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Marigold as a trap crop: efficacy and mechanism for sustainable pest and nematode management in solanaceous vegetable crops: *A review*

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ABSTRACT

Vegetables are succulent herbaceous crops that are easily affected by insects, pests and diseases. This reduces the yield and productivity and, decreases the economic benefit of the crops. To mitigate this problem, farmers have increased their is not necessary use of chemical pesticides and insecticides. However, the elevated use of these chemicals for crop protection increases toxicity in the soil and plants, as most of the chemical compounds are insoluble and accumulate in the plant and soil as residues. Thus, when such pesticide-treated plants are consumed by humans and other living organisms, they affect their health, leading to the generation of several harmful diseases. In the recent days, an alternative sustainable method has been adopted to keep the population of such insect pests under the economic threshold level which is known as trap cropping. It is considered an eco-friendly method of crop protection, which is cheaper and also provides various additional benefits. One such important crop used as a trap crop in vegetable production is the marigold. It is an ornamental crop grown for aesthetic value and is highly used for the extraction of essential oil with antibacterial and anti-fungal properties. The phytoremedial and allelopathic effect of the plant checks the nematode population and also acts as a natural herbicide. It is grown as a companion crop along with solanaceous vegetables such as tomato, potato, brinjal and chilli which traps several harmful pests such as tomato fruit borer, nematodes, jassids, whiteflies, epilachna beetles, cutworm *etc.,* and maintains their population below the threshold level which increases the marketable yield of the crop.

Key words: Insect, marigold, pest, solanaceous vegetable, trap crop.

INTRODUCTION

Vegetables are an important part of the human diet which provides nutritional security along with several health benefits to people. In India, the production of vegetable crops has been incessantly focused on in recent years to meet the rising demands and population of the people within the country and improve the country's economy through exports. According to the Ministry of Agriculture & Farmers Welfare, the total horticulture production for the years 2021-22 and 2022-23 stood at 347.18 million tonnes and 355.48 million tonnes, respectively. Notably, the production of vegetables has shown an increase from 209.14 million tonnes in 2021-22 to 212.55 million tonnes in 2022-23. This growth

primarily stems from increases recorded across all vegetables, with the exception of Chillies (Green), onion, radish, tapioca and tomato. The use of modern technologies and hybrid seeds has immensely boosted the production of major vegetable crops in the country. They are very sensitive in nature and show a rapid cessation of growth in the absence of water and nutrients in the soil. In the present era, the production and productivity of the crops have been adversely affected mostly due to the depletion of land and water resources, rapid urbanization of rural areas and fragmentation of land *etc.* Moreover, the losses caused due to attacks by several insect pests during the different growth stages of the crop also augmented the decline of vegetable production in the country. Globally, it has been observed that annual loss of vegetables in the field and storage conditions accounts for up to 15-20% and 18-20% respectively due to insect pests attack exclusively (Ofuya *et al.,* 2023). In order to mitigate such loss due to pests several chemical control methods are adopted by the growers, which help to decrease the insect population rapidly. However, excessive use of such harmful pesticides leaves toxic residues in the soil and plants which are ultimately consumed by the people. The consumption of such toxic chemicals for a long period causes severe health issues in humans and also reduces the population of beneficial insects such as pollinators. Therefore, an alternative sustainable method has been adopted to keep the population of such insect pests under the economic threshold level which is known as trap cropping and intercropping. It encompasses alteration in the habitat of an agroecosystem so as to reduce the pest population through crop diversification (Panwar *et al.,* 2021). A trap crop refers to the plant species that is grown along with the main crop so that it can attract the insects and thereby protect the main crop from the damaging effects of the pests (Shelton *et al.,* 2006). Furthermore, the trap crop can also be harvested to gain additional benefits for the growers. In cases where the sacrificial trap crops are grown which yield no return, the benefit can be achieved only if the yield of the main crop is much higher than the cost of production of the trap crop (Shelton *et al.,* 2006). Therefore, the selection of trap crop species and their modality should be carefully ascertained before the production of the crop so as to earn maximum benefits along with achieving significant insect pest control (Sarkar *et al.,* 2018). One such trap crop effectively used in control of insect pests in Solanaceous vegetables is Marigold. It is an ornamental crop that is grown for aesthetic value but also serves several other beneficial purposes such as the essential oil extracted from Marigold has antibacterial and anti-fungal properties. It also helps to heal wounds and other skin infections. The Phyto remedial and allelopathic effect of the plant checks the nematode population and also acts as a natural herbicide. Marigold, when grown as a companion crop along with Solanaceous vegetables such as tomato, potato, brinjal and chilli traps harmful pests such as tomato fruit borer, nematodes, jassids, whiteflies, Epilachna beetles, cutworm *etc.,* and maintains their population below the threshold level which increases the marketable yield of the crop. Thus, in this review, the potential and efficacy of Marigolds as a trap crop and the mechanism of their interaction with the main crop in managing the harmful insect pests have been discussed.

BOTANICAL CHARACTERISTICS OF MARIGOLD

The genus Tagetes, encompassing 56 species of which 27 are annual and 29 perennial, belongs to the Asteraceae family. Among these, *T. erecta, T. patula, T. minuta, T. tenuifolia* and *T. lucida*

are most commonly cultivated (Vasudevan *et al.*, 1997). Native to Central and South America, particularly Mexico, marigolds were introduced globally in the 16th century (Kaplan, 1960). Despite their American origin, *T. erecta* and *T. patula* are widely known as African and French marigolds, respectively. Both "African" and "French" marigolds come from Mexico and Central America (Taylor, 2011). African marigold plants grows upto a height of 90 cm (3 ft) in height, producing large flowers that range in colour from yellow to deep orange. By comparison, French marigolds are shorter (15-45 cm) and have smaller orange/red flowers. Traditionally, Marigolds propagated by seed, vegetative cuttings, especially stem cuttings, have emerged as alternative methods for commercial cultivation (Sharma *et al.*, 2022).

IMPORTANCE OF MARIGOLD

I. ***Medicinal properties :*** Marigold possesses antiseptic properties and has been traditionally employed as a wound-healing agent (Oguwike *et al.*, 2013). Ayurvedic and Unani medicinal systems attribute anti-inflammatory, antipyretic, antimicrobial, and antiepileptic properties to their flowers and leaves (Kasiram *et al.*, 2000). Traditionally administered in tincture, ointment, and infusion forms, marigold is applied topically to treat wounds and inflammatory skin and mucosal conditions (Bisset *et al.*, 2001). Scientifically, aqueous marigold extracts have been shown to contain polysaccharides with (1→3)-linked β-D-galactan, which stimulate human granulocyte phagocytosis (Varljen *et al.*,1989).

II. ***Essential oil :*** Marigold *(Tagetes spp.)* exhibits significant antifungal properties, with essential oils from leaves and thiophene-rich extracts from roots demonstrating efficacy against various soil-borne and foliar plant pathogens (Saha *et al.*, 2012). Essential oils are extracted through steam distillation of flower petals, with primary constituents including piperitone, trans-β-ocymene, terpinolene, and β-caryophyllene (Rondón *et al.*, 2006). Additionally, hydro-distillation of *Tagetes minuta* aerial parts yields an essential oil rich in limonene, piperitenone, β-terpinolene, piperitone, and ocimenone isomers (Meshkatalsadat *et al.*, 2010). Due to its intense, fruity fragrance and potential toxicity, marigold oil is employed judiciously in cosmetics and perfumery. Beyond aesthetics, this oil finds applications in insect repellence and as a potential treatment for bronchodilator conditions (Groom, 1997; Singh and Singh, 2005).

Important chemical compound present in the essential oil of marigold:

- Limonene
- α-pinene
- β-pinene
- terpinolene
- (E)-β-ocimene
- Dihydrotagetone
- Tagetone (represented as a mixture of (E)- and (Z)-isomers)
- Tagetenone (represented as a mixture of (E)- and (Z)-isomers)
- β-caryophyllene
- eugenol

III. Allelopathic effect : Allelopathy is an organism's ability to produce toxic chemicals that has a inhibitory effect on the other organisms. Marigold roots release the chemical alpha-terthienyl, one of the most toxic naturally occurring compounds found to date (Gommers and Bakker, 1988). This

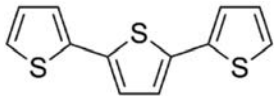

Fig. 1: Structure of sulphur-containing compound α-terthienyl.

compound has nematocidal, insecticidal, antiviral, and cytotoxic properties (Arnason *et al.*, 1989; Marles *et al.*, 1992). The presence of alpha-terthienyl inhibits the hatching of nematode eggs (Siddiqui and Alam 1988). However, in a field setting, it is unclear if marigolds producing alpha-terthienyl inhibit development because of the alpha-terthienyl itself or because marigolds are a non-host for certain nematodes. Nematodes may not feed or develop on non-host plants even when they do not contain allelopathic compounds (Krueger *et al.*, 2007). Furthermore, *Meloidogyne* spp. Juveniles were unable to fully develop in the roots of *T. erecta* (Ploeg and Maris, 1999).

CULTIVATION AND INTERCROPPING OF MARIGOLDS WITH VEGETABLE CROPS

Marigolds require a mild climate for good vegetative growth and flowering. The optimum temperature range is 18-20°C. Higher temperatures (> 35°C) can restrict plant growth leading to a reduction in flower number and size. Plants and flowers may get damaged due to severe frost during winter.

Soil: Marigolds can be grown in a wide range of soil. Soil should be well-drained with a soil pH of 7-7.5 considered. Avoid marigold cultivation in acidic and alkaline soil. Seeds and sowing:

The seeds are sown around the year, 1.5 kg seeds/ha and treat the seeds with *Azospirillum* (200 g in 50 ml of rice gruel) before sowing. The seedlings are transplanted after four weeks at 45 × 35 cm spacing (TNAU). Irrigation: Irrigation is required once a week or as and per necessity and water stagnation should be avoided. Fertilizer and Manuring: During last ploughing, incorporate 25 t/ha of FYM. Apply 45:90:75 kg NPK/ha as basal and 45 kg N/ha as top dressing 45 days after planting (Source: TNAU). Pinching: 40 days after planting terminal portion should be pinched/removed to encourage lateral branching. Intercropping, a widely employed farming practice, involves the simultaneous cultivation of two or more crop species or genotypes. This method is particularly prevalent in subsistence or resource-limited agricultural systems, offering genuine yield gains without increased inputs or enhanced stability of yield with decreased inputs. As emphasized by Brooker *et al.* (2015), intercropping presents a potential avenue for achieving 'sustainable intensification' in agriculture. Companion planting, a specific form of intercropping commonly observed in small-scale gardens, entails the cultivation of two or more plant species in close proximity to each other for mutual benefit. Notably, marigolds, due to their strong odour, serve to repel pests and hinder insects from locating their typical host plants. The efficacy of marigolds in reducing pest populations across various crops has been extensively documented.

THE SUCCESS OF MARIGOLDS AS A TRAP CROP IN SOLANACEOUS VEGETABLES

The Solanaceae family includes both fruit and tuber-bearing crops which are highly affected by insects such as fruit borer, whiteflies, jassids *etc.*, as well as nematodes. These insects not only damage the crop directly but also serve as vectors for viruses causing diseases. In this way, they hamper the plant growth and development which

ultimately decreases the total marketable quality standard and yield of the crop.

In tomato cultivation, the fruit borer (*Helicoverpa armigera*) is a major pest that causes 55% of crop loss. The larva of the insect affects the crop throughout the growing season and damage the fruits making them unfit for human consumption. However, it is found that when a tomato crop is grown along with marigold as a trap crop reduces the pest population largely and saves the main crop from heavy damage. A similar investigation was carried out at the Horticulture Farm, Rajasthan College of Agriculture, MPUAT, Udaipur, during the *Rabi* season, where the larval population of *H. armigera* was recorded at weekly intervals during the entire season of tomato growth. The damaged fruits in each plant showed a significant positive correlation with the number of larvae in the plant. It was observed that growing Marigolds as a trap crop with tomatoes (15 rows of tomato: 1-row of marigold) significantly reduced the larval population. Therefore, it was concluded that the fruit borer larvae invaded the tomato crop throughout its growing season but when tomato was grown with marigold as a trap crop, it effectively reduced the larval population as compared to the sole crop (Kumar *et al.,* 2017).

An integrated approach using IPM technology with one of its components being the African marigold as a trap crop was developed at the Indian Institute of Horticultural Research, Bangalore, to manage the population of tomato fruit borer. (Srinivasan *et al.,* 1993; Srinivasan *et al.*,1994). An economic analysis of farms following the IPM technology in Bangalore Rural and Kolar districts over the non-IPM users was studied by Gajanana *et al.* They observed that the yield on IPM farms was about 46% higher, the cost of cultivation about 21% less and the net returns were 119% higher over the non-IPM farms which also increased the (BCR) of IPM farmers (3.66) than the non-IPM farmers (1.95). However, the major limitations faced by the IPM adopters were a lack of planning in preparation for the marigold nursery before the sowing of the main crop. In 1996, Khan *et al.* also reported that the use of the trap crop for the management of borer gave an additional benefit of Rs 12,809/ ha to the farmers.

In 2003-04, a field experiment conducted at SKUAST-K during the *Kharif* season showed that the use of marigolds as a trap crop in tomatoes (3 rows of tomatoes with 1 row of marigolds) helped to reduce the population of *Helicoverpa armigera* and also increased the equivalent yield of the main crop.

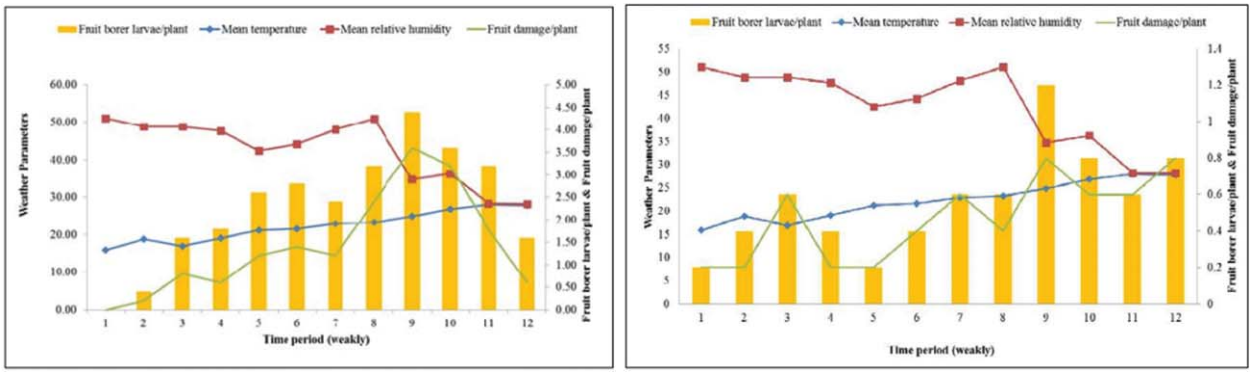

Fig. 2: Seasonal incidence of fruit borer on tomato without and with marigold as trap crop.

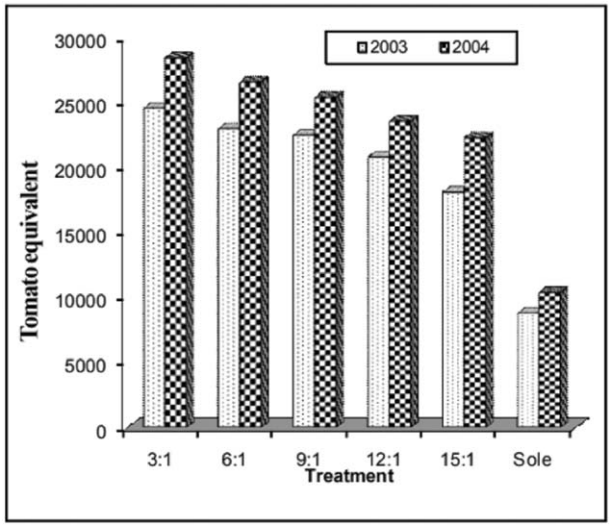

Fig. 3: Tomato equivalent yield.

In brinjal, several pests attack the crop at different stages of its growth period. One of the most damaging pests in brinjal is the Hadda beetle *(Henosepilachna vigintiopunctata)*. It feeds on the epidermal layer of the leaves which decreases the photosynthetic area and causes severe defoliation in Brinjal. The yield losses range up to 80% under favourable environmental conditions. Similarly, shoot and fruit borer is another such pest in brinjal which causes a yield loss up to 86%.

The other major pests affecting potatoes and chilli are nematodes, cutworms, whiteflies etc. Throughout the country, the growers depend largely on the use of chemical pesticides for the management of these insect pests which is highly expensive and also possesses several undesirable effects in the long run such as detrimental effects on the soil and environment, deterioration of the health of human and decreases the population of non-target beneficial insects. The majority of the synthetic pesticides are non-biodegradable and therefore develop residual toxicity in soil and pollute the groundwater level. In addition to these, synthetic pesticides are also reported to have caused substantial thinning of the ozone layer indirectly.

Brinjal is an important crop of the Solanaceae family which is attacked by several insect pests at different stages of its growth starting from the nursery to harvesting. One of the most important insect pests affecting the productivity of the crop is the Hadda beetle. Both the grub and adult stages of the beetle damage the crop profusely. These feed on the leaf epidermis and decrease the photosynthetic area which may cause a loss of up to 80% in the yield. To control the beetles, trap cropping with marigolds is effectively used to maintain the pest population under the economic threshold level. One such experiment was conducted at Bidhan Chandra Krishi Vishwavidyalaya, West Bengal to study the potential of marigolds as a trap crop in brinjal. It was found that marigolds contain 7 different types of volatiles and are highly odoriferous in nature which when raised with the main crop prevented the identification, feeding, and reproduction of the pests on the host plants.

Chilli is another solanaceous vegetable crop that is largely affected by insect pests. The major pests of the crop include aphids, whiteflies, thrips and yellow mites. These are sucking pests that serve as a vector for viruses that cause serious diseases in chilli such as chilli leaf curl. The yield losses due to aphids and whiteflies are approximately 50% whereas thrips cause 50-90% damage to the crop. The fruit borers also affect the crop and cause a yield loss of about 90%. Application of insecticides is not very economical in this crop as it is a short-duration crop but the use of trap crops to manage such pests is found very effective in increasing the yield and productivity of chilli. One such trap crop used successfully in chilli to control the population of the sucking pests is the marigold. In 2018-19, a field study was conducted at Spices Research Centre,

Bangladesh Agricultural Research Institute (BARI), Bangladesh during the Rabi season where chilli was grown along with a few trap crops such as tomato, groundnut, French bean, carrot, and marigold to evaluate their effectiveness. However, it was observed that out of all the trap crops, chilli + marigold was found to be most effective in managing the population of all the sucking pests as well as the fruit borer.

THE INTERACTION MECHANISM OF MARIGOLDS SUPPRESSES NEMATODES AND PESTS

Marigolds (*Tagetes* species) are primarily grown for commercial and ornamental purposes. Previous studies found that they can be highly toxic to plant-parasitic nematodes and are capable of suppressing a wide range (up to 14 genera) of nematode pests. The nematocidal property varies with the marigold species and cultivar, but the most widely used for nematode control is *Tagetes. erecta, Tagetes patula* and *T. minuta*. Marigold plants produce several potentially bioactive compounds, among which sulphur-containing compound α-terthienyl is abundant in marigold tissues, including roots, recognized as one of the most toxic effects *viz.* nematocidal, insecticidal, fungicidal, antiviral, and cytotoxic activities, and it is believed to be the main compound responsible for the nematocidal activity of marigold. Nematodes can therefore be killed by penetrating a marigold plant's root system or coming into contact with soil that contains the plant's bioactive substances. The nematocidal activity of marigolds has been detected in roots of growing plants but not in roots also in leaf extracts too. According to certain studies, the nematodes' movement and penetration through the root tissue trigger a series of reactions in the marigold roots that are believed to kill the nematodes. Nematocidal substances appear to infiltrate from marigold root tissues into nematodes connected to the root, but they are also thought to kill nematodes present in the rhizosphere, the soil around marigold roots. Thus, marigold is believed to be most effective in suppressing plant-parasitic nematodes when actively growing, but it is not as effective when incorporated as crop residues (Singh and Singh, 2005).

Some researchers believe that marigold root exudates prevent the nematodes from developing and their eggs from hatching. However, the nematode species and growth stages suppressed by marigold vary with the marigold species. For example, *Tagetes patula* 'Single Gold' is an extremely poor host of the root-knot nematode, and there is limited penetration and development by this nematode on this plant. However, another marigold species, *T. erecta* 'Cracker Jack' behaved as a trap crop: root-knot nematodes were attracted to and entered its roots, but the development of their offspring was impeded. In other cases, marigolds may behave as a trap crop by allowing penetration of nematodes but inhibiting their subsequent development and reproduction (Sharma *et al.*, 2022).

CONCLUSION

The use of marigolds as a trap crop offers a sustainable and environmentally friendly solution for pest control in Solanaceous vegetable crops. Marigolds significantly reduce the damage caused by harmful pests such as fruit borers, nematodes, and aphids by attracting pests away from the main crops like tomato, brinjal, and chili. This strategy not only minimizes reliance on chemical pesticides, which have detrimental environmental and health effects but also promotes biodiversity by preserving beneficial insects. The success of this method, as observed in various experiments, points to its efficacy in

improving crop yields and reducing pest populations. The versatility of marigolds, in terms of their antifungal, nematocidal, and insecticidal properties, further enhances their utility in integrated pest management (IPM) systems. Therefore, the implementation of marigolds as a companion crop in agricultural practices presents a promising avenue for sustainable pest management and improved agricultural productivity.

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