

EFFECTS OF MARIGOLD AS A TRAP CROP AGAINST TOMATO FRUIT BORER (*HELICOVERPA ARMIGERA*): A REVIEW

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Abstract

Tomato fruit borer (*Helicoverpa armigera*) is a major pest causing significant yield losses in tomato cultivation worldwide. Conventional chemical control methods face challenges including insecticide resistance and environmental harm, prompting the search for sustainable alternatives. This review explores the use of marigold (*Tagetes* spp.) as an eco-friendly trap crop to manage tomato fruit borer populations. The botanical characteristics of marigold and its emission of volatile organic compounds effectively attract *H. armigera*, diverting oviposition away from tomato plants. Field studies demonstrate considerable reductions in fruit borer infestation and corresponding yield improvements in tomato crops when marigold is grown alongside as a border or intercrop, typically at ratios ranging from 15:1 to 3:1. Integration into integrated pest management (IPM) systems reduces pesticide use and supports ecological balance, although practical challenges such as planting synchronization and land use remain. Key knowledge gaps include detailed chemical profiling of attractants, optimization of planting strategies, and socioeconomic adoption factors. Overall, marigold trap cropping presents a promising, sustainable strategy with significant benefits for tomato pest management.

Keywords: Marigold, Trap Cropping, Tomato Fruit Borer, IPM

1. Introduction

Tomato (*Solanum lycopersicum*) is one of the most widely cultivated and economically important vegetable crops worldwide. It plays a significant role in human nutrition, being a rich source of vitamins A and C, lycopene, and antioxidants, while also contributing substantially to agricultural economies and livelihoods (Kashyap & Verma, 1986; Singh & Narang, 1990). Despite its importance, tomato production is severely constrained by pests, especially the tomato fruit borer, *Helicoverpa armigera* (Hübner), a polyphagous insect pest notorious for boring into tomato fruits and causing substantial yield and quality losses (Canerday et al., 1969; Kumar, 2002).

Management of tomato fruit borer has largely depended on the use of chemical insecticides. However, repeated and indiscriminate pesticide applications have led to the development of insecticide resistance in *H. armigera*, as well as environmental contamination, non-target organism harm, and

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increased production costs (Mehta et al., 2010; Sajjad, 2011). These challenges underscore the necessity for more sustainable pest management approaches.

One promising method is trap cropping, an integrated pest management (IPM) tactic involving the use of a more attractive plant species to divert pests away from the main crop. Marigold (*Tagetes* spp.) has been identified as an effective trap crop for *H. armigera* due to its ability to attract the pest away from tomato plants, thereby reducing infestation levels in the main crop (Kashyap & Verma, 1986; Mehta et al., 2010).

This review aims to synthesize existing knowledge about the use of marigold as a trap crop against tomato fruit borer, examining its effectiveness, mechanism of action, and integration into sustainable pest management systems to support future research and practical applications

2. Biology and Damage Potential of Tomato Fruit Borer

Helicoverpa armigera (Hübner) is a polyphagous moth belonging to the family Noctuidae. It is also commonly known as the cotton bollworm or tomato fruit borer (Kumar, 2002). The life cycle comprises four main stages: egg, larva, pupa, and adult. Under favorable summer conditions (around 25–30°C), the full lifecycle completes in about 30–40 days, while in cooler seasons it can extend up to 70 days (Canerday et al., 1969; Zalucki et al., 1986). Females lay eggs singly or in clusters on the upper parts of tomato plants, including leaves, flower buds, and developing fruits. The eggs hatch within 3 to 6 days depending on temperature.

The larval stage is the most destructive, with six instars during which larvae actively bore into the tomato fruits, feeding internally and causing direct damage that results in fruit rotting and reduction in market quality (Singh & Narang, 1990). Early instars feed externally on leaves and flowers, but later instars penetrate fruit tissues. Once fully grown, larvae drop to the soil to pupate near the plant base, where pupation lasts about 10 to 14 days. Adults are nocturnal moths that live approximately 10 days and can disperse widely, laying hundreds to thousands of eggs during their lifespan (Kashyap & Verma, 1986).

Seasonally, *H. armigera* populations peak during warm months and are influenced by cropping patterns and climatic conditions. In tomato-growing regions, multiple overlapping generations arise during the crop season, leading to continuous infestation pressure (Mehta et al., 2010). The economic losses due to fruit borer infestation can reach 20-40% of total yield in severe outbreaks, significantly impacting smallholder farmers' incomes (Sajjad, 2011).

The biology of *H. armigera* closely informs control strategies. Its high fecundity, larval mobility, and diverse host range complicate effective management. Early targeting of small larvae through integrated methods is critical to reduce damage. Understanding its life cycle stages and seasonal population dynamics helps in timing interventions, such as deploying trap crops like marigold during peak oviposition periods to divert egg laying away from tomato plants (Kashyap & Verma, 1986; Mehta et al., 2010).

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3. Marigold as a Trap Crop

Marigold belongs to the genus *Tagetes*, which comprises about 50 species of mostly annual or perennial herbaceous plants in the family Asteraceae (The Editors of Encyclopaedia Britannica, 1998). Native primarily to Central and South America, marigolds are characterized by their bright, composite flowers typically in shades of yellow, orange, and red. The leaves are usually pinnate or bipinnate, with aromatic oils present in glandular structures on the foliage (Wikipedia contributors, 2003). Common garden and agricultural varieties vary in height from 0.1 to over 2 meters, with flower heads ranging about 1 to 6 centimeters in diameter.

Two widely cultivated species used as trap crops in pest management are *Tagetes erecta* (Mexican or African marigold) and *Tagetes patula* (French marigold). *T. erecta* is a tall, robust plant with large flower heads, whereas *T. patula* is smaller with a bushier habit and more varied flower colors including yellow, orange, and maroon highlights (The Editors of Encyclopaedia Britannica, 1998; Wikipedia contributors, 2005). Both species are highly adaptable to various soils but prefer well-drained conditions and full sun for optimal growth (North Carolina Extension Gardener, 2024).

Marigold's efficacy as a trap crop against tomato fruit borer (*Helicoverpa armigera*) is largely attributed to its emission of volatile organic compounds (VOCs), including limonene, ocimene, and z-beta-ocimene (Kashyap & Verma, 1986). These volatiles serve as attractants that disrupt pest host-finding behavior, drawing moths to the marigold rather than tomato plants (Mehta et al., 2010). The strong aromatic oils in marigold foliage also possess insect-repellent and nematocidal properties, contributing both directly and indirectly to pest management in cropping systems (Sajjad, 2011).

Agronomically, marigolds present high compatibility with tomato crops when used in intercropping or border-row trap cropping systems without significant competition for nutrients or water (Kashyap & Verma, 1986). Their growth habits complement tomato production cycles and can improve overall field biodiversity by attracting beneficial insects like pollinators and parasitoids (Mehta et al., 2010). This dual benefit supports sustainable integrated pest management (IPM) frameworks.

4. Mechanism of Attraction and Pest Diversion

Marigold (*Tagetes* spp.) attracts tomato fruit borer, *Helicoverpa armigera*, primarily through its emission of volatile organic compounds (VOCs) that influence the pest's host-seeking behavior. Studies employing electroantennographic (EAG) and olfactometer bioassays have identified several key volatile compounds from marigold flowers, such as benzaldehyde, linalool, phenylacetaldehyde, and limonene, which elicit strong antennal responses in female *H. armigera* moths (Bruce & Cork, 2001; Srinivasan et al., 1994). These volatiles act as chemical cues during the early stages of host location, guiding female moths' upwind flight towards the marigold plants where they preferentially oviposit.

Behavioral studies have demonstrated that female *H. armigera* moths exhibit oviposition preference for marigold flowers over tomato plants when given a choice. This preference is attributed to the attractive floral scent profile of marigold combined with visual cues such as flower color and

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morphology (Patel & Yadav, 1992). The bright orange and yellow inflorescences of marigold are visually conspicuous and, together with volatile cues, synergistically enhance pest attraction. The strong olfactory and visual signals create a “decoy” effect, diverting moths from the tomato crop and concentrating egg laying on the trap crop.

Field observations consistently show higher pest concentration and damage on marigold rows planted around or interspersed with tomato crops. Several trials report significant reductions in fruit borer infestation on tomato when marigold trap crops are deployed, with pest densities disproportionately higher on the marigold plants (Srinivasan et al., 1994; Mehta et al., 2010). This spatial redistribution of oviposition reduces economic damage to tomato fruits and facilitates targeted pest control measures focused on the trap crop.

5. Field Studies and Experimental Results

Numerous field studies, both in India and internationally, have evaluated the effectiveness of marigold (*Tagetes* spp.) as a trap crop for managing tomato fruit borer, *Helicoverpa armigera*. In India, one notable study conducted at Rajasthan College of Agriculture observed that planting marigold as a trap crop at a ratio of 15 rows of tomato to 1 row of marigold significantly reduced larval populations compared to tomato monoculture, resulting in decreased fruit damage (Kumar et al., 2017). Similarly, Srinivasan et al. (1993, 1994) at the Indian Institute of Horticultural Research developed an integrated pest management (IPM) approach incorporating African marigold as a trap crop, reporting a 46% higher yield and 119% greater net returns compared to non-IPM farms.

Field investigations frequently utilize border-row methods, such as planting 1 row of marigold around 14 to 16 rows of tomato, or intercropping methods with a ratio of 3:1 or 4:1 tomato to marigold plants. These arrangements effectively divert *H. armigera* oviposition onto marigold, leading to lower infestation in tomato fruits (Srinivasan et al., 1994; Chaturvedi et al., 2016). For example, trials in Arunachal Pradesh demonstrated that a 3:1 tomato-to-marigold ratio yielded a maximum fruit yield of 16.32 t/ha with only 5.47% fruit borer infestation, while the control plots without marigold experienced 18.32% infestation and a yield of 14.27 t/ha (Chaturvedi et al., 2014).

Quantitative synthesis from various studies shows consistent reduction in *H. armigera* larval population ranging from 40% to 70% in tomato plots utilizing marigold trap crops (Kumar et al., 2017; Srinivasan et al., 1994). Correspondingly, the yield improvements vary from 25% to 46%, with improved fruit marketability due to reduced pest damage (Mehta et al., 2010; Gajanana et al., 1994). The use of marigold as a trap crop also reduces pesticide applications, contributing to lower production costs and enhanced ecological sustainability.

These field results underscore marigold’s practical value as an eco-friendly trap crop that can be readily incorporated into tomato farming systems, enhancing pest management efficacy and farm profitability.

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6. Integration in IPM Practices

Marigold trap cropping is widely recognized as an effective component of integrated pest management (IPM) systems in tomato cultivation. Its role extends beyond direct pest attraction, as it complements biological control agents like parasitoids (e.g., *Trichogramma* spp.) and promotes reduced insecticide dependency (Srinivasan et al., 1994). The trap crop concentrates *Helicoverpa armigera* populations, allowing targeted interventions such as localized pesticide applications or biological treatments on the marigold rows while sparing the main tomato crop. This selective management approach reduces overall chemical input, mitigates resistant pest populations, and supports beneficial insect biodiversity. However, successful integration requires careful synchronization of marigold planting with the tomato crop cycle and monitoring to prevent pest spillover from the trap crop (Mehta et al., 2010).

7. Knowledge Gaps and Future Research

Although marigold has shown efficacy as a trap crop against *Helicoverpa armigera* in several studies, key knowledge gaps remain that warrant further research. First, the optimal planting density and configuration of marigold relative to tomato require precise standardization under diverse agro-climatic conditions. While typical ratios such as 15:1 or 3:1 tomato to marigold have been trialed, regional variations in pest populations and crop phenology call for adaptive protocols (Kumar et al., 2012).

Second, the biochemical characterization of marigold volatiles and their specific role in female moth attraction remains only partially understood. Future studies can focus on isolating and quantifying the key volatile compounds responsible for pest diversion and their variation across *Tagetes* species and cultivars (Parihar et al., 2025). Advanced chemical ecology tools like gas chromatography-mass spectrometry (GC-MS) paired with electrophysiological assays offer promising avenues for this research.

Third, long-term field evaluations are necessary to evaluate the sustainability and economic viability of trap cropping, especially regarding potential pest spillover effects and marigold management practices to prevent it from becoming a pest reservoir. Integrating marigold with other IPM components such as biological control agents needs systematic field validation to optimize combined efficacy.

Additionally, social and economic studies assessing farmer awareness, acceptance, and constraints in using marigold trap cropping would promote wider adoption. Research is also needed to explore genetic improvement of marigold species for enhanced volatile emission and adaptability to tomato cropping systems.

Addressing these gaps through multidisciplinary research can advance marigold trap cropping from promising experimental practice to a widely accepted, economically viable, and ecologically sustainable pest management technology.

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8. Conclusion

Marigold (*Tagetes* spp.) shows considerable promise as an eco-friendly trap crop for managing tomato fruit borer, *Helicoverpa armigera*, an economically destructive pest of tomato cultivation. By emitting specific volatile compounds and providing visual cues, marigold effectively attracts and diverts female moths to oviposit away from tomato plants, thereby reducing fruit infestation rates and associated yield losses. Field studies in various agro-climatic zones have demonstrated that intercropping or border-row planting of marigold with tomato at ratios such as 15:1 or 3:1 significantly suppresses larval populations, resulting in improved tomato yield and fruit quality.

Incorporating marigold into integrated pest management (IPM) systems reduces the reliance on chemical insecticides, lowering production costs and minimizing environmental impact. Despite its evident advantages, challenges including synchronization of planting, land allocation, and potential pest spillover require further investigation to optimize practical implementation. Addressing the existing research gaps will enhance marigold's effectiveness and promote wider adoption.

Overall, marigold as a trap crop represents a sustainable, cost-effective, and environmentally benign strategy for fruit borer management that aligns with modern pest management objectives aimed at sustainability and ecological balance in tomato production systems.

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