub plot size was 5 square metre. The experiment was conducted in randomized block design (RBD) with four treatments including untreated check and each with four replicates. The treatments were:

T_1: Neem oil (Multi Neem) @ 5ml/litre at an interval of 7 days

T_2: Neem oil (Multi Neem) @ 5ml/litre +chlorphenapyr 10 EC (Ustad) @ 100g *a.i.*/ha (4 gm or ml/litre) and emamectin benzoate 5% SG (Dhanuka EM-1) @ 12g *a.i.*/ha (0.5g/litre) at an interval of 14 days in alternate sprays

T_3: Neem oil (Multi Neem) @ 5ml/litre + chlorphenapyr 10 EC (Ustad) @ 100g *a.i.*/ha (4 gm or ml/litre) and emamectin benzoate 5% SG (Dhanuka EM-1) @ 12g *a.i.*/ha (0.5g/litre) at an interval of 14 days in alternate sprays + *Bacillus thuringiensis kurstaki* (Green Larvicide) @ 4g /litre once in every 14 days.

T_4: untreated check.

The per cent increase in fruit yield over control and the benefit cost ratios were also calculated as per the procedure laid down by Kumar *et al.* (2017). The data recorded on different parameters were calculated using the following formula:

% plant/shoot/fruit infestation = (Number of infested plant/shoot/fruit ÷Total number of plant/shoot/fruit) × 100

% increase or decrease over control = [(Mean of treated plot–Mean of untreated plot) ÷ Mean of untreated plot] × 100

ICBR (Incremental Cost Benefits Ratio) = Net profit gain ÷ Total cost.

RESULTS AND DISCUSSION

Insect Pests

Whitefly. The untreated check, T_4, had a very high whitefly, *Bemisia* sp., incidence (24.20/ 6 leaf) and damage (28.77% infested plant), indicating that it was an important pest on the tomato crop. T_3 recorded the mean 12.04 whitefly/6 leaf and 13.64% infested plant and was the most effective treatment in controlling the pest. T_2 was also equally effective as T_3 against whitefly recording low damage (13.71% infested plant) and incidence (14.49 white fly/6 leaf). The infestation in T_2 was statistically at par with T_3 but significantly inferior to T_3. Another safer treatment, T_1 [Neem oil (Multi neem) @ 5ml/litre], also performed well (17.68% infested plant, 15.48 whitefly/6 leaf) but significantly inferior to T_3 and T_2 in terms of performance damage though incidence (Table 1 and Fig. 1). Dimetry *et al.* (1996) showed that various formulations of neem seed extracts had bioactivity against *B. tabaci.* Sabillon and Bastamante (1995) noted that extracts of tobacco, *Nicotiana tabacum*, castor, *Ricinus communis* and neem, *Melia azadirachta indica* derived commercial product were efficacious against *B. tabaci* adults as well as the nymphal stages.

Table 1: Effect of the treatments on the incidence and damage of the pests in tomato during the cropping season 2020-21.

Treat.	Mean whitefly /6 leaf	Mean % whitefly infested plants	Mean leaf miner population /Plant	Mean leaf miner infestation (%)	Mean flea beetle/ Plant	Mean no. of *H. armigera* larvae/Plant	Mean % *Helicoverpa* infested plants
T_1	15.48 (4.0) **	17.68 (24.86) *	14.09 (3.82)	27.34 (31.53)	1.48 (1.41)	2.07 (3.20)	9.77 (18.21)
T_2	14.49 (3.87)	13.71 (21.73)	12.47 (3.60)	24.91 (29.94)	1.35 (1.36)	0.67 (2.70)	6.81 (15.13)
T_3	12.04 (3.54)	13.64 (21.67)	10.73 (3.35)	21.48 (27.61)	0.81 (1.14)	0.25 (2.44)	5.45 (13.50)
T_4	24.20 (4.97)	28.77 (32.44)	16.20 (4.09)	31.70 (34.27)	2.70 (1.79)	6.38 (3.94)	15.03 (22.81)
SEm ((±)	0.29	0.34	0.26	0.62	0.04	0.08	0.33
CD at 5%	0.84	1.02	0.76	1.83	0.12	0.23	0.83

*Figures in parentheses are arcsine√p transformations
**Figures in parentheses are square root transformed *i. e.* √ (x + 0.5) values

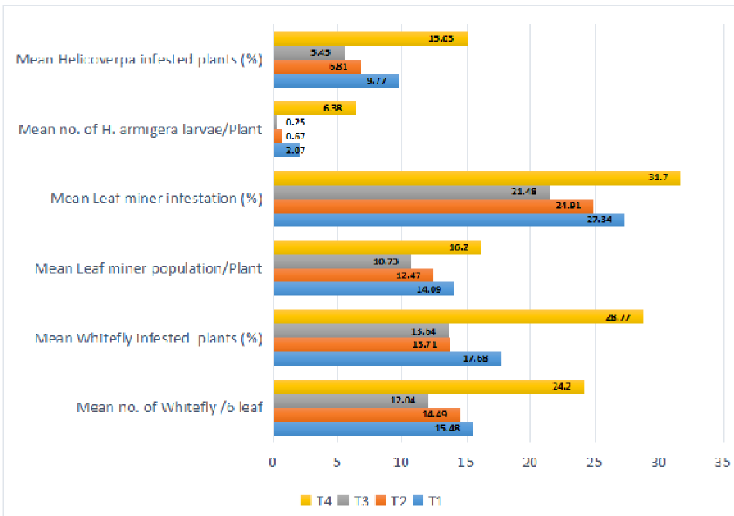

Fig. 1. Effect of the treatments on the incidence and damage of the pests in tomato.

Leaf miner. The invasive pest from U.S.A, serpentine leaf miner, *Liriomyza* sp. was observed to be a significant pest, as evidenced by a high infestation rate (31.70%) and active mines (16.2/plant) in T_4. T_3 recorded the low infestation of 10.73 active mine/plant and 21.48% infested plant and was the most superior treatment in controlling the pest. T_2 was also equally effective against leaf miner recording low damage 12.47 active mine/plant and 24.91% infested plant, but significantly inferior to T_3. T_1 performed well that had 14.09 active mine/plant and 27.34% infested plant but significantly inferior to T_3 and T_2 in terms of performance damage though mining (Table 1 and Fig. 1). Vikraktamath *et al*. (1993) reported that a 4 per cent neem seed kernel extract could significantly control the devastating *L. trifolii* on tomato crop. Jayakumar and Uthamasamy (1997) observed that neem oil (3%) caused 93.3 per cent mortality of *L. trifolii* larvae, neem seed kernel extract (5%) and mahua oil (3%) (*Madhuca longifolia*) caused 90% and 90% mortality of *L. trifolii* larvae, respectively.

Flea beetle. The leaf-damaging flea beetle, *Phyllotreta* sp., was also observed, though there was not a large population (Table 1). T_4 had an elevated infestation rate of 2.70 beetles/plant. The lowest population of 0.81 per plant was observed in T_3. T_2 (1.35 beetle/plant) and T_1 (1.48 beetle/plant) closely followed the T_3. Safer treatments T_2 and T_1 were inferior to T_3 in suppressing the population build up of the coleopteran and the difference was statistically significant (Table 1 and Fig. 1). Flea beetles were effectively repellent to the horticultural oils and some neem-based insecticide groups which could be useful in avoiding field infestations and helped in pest management programmes (Cranshaw, 2013). Neem, and mostly botanical pesticides were recommended for controlling the population of flea beetles (Ellis and Marshall 1992).

Fruit borer. Fruit borer of tomato or tomato fruit worm, *Helicoverpa armigera,* was also found to cause significant damage to green fruits and had a quite high infestation rate (15.03% fruit damage, 6.38 larva/plant) in T_4. The least damage of 5.45% fruit infestation and 0.25 larva/plant was found in T_3. T_3 was the most effective treatment in contolling the population build up and damage by the fruit borer. It was very closely followed by T_2 with 6.81% fruit damage and population density of 0.67 larva/plant. T_1 was also quite effective against the borer (9.77% fruit damage, 2.07 larva/plant) but was inferior to both T_3 and T_2 (Table 1 and Fig. 1). Kumar and Prasad (2002) found that applying *B. thuringiensis* subsp. *kurstaki* (Dipel @ 1.0 liter ha^{-1}) in bengal gram resulted in *H. armigera* larval reductions ranging between 51.01 to 92 per cent. Ravi *et al.* (2008) found that nucleo polyhedron virus of *H. armigera* (Ha NPV at 1.5×10^{12} POB ha^{-1}), *Bacillus thuringiensis var. kurstaki* (Delfin 25 WG @ 1 kg ha^{-1}), spinosad 45 SC (@ 75g *a.i.* ha^{-1}), endosulfan 35 EC (@ 350 g *a.i.* ha^{-1}), quinolphos 25 EC (@ 250 g *a.i.* ha^{-1}) and indoxacarb 14.5 SC (@ 75 g *a.i.* ha^{-1}) were found to be equally effiicacious in supressing *H. armigera* population. Kumar and Ravi (2013) investigated the efficacy of chemical insecticides such as emamectin benzoate 5 SG @ 11 g *a.i.* ha^{-1}, emamectin benzoate 5 SG @ 22 g *a.i.* ha^{-1} and *Bacillus thuringiensis* @ 25 g *a.i.* ha^{-1} for controlling *H. armigera*. Murugraj *et al.* (2006) observed that application of emamectin benzoate (proclaim 05 SG) @ 11g *a.i.* ha^{-1} was successful in reducing the population of *H. armigera* larvae and also the fruit damage, and thereby greatly increased yield.

Natural enemies. Natural enemies, coccinellids *C. transversalis*, *Cheilomenes sexmaculata* (Fab.), *C. septempunctata,* spiders, lynx *Oxyopes* sp., jumping *Phiddipus* sp. and wolf *Marpissa* sp., and rove beetle *Paederus* sp., red ant *Solenopsis* sp. and damselfly was observed in the experimental plots (Table 2 and Fig. 2).

Table 2: Effect of treatments on the population of the pollinators and the natural enemies found in tomato during the cropping season 2020-21.

Treatments	Mean number						
	Coccinellids /Plant	Spider/ Plant	Red ant/ Plant	Damselfly /Plot	Rove beetle/Plot	Carpenter bee/Plot	Honey bee/Plot
T_1	1.68 (1.48) *	2.08 (1.61)	1.31 (1.35)	0.26 (0.87)	0.43 (0.96)	0.48 (0.99)	0.80 (1.14)
T_2	1.45 (1.40)	2.05 (1.60)	1.2 (1.30)	0.20 (0.84)	0.34 (0.92)	0.44 (0.97)	0.77 (1.13)
T_3	1.38 (1.37)	2.05 (1.60)	1.12 (1.27)	0.17 (0.82)	0.23 (0.85)	0.40 (0.95)	0.60 (1.05)
T_4	1.74 (1.50)	2.14 (1.62)	1.41 (1.38)	0.29 (0.89)	0.49 (0.99)	0.50 (1.00)	0.84 (1.16)
SEm ((±)	0.05	0.02	0.05	0.01	0.02	0.02	0.01
CD at 5%	0.16	0.07	0.14	0.03	0.06	0.05	0.04

*Figures in parentheses are square root transformed *i. e.* $\sqrt{(x + 0.5)}$ value

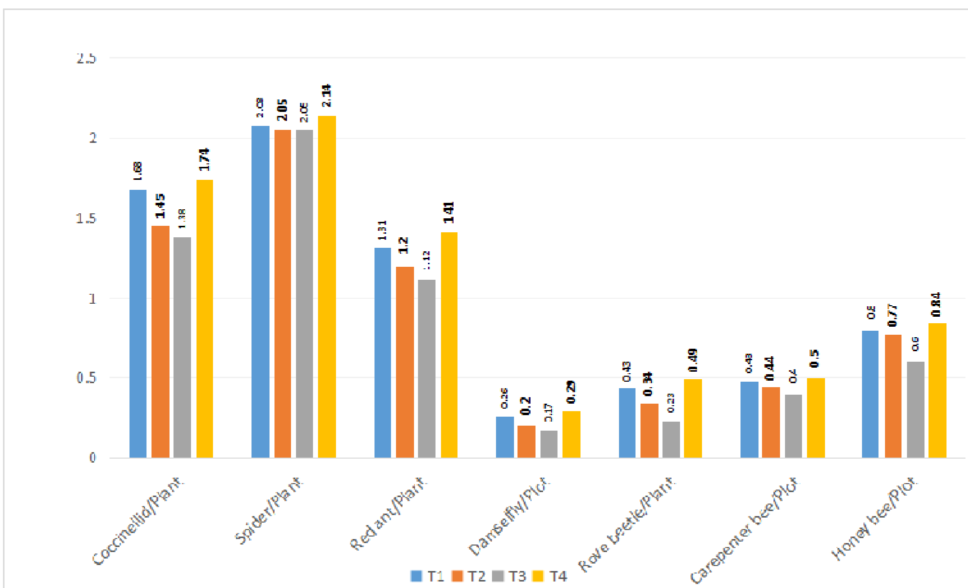

Fig. 2. Effect of the treatments on the population of the pollinators and the natural enemies found in tomato.

Coccinellid. T_4 had the highest population of coccinellid beetles (1.74 beetle/plant), followed by T_1 (1.68 beetle/plant). T_4 and T_1 were statistically at par with each other. Coccinellids, 1.45 per plant were recorded in T_2. T_3 (1.38 beetle/plant) was inferior to T_2, but was statistically at par with T_2. T_1, T_2, and T_3 had the most beetles, followed by the T_4. However, there was no statistically much difference among different treatments (Table 2 and Fig. 2).

Spider. The T_4 showed the highest population of spiders (2.14 Spiders/plant). T_1 had 2.08 Spiders/plant. T_2 and T_3 had the same number of spiders, 2.05 Spiders/plant. T_1, T_2 and T_3 were statistically at par with each other. The T_4 was the superior among all treatments (Table 2 and Fig. 2).

Red ant. The T_4 recorded the highest population of red ants (1.41 ants/plant) and closely followed by T_1 (1.31 ants/plant). T_4 and T_1 were statistically at par with each other. T_2 (1.2 ants/plant) and T_3 (1.12 ants/plant) were statistically at par with T_2. There was no statistical differences among treatments were recorded (Table 2 and Fig. 2).

Damselfly. The T_4 recorded the highest population of damselfly (0.29/plot) and closely followed by T_1 (0.26

/plot). T_4 and T_1 were statistically at par with each other. T_2 (0.20/plot) and T_3 (0.17/plot) were statistically at par with T_2. There was very less population of damselfly in the experimental field (Table 2 and Fig. 2).

Rove beetle. The T_4 recorded the highest population of rove beetle (0.43 beetle/plant) closely followed by T_1 (0.39 beetle/plant) and T_2 (0.34 beetle/plant). T_4, T_1 and T_2 were statistically at par with each other. T_3 had lowest number of population (0.23 beetle/plant) and it was inferior to all the other treatments (Table 2 and Fig. 2).

Pollinators. Data on pollinators (Table 2 and Fig. 2) found in tomato ecosystem showed that mostly common bees, three species of honey bees *A. mellifera, A. dorsata* and *A. cerena indica* and one species of carpenter bees and bumble bees *Bombus* sp. were visited. Generally, more number of bees were visited in T_4 (0.84 honey bee/plot) and (0.5 carpenter bees/plot) and other treatments had very low number of bees visiting in plot. The solanaceous crops are mainly self pollinated and having nectarless flower so pollinators population is generally low.

Economics and Yield of Different Treatments. The highest yield of 60.6 t/ha was registered by the T_3 (25.6 t/ha or 73.14% higher yield over T_4) followed by T_2. Another safer treatment, T_2 also sponsored fairly good yield 52.5 t/ha or 50% higher yield (17.5 t/ha) over T_4. In T_1, yield was 42.5 t/ha or 21.4% higher yield (7.5 t/ha) over T_4 (Table 3). Maximum net realization (519015 Rs/ ha) was found in T_3 followed by T_2 (455419 Rs/ha) and T_1 (385816 Rs./ha). The incremental cost benefit was found to be the highest in T_3 (1: 2.06) followed by T_2 (1: 1.66). The ICBR of T_1 was 1: 1.18 which was the lowest ratio among all (Table 3). Thus, T_3 was found to be the most effective and superior to all treatment.

Table 3: Economics of treatments in tomato.

Treat.	Cost of insecticide (Rs/ha)	Total cost (Rs/ha)	Yield (t/ha)	Extra yield over control (t/ha)	% of yield increase over control	Gross realization (Rs)	Net realization (Rs)	Net gain (Rs)	ICBR
T_1	28800	39296	42.5	7.5	21.4	425112	385816	46177	1: 1.18
T_2	54000	69744	52.5	17.5	50.0	525163	455419	115780	1: 1.66
T_3	66600	86936	60.6	25.6	73.14	605951	519015	179376	1: 2.06
T_4	-	10496	35.0	-	-	350135	339639	-	-

*Labour charge – Rs 328/day
*Neem oil – 100ml – Rs 60/- *Chlorfenapyr – 100ml – Rs 150/-
*Emamectin benzoate – 100gm – Rs 900/- **Bt var. kurstaki* – 1000ml – Rs 750/-

CONCLUSIONS

All the treatments were significantly superior to untreated check but efficacy level varied between treatments. T_3 produced the best impact, the lowest damage and the least number of insect pests/plant. It was followed by T_2 and T_1 in the order. However, T_3 was significantly superior to T_2 and T_1. The highest number of natural enemies were recorded in T_4 and T_1 was at par safe with it. T_2 and T_3 were also apparently safe to predatory coccinellids and spiders but both were inferior to T_1 and T_4 in terms of safety to natural enemies. The ICBR was superior in T_3 (1: 2.60) followed by T_2 (1: 1.66) and T_3 (1: 1.18) subsequently. The population of natural enemies, mostly spiders and coccinellids and pollinators, bee species, was less variable in T_3 treatment.

FUTURE SCOPE

Extensive research on the biology and life table parameters of various natural enemies' and their predation efficacy is needed. Research on bio-ecology of major tomato insect pests in different climatic zones of Odisha is needed. Appropriate integrated pest management strategies for various pests in this region needed to be devised. To compare the efficacy of phyto-extract products with appropriate insecticides against major tomato insect pests, large-scale trials should be conducted.

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Conflict of Interest. None.

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