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Management approaches for tomato (*Solanum lycopersicum* L.) insect pests, with special attention on *Helicoverpa armigera*

Chatra Ram Godara[1]*, Mahesh Kumar Meena[2], Virender Kumar[3], Saroj[4], Shashi Jakhar[4]
[1] Assistant Professor, Department of Zoology, Government Science College, Sikar, Rajasthan, India
[2] Assistant Professor, Department of Zoology, University of Rajasthan, Jaipur, Rajasthan, India
[3] Assistant Professor, Department of Zoology, Government Bangur College, Didwana, Nagaur, Rajasthan, India
[4] Research Scholar, Department of Zoology, University of Rajasthan, Jaipur, Rajasthan, India

Abstract
Tomato (*Solanum lycopersicum* L.) is an important vegetable of a balanced diet and a good source of several nutrients. A variety of insect pests, such as whiteflies, jassids, serpentine leaf miners, and aphids, which infest at various stages of crop growth, have a significant impact on the quality and quantity of tomato fruit. To combat insect pest the usage of insecticides has increased many fold now-a-days. In some areas farmers have been also using bio-control agents in Integrated Pest Management (IPM) for the safety of environment and human health. Numerous researchers have reported the potential use of various microbes and plants extracts in pest management. This strategy is the most effective for controlling pests since the diseases prevent pests both temporarily and permanently while causing the least disturbance of the natural equilibrium of the environment.

Keywords: Vegetables, *Solanum lycopersicum,* integrated pest management (IPM)

Introduction

The tomato (*Solanum lycopersicum* L.), a plant belonging to the Solanaceae family, is an important vegetable. The production of tomatoes, a warm-season crop, requires both warm and temperate climates. Unfavourable climatic conditions have a significant impact on the plant health (Bihon *et al*., 2022) [6]. It requires a variety of environmental factors such as optimum temperature, humidity, soil profile, etc. for seed germination, seedling development, flower and fruit set, and fruit quality (Dube *et al*., 2020) [9].

The top-producing states in India involve Madhya Pradesh, West Bengal, Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, and Maharashtra. (Source: https://www.nhb.gov.in/statistics/Reports/TomatoOctober2021).

Numerous epidemiological studies conducted recently have demonstrated that tomatoes guard against prostate and digestive tract cancer (Ali *et al*., 2021) [2]. Additionally, including tomatoes in your diet might cut your risk of prostate cancer by up to 45% (Rai and Yadav, 2005) [35]. It is also applied to bronchitis sufferers and used as an intestinal antiseptic. It is an excellent natural stimulant for the kidneys and a mild stimulant that helps the body remove impurities. The highest concentration of lycopene, a phytochemical that functions as an antioxidant to shield human cells from free radicals that have been related to cancer in people, may be found in tomatoes (Mandloi, 2013) [26].

Major pest studied on tomato

According to Anonymous (2007) [3], insect pest infestations have caused losses of 30 to 35 % of tomato crops. Kumar (2008) [23] observed five species of insects on tomato, which represented 3 orders and 5 families, *viz*., whitefly (*Bemisia tabaci)*, tomato serpentine aphid (*Aphis gossypii)*; jassid, *Amrasca devastans*; serpentine leaf miner, *Liriomyza trifolii;* and fruit borer, *Helicoverpa armigera*. Similarly, Mandal (2012) [25], the main insect pests of tomatoes have included the fruit borer, aphid and the white fly. According to Oda *et al*., (2012) [30] tomato crops are commonly infested by a number of insect pests, including cotton bollworm, aphids, thrips, whiteflies, leaf miners, and insects from the Coccidae and Miridae families. The tomato borer, *Tuta absoluta* (Meyrick), an invasive insect that is native to South America, has caused a significant output loss in the tomato industry since it arrived in Europe, according to Zappala *et al*., (2012) [53]. Juma (2015) [18] identified a total of seven pest species infesting tomato seedlings (*Thrips* , *Aphis gossypii*, *Agrotis* spp., *Bemisia tabaci*, *Tetranychus* spp., *Schizonycha* spp., and *Liriomyza trifolii),* while nine pest species were identified infesting tomato plants during field production (*Aphis gossypii*, *Thrips* spp., *Liriomyza trifolii, and Planococcus* spp.). Sam *et al.,* (2014) [40] reported that *T. tabaci*, *B. tabaci*, *Htabaci. armigera*, *A. gossypii*, and *Liriomyza* sp. were the most important insect pests that attack tomatoes.


Fig 1: & **Fig 2:** *H. armigera* infestation in tomato fruits

Studies on insect pest complexes on tomatoes and their natural enemies revealed that tomato serpentine aphid (*Aphis gossypii*, *Myzus persicae* Sulzer and *Macrosiphum euphorbiae*), leaf miner, white fly, thrip (*Scirtothrip dorsalis*, *Thrips palmi* Karny) and jassid were major insects causing damage at various growth stages of the crop. The tomato fruit borer and the tobacco caterpillar (*Spodoptera litura*), two additional significant insect pests, were discovered during the crop's fruiting stage (Sen, 2016) [41].

In an another study it was revealed that 41 different bug species from 21 different families attacked the tomato crop (Kachave *et al.,* 2020) [19].

Numerous insect pests that infest the crop at various growth stages have a significant impact on the quality of tomato fruit output. The aphid, leaf miner, whitefly, jassid, and fruit borer are the main insect pests that contribute most to the financial losses of the tomato crop (Singh *et al.,* 2023) [45].

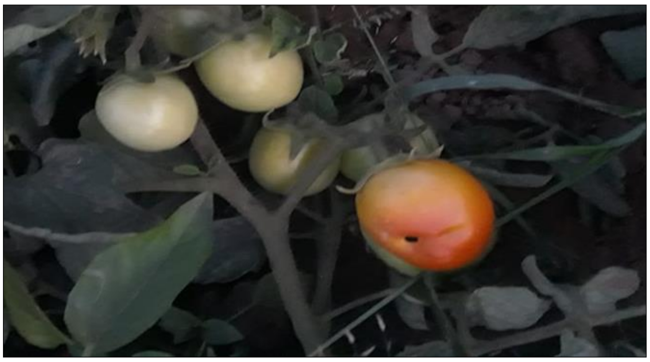

Fig 3: *H. armigera* infestation in tomato fruits in the field condition

Among tomato insect pests, the whitefly is particularly devastating, leading to losses of up to 100%, costing more than a hundred million dollars annually (Mrosso *et al.,* 2023) [29]. Ravipati *et al.,* (2021) [37] and Kaur *et al.,* (2010) [20] discovered that the incidence of the leaf miner was remarkably low and that whiteflies were only present in the early part of the growing season.

In addition to viruses and fungi, other pathogens that may severely damage tomatoes include Fusarium wilt (*Fusarium oxysporum* f. sp. lycopersici), powdery mildew (*Sphaerotheca fuliginea*), bacterial wilt (*Ralstonia pseudosolanacearum*) (Klass *et al.,* 2020) [21], and late blight (*Phytophthora infestans*). The viruses known as tomato yellow leaf curl viruses are the most prevalent in tomato crops (Hussain *et al.,* 2022; Ghosh and Ghanim, 2021) [15, 13].

***Helicoverpa armigera*: The major pests of tomatoes**

The most important pest of tomato crop is *H. armigera* commonly known as fruit borer. Shinde, S. (2007) [43] found that pest succession on tomatoes was mainly three insect species, *viz*., the white fly (*Beemisia tabaci* Genn.), the fruit borer (*H. armigera* Hub.), and the American serpentine leaf miner. A widely recognized pest on the Indian subcontinent is the fruit borer, *H. armigera*. One of the main pests of tomatoes, the borer is thought to be responsible for severe crop losses in India. This bug was recently identified as a nuisance on a national level (Singh and Singh, 2006) [46].

Tomato fruit damage from *H. armigera*'s seasonal occurrence began in the first week of October at a rate of 2.81 % rose over the following weeks and peaked at 39.54 % in the middle of November (Ramya *et al*., 2017) [36].

Similar study done by Kurl and Kumar (2010) [24], *H. armigera* larvae started to develop on tomato crops in the second week of January and persisted until the first week of June. The third week of April saw the greatest population growth of larvae. A survey was conducted by Jadhav *et al*., (2010) [16] of *H. armigera* infestation on different plants in the north-eastern region of Karnataka during 2004-2005 revealed that the activity of *H. armigera* was seen on tomato and chilli crops from month March to May.

Fig 4: *Helicoverpa armigera*: An important pest of tomatoes

Reddy and Kumar (2004) [38] found a significant negative correlation between the population of *H. armigera* with minimum temperature and non-significant relationships with maximum temperature, relative humidity, and rainfall in tomato.

Although Wade *et al*., (2020) [50] and Wakil *et al.,* (2011) [52] found a positive association between the average maximum and lowest temperatures and the density of *H. armigera* eggs, larvae, and adults was seen during the study. Whereas, the population of *A. gossypii* was significantly negatively impacted by abiotic variables such as maximum temperature, lowest temperature, temperature gradient, average temperature, minimum relative humidity, and sunlight hours (Ghazanfar *et al.,* 2010) [11].

The average maximum temperature (32.90 C), minimum temperature (17.90 C), morning humidity (74.2%), evening humidity (30.1%), and rainfall (6.0 mm) from the 10^{th} to the 15^{th} standard week were found to be most suitable for the larval population build-up of *H. armigera* (Kurl and Kumar, 2010) [24].

On the basis of above studies, it is concluded that temperatures between 18°C to 33°C and relative humidity around 50% are the ideal conditions for the occurrence and population growth of *H. armigera* larvae.

Integrated pest management (IPM)

A comprehensive strategy for managing pests known as integrated pest management (IPM) employs a variety of techniques to address all pest threats seen in a crop system (Porras *et al.,* 2022) [33]. As the first stage in an IPM strategy, accurate identification of pest, pathogen, and beneficial species is required. After that, a package for IPM may be created and applied (Dinakaran *et al.,* 2013) [8].

Systematic observations are required to confirm the presence of the pest in a particular field. Based on this expectation, preventative measures may be included in the package (Shankarappa *et al.*, 2022) [42]. These precautions may include adjusting planting dates, choosing resistant crop varieties, sanitizing seed treatments, adding soil amendments, promoting the growth of plants that serve as food sources for natural enemies, avoiding the use of pesticides that are harmful to these creatures, encouraging the establishment of natural enemies, using a row cover on the seedbed, and other physical barriers (Grasswitz, 2019) [14].

Crop monitoring might be supplemented with sticky cards, human assessments, and sex pheromone traps. Within-season management techniques might include pulling sick plants and employing pesticides sparingly as needed, depending on crop inspection. Choosing a technique requires considering into account its efficacy, financial rewards, and potential dangers to human health and the environment (Barzman *et al.*, 2015) [4]. The cultivation of tomatoes in Asia has seen the introduction of several IPM schemes. For instance in Bangladesh pesticide use was reduced, resulting in a 39% increase in profit (Rahman *et al.*, 2018) [34].

Trap crop method: Pests are directed away from the main crop or focused in certain areas of the field where they may be readily caught or managed by trap crops. The main benefit of trap crops is that they provide additional benefits for natural enemies and are far more attractive to pests than the main crop.

Fig 5: Pheromone trap method

Intercropping method: Intercropping and strip cropping reduce pest effect on the cash crop by using either a push (deterrent from cash crop) or a pull (attraction to other species) technique (Rosulu *et al.*, 2022) [39].

Crop rotation: It is possible to control some specific pests of vegetables by appropriately rotating various leafy, fruit, and root crops on the same farms; however, this has to be confirmed via experimental research (Umeh *et al.*, 2002) [49].

Allelochemicals: These chemicals are the phytochemicals, in particular, stop pests from proliferating, growing, changing form, and metamorphosing, according to Ahmad (2015) [1]. The "anti-insect plant factor" or "repellency factor" was emphasized in the pest control module's design since plant volatiles are known to have a significant influence in the host selection process.

Natural enemies: According to Ogah and Nwilene (2017) [31], the insect fauna of agricultural agro-ecosystems usually contains insect species that act as natural enemies, such as parasitoids and predators of insect pests.

These are some of the IPM methods which we can incorporate in field to combat the insect pests.

By chemical agents

Several chemicals have been formulating and using in the field to minimize the impact of the pests. Due to their quick results, simplicity of use, and availability, pesticides are now absolutely necessary for enhancing vegetable crop productivity. But due to the negative impact on the food chain, persistency in the food product, lethal impact on the natural enemies and harmful effect on the environment, people are searching the replacement of these chemical pesticides.

However, Ghosh *et al*., (2010) [12] conducted a field experiment and revealed the lowest percentage of tomato fruit damage by *H. armigera* in plots treated with spinosad at 45% SC @ 73 and 84 ga.i/ha as compared to untreated control (78.61%). Emamectin benzoate 5 SG @ 9.5 g a.i./ha (213.74 q/ha) was the second-best treatment in terms of fruit output.

While, Juma *et al.*, (2015) [18] observed that the 0.9 mm size nets treated with alpha cypermethrin are most effective in protecting tomato plants against *H. armigera, Planococcus* spp., *Bemisia tabaci, Liriomyza trifolii,* and *Aphis gossypii.* According to Tarate *et al.*, (2016) [48], emamectin benzoate was shown to be the most effective pesticide against the tomato leaf miner after transplanting.

Tomato fruit borer controls with six more recent pesticides were used. viz., Quinalphos 25% EC, Novaluron 10% EC, Chlorantraniliprole 18.5% SC, Flubendamide 39.35% SC, Emamectin benzoate 5% SG, and Indoxacarb 14.5% SC (Patidar *et al.*, 2023) [32]. These pesticides are frequently used improperly, which raises the cost to the farmer, provides insufficient insect control, reduces ecosystem services like pollination and causes water contamination (Singh *et al*., 2021) [44].

Botanical pesticides

In an important study, Kulat *et al.* (2001) [22] found that the crop treated with *N. tabacum* leaf extract, *P. glabra* seed extract (5%), and Indiara seed extract (1%) as well as neem seed kernel extract (5%) showed less population increase than the *H. armigera* control. In similar study, Jeyakumar and Gupta (1999) [17] found that applying 3% neem oil resulted in 93.3% larval death, whereas applying 3% mahua oil and 5% neem seed kernel extracts caused 90% and 5% mortality of *L. trifolii*, respectively. Subapriya and Nagini, (2005) [47] also reported 5% neem oil as an effective botanical in reducing fruit borer infestation. It functions as an insect feeding deterrent but also acts as a repellent, growth regulator, oviposition (egg deposition) suppressor, sterilant, and other things in different forms.

In 2006 study on effectiveness of microbial insecticides, Mayoral *et al.*, [28] examined that *B. bassiana*-based bioinsecticides used at various dosages to manage whiteflies on protected tomato plants was found significantly effective. While, study on botanical insecticides, Mathuru and Mehta (2016) [27], found that botanical insecticides based on extracts from *A. vasica* rhizome, *V. negundo* leaf and *A. calamus* rhizome were more effective against *H. armigera* larvae than *D. deltoidea* tuber extract. An investigation was conducted by Bihari and Narayan (2010) [5] on the effects of tobacco leaf extract, tea extract, neem leaf extract, neem seed kernel extract (NSKE), jatropha leaf extract, jatropha kernel extract, karanj leaf extract, tulsi leaf extract, onion-garlic bulb extract and chilli fruit extract on tomato plant and fruit borer incidence and found positive results against the pest.

According to da Costa Inácio *et al.* (2020) [7], *T. diversifolia* extract may be used as a botanical pesticide, primarily against Lepidoptera that defoliates plants. Applying *T. diversifolia* extract for *H. armigera* larvae, the results demonstrate substantial mortality, up to 80% of larvae, and antifeedant efficacy for all plant species evaluated. The results of Wakil *et al.* (2022) [51] demonstrate that HaNPV (*H. armigera* nucleopolyhedrovirus) and chlorantraniliprole combined are a financially feasible way to manage *H. armigera* on tomato plants. Crude plant extracts or refined plant compounds can also be used as these insecticides (Gao *et al.*, 2023) [10].

The use of botanical insecticides is growing in acceptance day by day as they are eco-friendly as well as are beneficial for human and Animals health.

Conclusion

The overuse of pesticides in the quest for increased yields might be the cause of both the present and future ecological disasters. Pesticide resistance, pesticide poisoning, insect pest resurgence, extinction of predator species, environmental toxicity, adverse effects on other non-target organisms, disruption of the food chain, increasing prevalence of pesticide residues in food, and decreased tomato yields are a few potential issues. The application of thoughtful IPM solutions might prevent these issues. Although there are various IPM strategies, particularly created for the tomato industry, acceptance is still low due to the misconception that "chemical-free" tactics are less efficient than frequent pesticide usage. But, research is still going on to increasing the productivity with the use of botanicals and microbial pesticides and gradually people are understanding the value of the environment and their own health. Hopefully, we completely move on to the natural pesticides in future.

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