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Marigolds As a Companion Crop: Impact on Pest Control and Pollinator Attraction in Mixed Cropping Systems

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Abstract

Marigolds (*Tagetes spp*.) have gained attention for enhancing pest control and pollinator attraction in mixed cropping systems. This study investigates the impact of marigolds as a companion crop, assessing their effectiveness in pest deterrence and their ability to attract beneficial pollinators. Results from field studies and existing research reveal that marigolds release bioactive compounds, such as thiophene and alpha-terthienyl, which effectively repel pests including aphids, whiteflies, and root-knot nematodes. This repellent action mitigates crop damage and improves agricultural yields. Marigolds also support beneficial insect populations, including ladybugs, hoverflies, and parasitic wasps, which enhance biological pest control and contribute to agroecosystem health. Moreover, marigolds effectively attract pollinators by providing a reliable source of nectar and pollen, thereby boosting pollination rates and crop productivity. This study underscores the value of incorporating marigolds into mixed cropping systems as a sustainable strategy for integrated pest management and pollinator support. The results offer critical insights for optimizing agricultural practices and advancing sustainable farming through strategic companion planting.

Keywords: *Allelopathy, beneficial insects, IPM, pollinator, Tagetes, trap crop*

Introduction

Marigolds (*Tagetes spp*.), with their vivid flowers and distinctive scent, have gained attention not only for their ornamental value but also for their functional roles in agricultural systems

(Joshi et al., 2022). The increasing demand for sustainable agricultural practices has led to a resurgence of interest in traditional cropping strategies like companion planting and mixed cropping, which blends ecological principles with contemporary farming methods. Among companion plants, marigolds (*Tagetes spp.*) have gained significant attention due to their dual role in pest control and pollinator support (Conboy et al., 2019). The use of marigolds as a companion crop is primarily attributed to their ability to mitigate pest populations through several mechanisms. Marigolds produce a range of bioactive compounds, such as thiophenes, alpha terthienyl known for their insecticidal, nematicidal, and fungicidal properties (Gommers & Bakker, 1988). These compounds have been demonstrated to repel or inhibit various pests, including root-knot nematodes (*Meloidogyne spp.*), aphids, whiteflies, and certain soil-borne pathogens (Otipa, 2003). Additionally, marigold root exudates exhibit allelopathic effects, which can suppress weed growth and reduce competition for resources within mixed cropping systems (Didyk & Mashkovska, 2022).

In addition to their role in pest control, marigolds are instrumental in attracting pollinators to agricultural fields. The vibrant and conspicuous flowers of marigolds are highly attractive to a wide range of pollinators, including bees, butterflies, and other beneficial insects along with a population of natural enemies (Silveira et al., 2009). This increased pollinator activity enhances the pollination of nearby crops, contributing to improved crop yields and fostering a more diverse and resilient agroecosystem. In mixed cropping systems, where plant diversity is a key strategy, marigolds contribute to the ecological balance and stability of the farming environment (Alam et al., 1977). The integration of marigolds as a companion crop in mixed cropping systems represents a promising strategy for sustainable agriculture. This approach aligns with the goals of reducing chemical inputs, promoting biodiversity, and enhancing ecosystem services (Qasim et al., 2023). However, the effectiveness of marigolds in pest control and pollinator attraction can be influenced by factors such as crop combinations,

environmental conditions, and management practices. Thus, it is crucial to investigate the specific interactions between marigolds and other crops within these systems to optimize their beneficial effects.

This study aims to investigate the impact of marigolds as a companion crop on pest control and pollinator attraction in mixed cropping systems. Through a review of existing literature and field experiments, this research seeks to elucidate the role of marigolds in enhancing the sustainability and productivity of mixed cropping systems. The findings are expected to contribute to the development of more effective and ecologically sustainable agricultural practices, supporting the transition toward more resilient food production systems.

Marigolds in Agricultural Systems: An Overview

Marigolds, belonging to the Asteraceae family, are herbaceous plants originally native to the Americas and are now cultivated in a variety of climatic regions worldwide (Bakshi & Ghosh, 2022). The primary species of marigold used in agriculture are *Tagetes erecta, Tagetes patula,* and *Tagetes tenuifolia* (Awasthi, 2024). These species are annuals, characterized by their bright, showy flowers, which range from yellow and orange to red and white. Marigolds are also known for their aromatic foliage, which releases a strong scent due to the presence of volatile oils and other compounds (Awasthi, 2024). Marigolds are relatively easy to grow, requiring minimal inputs and thriving in a variety of soil types, as long as the soil is well-drained (SHOME, 2019). They prefer full sunlight and are tolerant of heat and drought, making them suitable for a wide range of climates (Sheoran et al., 2022). Typically, marigold seeds are sown directly into the soil, and the plants reach maturity within 60 to 90 days, depending on the species and growing conditions.

Marigolds significantly contribute to agricultural systems through their role in pest management. They are known for their ability to repel and suppress a variety of pests, including insects, nematodes, and certain soil-borne pathogens (Pandey et al., 2021). This pest control capability is primarily due to bioactive compounds produced by marigolds, especially thiophenes, which have insecticidal, nematicidal, and fungicidal properties (Sharma et al., 2022). Marigolds are effective at repelling insects such as aphids, whiteflies, and mosquitoes (Fabrick et al., 2020). The strong aroma of marigold leaves and flowers is believed to mask the scent of nearby crops, making them less attractive to pests. Additionally, marigold flowers attract beneficial insects like ladybugs and lacewings, which are natural predators of many common crop pests. Marigolds are particularly valued for their ability to control root-knot nematodes (*Meloidogyne spp.*), which are microscopic worms that attack plant roots, leading to significant yield losses. Marigolds produce toxic compounds in their roots that are lethal to nematodes, reducing their populations in the soil and protecting susceptible crops (Karakas & Bolukbasi, 2019). This property makes marigolds a valuable companion crop in nematode-prone areas. Marigolds also enhance soil health by suppressing certain soil-borne pathogens and improving soil structure. The decomposition of marigold residues adds organic matter to the soil, boosting fertility and microbial activity. Additionally, the allelopathic effects of marigold root exudates can suppress weed growth, reducing competition for nutrients and water in the field (Sadia et al., 2015). Marigolds are highly attractive to pollinators, including bees, butterflies, and other beneficial insects, due to their vibrant colors and nectar-rich flowers. The presence of marigolds in agricultural fields can increase pollinator activity, which is crucial for the pollination of many crops. Enhanced pollinator presence not only boosts crop yields but also promotes biodiversity and the overall health of the agroecosystem. In mixed cropping systems, where multiple plant species are grown together, marigolds can play a vital role in maintaining ecological balance by supporting pollinator populations. This is particularly

important in agricultural landscapes degraded by the overuse of pesticides and monoculture practices, which have led to declines in pollinator populations.

Marigolds are often used as companion plants in mixed cropping systems due to their pest-repellent properties and ability to enhance pollinator attraction. Companion planting involves growing marigolds alongside other crops to create a symbiotic relationship that benefits both plants. For example, marigolds can be planted with vegetables like tomatoes, peppers, and beans to protect them from pests and improve their growth (Dikr & Belete, 2021). In mixed cropping systems, marigolds contribute to the diversity and resilience of the cropping system by reducing pest pressure, improving soil health, and attracting pollinators. This approach aligns with sustainable agriculture principles, which emphasize biodiversity, ecological balance, and reduced reliance on chemical inputs.

The increasing interest in organic farming and sustainable agriculture has underscored the importance of marigolds in agricultural systems. As a natural means of pest control and pollinator support, marigolds are aligned with the goals of reducing chemical inputs and promoting ecological health (Bakshi & Ghosh, 2022; Tudora et al., 2024). Their use in organic farming systems can help farmers manage pests without synthetic pesticides, thereby reducing agriculture's environmental impact and protecting human health. Besides pest management and pollinator attraction, marigolds can also be used in crop rotation and cover cropping systems to improve soil health and prevent the build-up of pests and diseases in the soil (Hooks et al., 2010; Xie et al., 2016; Zhang et al., 2022). Their ability to break pest and disease cycles makes them a valuable component of sustainable crop management practices.

Impact of Marigolds on Pest Control

Marigolds serve as a valuable companion crop in mixed cropping systems by offering multiple benefits for pest control. Their ability to repel insect pests, suppress nematodes, attract beneficial insects, and disrupt pest life cycles makes them a key component in sustainable

agriculture. As the demand for eco-friendly pest management practices continues to grow, marigolds are expected to play an increasingly important role in reducing pesticide use and enhancing the resilience of agricultural systems.

Allelopathy: Marigolds synthesize and release secondary metabolites, notably thiophenes, which have strong nematicidal and insecticidal properties to deter pests like aphids, whiteflies, and certain beetle species (Gommers & Bakker, 1988). This repellent effect is especially advantageous in mixed cropping systems where susceptible crops such as tomatoes, cucumbers, and beans benefit from marigold's protective properties (Conboy et al., 2019). The strong aroma emitted by marigold flowers and foliage is highly effective in repelling aphid, a common pest in many horticultural crops (Dardouri et al., 2017). In such cases, marigolds serve as a protective barrier, reducing the risk of infestation and subsequent damage to the companion crops.

Marigolds are widely recognized for their ability to suppress soil-borne pests, particularly nematodes (Natarajan et al., 2006). These include root-knot nematodes which cause extensive root damage in many crops, impairing nutrient uptake and reducing crop yield. Marigold roots exude alpha-terthienyl a potent nematicide that either kills or repels nematodes, leading to a significant reduction in nematode populations in the soil (Olabiyi & Oyedunmade, 2007). In mixed cropping systems, this nematode-suppressing capability is especially beneficial for crops like carrots, potatoes, and beans, which are highly susceptible to nematode damage (Nagachandrabose, 2018). Marigold planting can decrease nematode populations by up to 90%, promoting healthier plant growth and improved crop productivity.

Trap Cropping: Marigolds are frequently employed as trap crops in agricultural systems, where they are used to lure harmful pests away from economically valuable crops as in tomatoes to prevent fruit borer (KUMAR et al., 2012; Srinivasan et al., 1994). As trap crops, marigolds attract pests such as leaf miners which feed on their foliage but are unable to successfully

reproduce, leading to a decline in pest populations over time (Ganai et al., 2017). For example, marigolds can help protect crops like spinach, lettuce, and celery from leaf miner damage by serving as an alternative feeding site. The strategic use of marigolds as trap crops in mixed cropping systems offers an eco-friendly pest management solution, reducing the need for chemical insecticides and supporting sustainable farming practices.

Interruption of Pest Life Cycles: Marigolds can disrupt the life cycles of various insect pests. While they may attract certain pests, such as thrips and leaf miners, these pests often fail to reproduce or thrive on marigolds, ultimately reducing their populations (Souza, Marucci, et al., 2018). In this way, marigolds function as a "decoy" crop, diverting pests from the main crops and minimizing the overall pest pressure in the system. In mixed cropping systems, this decoy function of marigolds serves to protect the primary crops by attracting and trapping pests while also acting as a biological barrier against pest invasion (Laffon et al., 2022; Mrnka et al., 2023).

Attraction of Beneficial Insects: In addition to repelling harmful pests, marigolds play a vital role in attracting beneficial insects that contribute to natural pest control. Marigolds provide a rich nectar source for predatory insects such as ladybirds, lacewings, and hoverflies, whose larvae prey on pests like aphids, mites, and other small insect pests (Sutton & Rosenfeld, 2006; Silveira et al., 2009). Parasitic wasps which parasitize caterpillars and aphids, are also frequently attracted to marigold flowers. By promoting the presence of these beneficial insects, marigolds help establish a balanced ecosystem in mixed cropping systems, reducing pest populations through biological control and minimizing the reliance on synthetic pest control methods.

Suppression of Fungal Pathogens: Marigolds have demonstrated the ability to suppress various soil-borne fungal pathogens. Marigold root exudates can inhibit the growth of pathogens such as Fusarium, Verticillium, and Rhizoctonia which cause significant plant diseases like wilt and root rot (Jambhulkar et al., 2012; Li et al., 2020). Incorporating marigolds into mixed cropping

systems fosters healthier soils by reducing the prevalence of these pathogens, thereby lowering disease pressure on susceptible crops. This characteristic is particularly valuable in organic and low-input farming systems, where the use of synthetic fungicides is limited or avoided.

Marigolds and Pollinator Attraction

Marigolds are well-known not only for their pest control properties but also for their crucial role in attracting pollinators, making them a vital component in mixed cropping systems. The vibrant coloration of marigold flowers, coupled with their unique scent and the steady supply of nectar and pollen, makes them particularly appealing to a variety of pollinating insects (Gurung et al., 2020; Shilpa et al., 2014). These characteristics create a favorable environment for pollinators, which enhances both ecosystem health and crop productivity when marigolds are used as companion plants. Marigolds provide essential food resources nectar and pollen, especially during periods when other crops may not be flowering. This continuous availability of floral resources helps sustain pollinator populations in the field, ensuring they remain active and effective in pollinating nearby crops. This sustained pollinator presence directly correlates with improved crop yields. Enhanced pollination often leads to increased fruit sets and higher-quality produce. Integrating marigolds into cropping systems, particularly with crops like tomatoes and beans, significantly improves pollination efficiency. Honeybees are drawn to marigolds due to their abundant nectar, which provides critical nourishment (Bista & Shivakoti, 2001). This attraction increases the likelihood that bees will pollinate adjacent crops, such as cucumbers, squash, and tomatoes, which benefit from their activity.

Moreover, marigolds contribute to broader biodiversity and ecosystem services, which are vital for sustaining agricultural systems. Given the global decline in pollinator populations due to habitat loss, pesticide exposure, and climate change, marigolds play a critical role in providing a refuge for these beneficial insects (Souza, Tomazella, et al., 2018). By supporting a diverse range of pollinators, marigolds contribute to ecosystem balance, reducing the reliance on

chemical inputs and bolstering the resilience of farming systems. Additionally, the increased presence of beneficial insects aids in natural pest control, further reducing the need for synthetic interventions.

Despite the numerous advantages of marigolds in pollinator attraction, certain factors must be considered when incorporating them into mixed cropping systems. One potential concern is the competition for pollinators between marigolds and the primary crops, particularly if the companion crops are less visually or chemically appealing to pollinators. To mitigate this, careful management of marigold planting density and timing is essential. Aligning the flowering periods of marigolds with those of companion crops will maximize their pollination benefits without detracting from other plants.

Challenges and Limitations

The integration of marigolds as companion crops for pest control and pollinator enhancement in mixed cropping systems entails several scientific and practical challenges. A primary concern is the differential effectiveness of marigold species. French marigolds and African marigolds are notably superior in managing nematode populations compared to other species of marigolds (Krueger et al., 2024). Thus, selecting the appropriate marigold species is crucial to achieving optimal pest control. Additionally, marigolds have specific environmental requirements, including warm temperatures, well-drained soil, and ample sunlight. Their performance in regions with less favorable conditions may be compromised, limiting their effectiveness as a pest management strategy.

The reliance on marigolds alone for pest management also poses limitations. Marigolds do not offer universal protection against all pest species. They may not deter certain insects, such as caterpillars or slugs, leading to potential crop damage. Moreover, the presence of marigolds can result in competition with the primary crops for vital resources like water, nutrients, and

light. Without appropriate management practices, this competition can negatively impact the yield and health of the main crops.

Furthermore, marigolds might inadvertently attract pests such as spider mites and leafhoppers, which could potentially harm adjacent crops. Although marigolds can attract beneficial pollinators, their efficacy in this regard may be limited compared to other nectar-rich plants. The strong scent of marigolds, intended to repel pests, may also affect pollinator behavior, potentially reducing their attractiveness to these beneficial insects. The maintenance and labor associated with growing marigolds, including the need for annual replanting and ongoing monitoring, can add to the operational burden for farmers. This is particularly relevant in areas where labor resources are constrained. The economic feasibility of using marigolds as companion crops may also be questioned, as the costs of seeds, labor, and land could outweigh the benefits if the primary crop does not see substantial yield improvements.

Inconsistent findings in research studies further complicate the application of marigolds. While some research supports their role in enhancing pest control and pollinator attraction, other studies report limited impacts, making it challenging for practitioners to rely on marigolds consistently. Additionally, marigolds may not be compatible with certain crops, such as legumes, whose growth could be adversely affected by the compounds released by marigolds. Despite these challenges, marigolds can be a valuable component of integrated pest management systems when carefully managed, but their limitations must be thoroughly understood to optimize their benefits in mixed cropping systems.

Conclusion

This review underscores the potential of marigolds as a versatile and effective companion crop within sustainable agricultural systems. Marigolds contribute to pest suppression and pollinator attraction, leading to increased crop yields, reduced chemical inputs, and enhanced biodiversity. Integrating marigolds into IPM strategies offers a promising approach to

sustainable pest management while minimizing environmental impact. However, further research is necessary to optimize their use in various cropping systems and fully understand their long-term ecological effects. The findings highlight the importance of marigolds in advancing resilient and ecologically sound farming practices and emphasize the need for continued research into their potential in sustainable agriculture.

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