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Integrated Pest Management Strategies for Controlling *Tuta absoluta* and Enhancing Tomato Seed Yield and Quality

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ABSTRACT

A field experiment was conducted in the mid-hills region of Himachal Pradesh, India, during April, 2019–January, 2020, to evaluate various insect management strategies, including eco-friendly approaches, against *Tuta absoluta* and other pests on tomato crop. Six treatment modules were compared to untreated control plants. Among all treatments, T_4, which included lambda cyhalothrin, indoxacarb, rynaxypyr and novaluron, was most effective, recording the lowest number of *Tuta absoluta* larvae (0.43) and leaf mines (0.75) plant^{-1}. This treatment also showed the lowest populations of aphids (10.49), serpentine leaf miners (0.83), and fruit borers (1.28) plant^{-1}. T_4 significantly enhanced growth and yield parameters, with the highest number of flower clusters (7.73), fruits (29.36), healthy fruits (23.23) plant^{-1}, seeds fruit^{-1} (87.73), 1000-seed weight (2.76 g), and seed yield (5.32 g plant^{-1}, 63.84 g plot^{-1}, 149.35 kg ha^{-1}). Seed quality was also superior in T_4, showing maximum germination (87.25%), seedling length (16.14 cm), dry weight (1.88 mg), seedling vigor indices I and II (1,412.57 and 164.71), and germination after accelerated ageing (75.25%). The enhanced performance can be attributed to the collaborated action of eco-friendly chemicals, which effectively reduced pest populations, allowing the plants to utilize their energy for growth and seed development. This study underscores the importance of integrated use of pest management strategies in optimizing tomato production, seed yield and quality, highlighting the possible benefits for agricultural economies. This study identifies an effective eco-friendly approach using specific insecticides to control Tuta absoluta and improve tomato yield and seed quality while minimizing environmental impact.

KEYWORDS: Aphid, leaf miner, quality, seed, tomato, tuta

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1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.), a vital vegetable crop originating from the Peru, Ecuador, and Bolivia regions of Central and South America (Prasanna et al., 2023), is cultivated worldwide for both fresh consumption and processing due to its adaptability to diverse agroclimatic conditions (Cammarano, 2022; Raj et al., 2018). Each year, the world produces around 182.30 mt of tomatoes on 4.85 m ha of land. Asia leads the way, growing 61.1% of tomatoes, while Europe, America and Africa contribute 13.5%, 13.4%, and 11.8%, respectively. The yield can vary dramatically; for instance, the Netherlands can produce over 508 tons ha^{-1}, whereas Somalia yields less than 1.5 t ha^{-1}, with the global average sitting at 376 t ha^{-1} (Anonymous, 2019). When it comes to eating tomatoes, countries like China, India, North Africa, the Middle East, the US, and Brazil are the biggest consumers, with per capita consumption ranging from 61.9 to 198.9 kg (Anonymous, 2019). In India, tomato ranks as the second-largest vegetable crop after potato, with significant cultivation in states like Uttar Pradesh, Karnataka, Himachal Pradesh, Maharashtra, Haryana, Punjab, and Bihar (Anonymous, 2017). In Himachal Pradesh, Solan district stands out for its considerable contribution to the region's agricultural economy and regarded as tomato bowl of the state (Agarwal et al., 2009, Thakur et al., 2019).

Despite its global significance, tomato yields in India are relatively low compared to their potential, primarily due to insufficient scientific cultivation practices. Due to intensive selection and significant genetic bottlenecks during its evolution and domestication, the cultivated tomato (*Solanum lycopersicum*) has limited genetic diversity (Blanca et al., 2015). As a result, tomatoes are highly susceptible to a wide range of diseases. Throughout both cultivation and post-harvest periods, they can be affected by more than 200 diseases caused by various pathogens globally (Singh et al., 2017). A significant challenge is the infestation by around 200 insect species, with *Tuta absoluta* being among the most severe (Panno et al., 2021). Originally from South America, this pest was first detected in Spain, outside its native region in 2006 (Biondi et al., 2018) and has since spread to many countries including India. In India, it was first documented at the ICAR-Indian Institute of Horticultural Research in Bengaluru infesting tomato crop in 2014 (Prasannakumar et al., 2021; Manjula et al., 2020). Since then, *Tuta absoluta* has spread across almost all tomato-growing regions in India (Fand et al., 2020; Kalleshwaraswamy et al., 2015; Shashank et al., 2015; Sharma and Gavkare, 2017), causing significant crop damage by feeding on leaves, buds, flowers, shoots, and fruits (Kasi et al., 2022; Sharma and Gavkare, 2017). It is a neotropical pest that specializes in feeding on solanaceous plants. Although it primarily affects tomatoes, it can also thrive on other crops like potatoes, eggplants, and common beans. The pest's aggressive nature, multiple generations year^{-1}, and resistance to insecticides pose substantial challenges for tomato growers globally (Secretariat et al., 2021). To combat this, various management strategies, including integrated pest management (IPM) approaches combining chemical and eco-friendly methods have been used. This study aims to evaluate the effectiveness of different management modules for *T. absoluta* and their impact on tomato growth and seed yield and identify an ecofriendly and sustainable approach for management of insects in tomato crop. The objectives are to assess the efficacy of these modules against *T. absoluta* and other insects and to determine their effects on tomato growth, seed yield and quality of harvested seed.

2. MATERIALS AND METHODS

The present investigations were conducted in Department of Seed Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India (during April 2019–January, 2020). The investigational area is located at14 km distance from Solan at latitude of 30°51'0" North and longitude of 77°11'30" East at 1276 m above mean sea level. The area falls in the mid zone of Himachal Pradesh. The experimental site experiences a sub-temperate, semi-humid climate with mild summers and cold winters. Design used for field experiments was RBD. Healthy, disease free and bold tomato seeds of variety 'Solan Lalima' were sown in April first week in a nursery and transplanted on April 21, 2019, with a spacing of 90×30 cm^2 within plots measuring 1.8×1.8 m^2 containing twelve plants in each plot. There were 7 treatment modules (Table 1) replicated thrice. In the treatments T_1 to T_5 the first spray was given at 30 days after transplanting and after that each spray is given at 15 days interval. Recommended dose of fertilizers was applied for nutrient requirements of the crop. The standard cultural practices viz. weeding, hoeing, irrigation etc. were followed throughout the experiment from planting till termination. Observations for insect population and leaf mines plant^{-1} was taken by counting the larvae and leaf mines on six leaves i.e. 2 each from top, middle and bottom portion of five plants in each plot after 5, 10 and 15 days after spray and then averaged. Harvested seeds were taken to the laboratory and seed quality was tested according the ISTA procedures with four replications of 100 seeds each, using completely randomized design. The data was analysed with the procedures suggested by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1. Insect control

Effect of different management modules on *Tuta absoluta* larvae, leaf mines formed by *Tuta absoluta* and infestation

Table 1: Treatment details

Treatments	Details
T_1	Spray of azadirachtin @ 5 ml l^{-1}+Emamectin benzoate @ 0.4 g l^{-1}+Rynaxypyr @ 0.3 ml l^{-1}
T_2	Spray of azadirachtin @ 5 ml l^{-1}+Emamectin benzoate @ 0.4 g l^{-1}+Rynaxypyr @ 0.6 ml l^{-1})
T_3	Spray of NSKE 5%+pongamia soap @ 10 g l^{-1}+neem soap @ 10 g l^{-1}+Spinosad 45 SC @ 0.3 ml l^{-1}
T_4	Spray of lambda cyhalothrin @ 2.5 ml l^{-1}+indoxacarb 14.5 SC @ 1 ml l^{-1}+rynaxypyr @ 0.3 ml l^{-1}+novaluron 10 EC @ 1.5 ml l^{-1}
T_5	installation of yellow sticky traps (10 acre^{-1})+Neem cake @ 2.5 t ha^{-1} at field preparation+Spray of NSKE @ 5%+Neem oil @ 3 ml l^{-1}+*Beauveria bassiana* @ 1 g l^{-1}+*Bacillus thuringiensis* @ 1 ml l^{-1}
T_6	Beejamrit seed treatment+soil application of jeevamrit+foliar spray of jeevamrit (at interval of 15 DAT)+foliar spray of neemastra (1st spray at 30 DAT and after that at interval of 15 days)
T_7	Control (No spray)

DAT: Days after transplanting

of other insects is presented in Table 2. The outcome of the study revealed that least *Tuta absoluta* larvae (0.43) and leaf mines (0.75) plant^{-1} were noted in treatment T_4 whereas the treatment T_7 (control) had the maximum number of larvae (1.62) and leaf mines (2.54) plant^{-1}. The lowest population of aphids (10.49), serpentine leaf miners (0.83) and fruit borers (1.90) plant^{-1} were detected in the treatment T_4 however the maximum population was observed in T_7 i.e. Control (no spray) with 23.22 aphids, 2.81 serpentine leaf miners and 3.64 fruit borers plant^{-1}. The decrease in the insect population may be attributed to the combined action of ecofriendly chemicals included in the treatment. Lambda-cyhalothrin, a synthetic pyrethroid insecticide, disrupts insect nervous systems by prolonging sodium channel opening. This causes hyperexcitation, paralysis, and ultimately death, primarily through contact and ingestion (Whitacre, 2008). Indoxacarb, a potent foliar insecticide, against Lepidoptera and other sucking insects act by bioactivation to N-decarbomethoxyllated metabolite, which blocks insect voltage-gated sodium channels (Keith et al., 2000). Rynaxypyr is primarily effective through ingestion but also on contact, it blocks the ryanodine receptors of insect muscle cells, there by killing insect by sustained muscle contraction and paralysis (Lahm et al., 2007). Novaluron disrupts insect development by inhibiting chitin synthesis, preventing exoskeleton formation and leading to impaired growth and death (Ghoneim et al., 2015). Similar results of decrease in the population of larvae of *T. absoluta* was observed when sprayed with Superlambda 5% EC (lambda cyhalothrin) (Taleh et al., 2021), indoxacarb (Shahini et al., 2021), ranxpyr 18.5% SC followed by spinosad 45% SC (Bajracharya et al., 2017), novaluron (Ramarao, 2019). Moreover, sequential application of chlorantraniliprole+lambda cyhalothrin gave the best result in controlling fruit borer (Khinchi and Kumawat, 2021) and serpentine leaf miner (Floret and Regupathy, 2019).

3.2. *Flowering, fruiting and seed yield*

Table 3 provides data on the impact of various insect control measures on the flowering, fruiting and seed yield of the tomato variety "Solan Lalima". On evaluation of data treatment T_4 comprising of spray of lambda cyhalothrin @ 2.5 ml l^{-1}+indoxacarb 14.5 SC @1 ml l^{-1}+rynaxypyr @0.3 ml l^{-1}+novaluron 10 EC @ 1.5 ml l^{-1}, demonstrated the highest effectiveness for enhancement of flowering, fruit development and seed yield comprising of the maximum values for number of flower clusters (7.73), fruits (29.36) and healthy fruits (23.23) plant^{-1}, also the seeds fruit^{-1} (87.73), 1000 seed weight (2.76 g) and seed yield (5.32 g plant^{-1}, 63.84 g plot^{-1} and 149.35 kg ha^{-1}) were highest

Table 2: Effect of management modules on infestation of *Tuta absoluta* and other insects

Treatments	*T. absoluta* larvae plant^{-1}	*T. absoluta* leafmines plant^{-1}	Aphids plant^{-1}	Serpentine leafminer plant^{-1}	Fruit borer plant^{-1}
T_1	0.65	0.86	12.12	1.10	1.49
T_2	0.52	0.81	11.66	1.01	1.30
T_3	0.83	0.95	13.79	1.36	2.06
T_4	0.43	0.75	10.49	0.83	1.28
T_5	0.92	1.11	14.74	1.27	1.90
T_6	1.09	2.18	16.51	1.82	2.52
T_7	1.62	2.54	23.22	2.81	3.64
CD (p=0.05)	0.25	0.15	1.67	0.30	0.54

Table 3: Effect of different modules on flowering, fruiting and seed yield parameters tomato fruits during the management of *Tuta absoluta*

Treatments	Flower clusters $plant^{-1}$	Fruits $plant^{-1}$	Healthy fruits $plant^{-1}$	Damaged fruits $plant^{-1}$	% Fruit damage*	Seeds $fruit^{-1}$	Seed yield			1000 seed weight (g)
							g $plant^{-1}$	g $plot^{-1}$	kg ha^{-1}	
T_1	7.53	27.83	20.56	7.27	26.12 (30.71)	84.51	4.66	55.92	130.81	2.70
T_2	7.53	28.00	21.00	7.00	24.98 (29.97)	84.35	4.75	57.04	133.43	2.69
T_3	7.40	27.42	18.87	8.56	31.48 (34.11)	83.37	4.16	49.92	116.77	2.63
T_4	7.73	29.36	23.23	6.13	20.85 (27.11)	87.73	5.32	63.84	149.35	2.76
T_5	7.60	28.07	19.70	8.37	29.80 (33.07)	83.85	4.21	50.56	118.27	2.71
T_6	7.67	28.53	18.37	10.16	35.61 (36.61)	85.70	4.01	48.16	112.66	2.74
T_7	7.00	25.80	13.00	12.80	49.58 (44.74)	79.96	2.95	35.44	82.90	2.49
CD (p=0.05)	0.15	1.19	0.87	1.24	2.23	1.82	0.23	2.67	6.38	0.03

* Figures in the parenthesis are angular transformed values

in T_4. In comparison to this the minimum flower clusters (7.00), fruits (25.08) and healthy fruits (13.00) $plant^{-1}$, seeds $fruit^{-1}$ (79.96), 1000 seed weight (2.49 g) and seed yield (2.95 g $plant^{-1}$, 35.44 g $plot^{-1}$ and 82.90 kg ha^{-1}) were in T_7 (Control). The observed increase in flowering, fruiting, and seed yield can be credited to combined action of eco-friendly chemicals used. These chemicals effectively eradicated various insects infesting the crop, including *T. absoluta*, which were present on the growing tips of the plants, formed mines inside the stems, and consumed the mesophyll tissues of the leaves, thereby reducing the photosynthetic activity of the plants (Rwomushana et al., 2019). The infestation by these insects, which feed on leaves, flowers, and fruits, cause damage and hinders its normal crop growth. However, following insecticide application, the insect population was significantly reduced, leading to improved growth, flowering, and yield (Bhauarya, 2019).

3.3. Seed quality

Table 4, presents the impact of insect management modules on seed quality. The results indicated that T_4 which had the minimum population of insects showed the maximum seed

Table 4: Effect of different modules on seed quality during the management of *Tuta absoluta*

Treatments	Germination (%)	Seedling length (cm)	Seedling dry weight (mg)	Seedling vigour index I	Seedling vigour index II	EC (µS cm^{-1})	Germination (%) after AAT
T_1	84.75 (9.26)	15.21	1.798	1,289.00	152.35	4.22	72.00 (58.03)
T_2	84.25 (9.23)	15.10	1.783	1,272.35	150.18	4.29	71.75 (57.87)
T_3	82.50 (9.14)	14.32	1.740	1,181.39	143.55	4.54	68.25 (55.68)
T_4	87.25 (9.40)	16.14	1.883	1,412.57	164.71	3.71	75.25 (60.16)
T_5	85.25 (9.28)	15.57	1.820	1,327.11	155.16	4.14	72.25 (58.19)
T_6	86.00 (9.33)	15.96	1.863	1,372.40	160.18	3.92	73.50 (58.99)
T_7	78.75 (8.93)	13.35	1.700	1,051.30	133.89	5.66	64.75 (53.57)
CD (p=0.05)	2.07	0.33	0.028	41.40	4.66	0.29	2.21

* figures in the parenthesis are square root transformed values; AAT: Accelerated ageing test

quality resulting in highest germination (87.25%), seedling length (16.14 cm), seedling dry weight (1.88 mg), seedling vigor index I (1412.57), seedling vigor index II (164.71), electrical conductivity of seed leachates (3.71 μS cm^{-1}) and germination after accelerated ageing (75.25%). Whereas the minimum values were in treatment T_7 (control). The increased seed quality can be credited to the sequential application of the insecticides which reduced the population of insect pests during the growth, flowering and crop development, as the insect population was reduced the plants were able to utilize all of the energy for reserve accumulation within the seeds thus resulting in high vigor seeds with maximum seed quality. Similar findings were observed by Meena et al. (2017) who observed that the foliar spray of insecticides reduced insect infestation and enhanced the chilli seed quality as compared to control.

4. CONCLUSION

Treatment T_4, comprising a combination of eco-friendly chemicals, demonstrated remarkable effectiveness in controlling insect populations, thereby enhancing tomato growth, flowering and seed yield. Moreover, this approach positively influenced seed quality, ensuring high-vigor seed production.

5. ACKNOWLEDGEMENT

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