

Research article

EFFICACY OF AFRICAN MARIGOLD (*Tagetes erecta* L.) IN MANAGING CABBAGE INSECT PESTS IN TROPICAL VEGETABLE FARMING SYSTEMSNimantha H.H.P. ^{1*}, Rankoth L.M. ¹, Samita S. ¹, Ranil R.H.G. ¹, Jayasinghe W.H. ², De Silva S.H.N.P. ¹, Suriyagoda L.D.B. ¹¹Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.²Department of Agricultural Biology, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.*Corresponding author: pradeepnimantha1998@gmail.com

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ABSTRACT

Cabbage farming in Sri Lanka relies heavily on synthetic insecticides, but their high costs reduce overall profitability. Additionally, synthetic insecticides pose considerable environmental risks. Therefore, it is important to explore alternative strategies for insect pest management. This study investigated African marigold (*Tagetes erecta* L.)-based insect pest management strategies for controlling major leaf-eating caterpillar pests in cabbage under field conditions. A Randomized Complete Block Design with three blocks was used to compare five treatments: untreated cabbage sole crop as the control (T_1), cabbage treated with synthetic insecticides containing Thiamethoxam 25% (w/w) and Emamectin Benzoate 5% (w/w) (T_2), cabbage treated with marigold water extract (50 g fresh plant matter/1 L; T_3), cabbage intercropped with marigold as an additive (T_4) and cabbage intercropped with marigold in replacement (T_5). In T_4 , marigold was intercropped with cabbage without reducing cabbage density, while in T_5 , some cabbage plants were replaced by marigold. Treatments T_2 , T_4 and T_5 significantly reduced ($P < 0.05$) leaf-eating caterpillar abundance by 94%, 94% and 83%, respectively, compared to the control. Both intercropping methods (T_4 and T_5) were equally effective in suppressing caterpillar populations, while T_3 showed no significant difference ($P < 0.05$) from the control, indicating ineffectiveness of the treatment. Ladybird beetle (*Coccinella* spp.) abundance significantly increased ($P < 0.05$) under T_4 and T_5 (by 100 % and 95 %, respectively), but declined sharply under T_2 (-95 %), revealing the negative impact of T_2 on non-target organisms. Cabbage plant diameter remained consistent across all treatments, confirming that marigold intercropping did not hinder cabbage growth. Economically, additive intercropping (T_4) was the most favorable strategy, maintaining full cabbage plant density and eliminating pesticide costs. These results suggest that additive intercropping with African marigold is a promising agronomic strategy for managing leaf-eating caterpillar pests in cabbage production in Sri Lanka.

Key words:

cabbage, African marigold, additive intercropping, replacement intercropping, ladybird beetle

Abbreviations:

DOA – Department of Agriculture; GENMOD – Generalized Linear Model; LSD – Least Square Difference; LSMEANS – Least Square Means; MLPES – Maximum Likelihood Parameter Estimates; RCBD – Randomized Complete Block Design; WAP – Weeks after Planting

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INTRODUCTION

Cabbage (*Brassica oleracea* L. var. *capitata* L.) is one of the major vegetable crops cultivated in Sri Lanka (Singhamuni et al., 2021), currently grown on over 4000 ha throughout the country (DOA, 2022). Though the potential productivity of cabbage is 40-45 t ha⁻¹, Sri Lankan cabbage farmers have only been able to achieve productivity of less than 30 t ha⁻¹ (DOA, 2023a). Such low productivity is partially attributed to the damage caused by several cabbage leaf-eating caterpillar pests, including *Spodoptera litura* (Fabricius), *Hellula undalis* (Fabricius), *Chrysodeixis eriosoma* (Doubleday), *Crociodolomia binotalis* Zeller and *Plutella xylostella* (Linnaeus) (DOA, 2017). These insect pests severely damage and reduce the marketable yield of cabbage (Singhamuni and Hemachandra, 2013; Hemachandra et al., 2015).

In Sri Lanka, the control of insect pests in cabbage farming relies heavily on synthetic insecticides (Singhamuni and Hemachandra, 2013), which also increases the production costs. During 2021/2022 Maha season, which is the major cultivation season in Sri Lanka, cabbage had the second highest total production costs among all up-country vegetables (mostly temperate vegetable crops grown at higher elevations of the country) (DOA, 2022). The same report indicated that the material costs constituted almost 50% of total cabbage production costs, with seeds and agro-chemicals being the main components. In addition, synthetic insecticides have negative toxicological and ecological impacts (Jankowska et al., 2009), including impact on non-target organisms.

Therefore, minimizing the use of agro-chemicals in vegetable farming, including cabbage cultivation, has become an urgent need. *Tagetes erecta*, commonly referred to as African marigold, contains phytochemicals with pesticidal properties, including insecticidal properties (Gopi et al., 2012). Owing to its relatively short cultivation period (Vasudevan et al., 1997), marigold is also used in multi-species cropping systems including rotational cropping, cover cropping and intercropping, which are helpful in deterring pests and attracting natural enemies (Iamba, 2021). According to Niu et al. (2022), the odors released by *T. erecta* significantly repelled the tea green leafhopper, *Empoasca flavescens* (Fabricius), a major pest in Chinese tea plantations. In addition, *T. erecta* attracts natural enemies and maintains high natural enemy biodiversity (Liu et al., 2006). Its extracts have been traditionally used to reduce pest infestations in some crops. This is likely due to non-host plant volatiles released by *T. erecta* that supposedly repel phytophagous insect pests. There are several studies showing antifeedant and larvicidal effects against *Spodoptera frugiperda* (J.E. Smith) (Aldana-Llanos et al., 2012; Salinas-Sánchez et al., 2012), whereas Toribio-Hernandez and Grande-Romero (2020) found the extract effective as a bio-insecticide against *Zadiprion vallicola* Rohwer, a forest insect pest. These findings indicate that African marigold has the potential to be a key tool in insect pest management in crop cultivation. However, using *T. erecta* as an insect management intercrop cannot be applied in all circumstances. Intercropping requires careful planning rather than ad-hoc implementation, due to concerns that non-crop plants can sometimes act as 'green bridges', allowing pests to spread to cash crops (Dunbar et al., 2016). Therefore, selecting appropriate intercrops for pest control requires a thorough understanding of the primary crop, its insect pests, their behavior and ecology (Huss et al., 2022). For instance, intercropped plants may compete for resources, potentially reducing cabbage productivity and making the approach counterproductive. To evaluate this, this study assessed key growth parameters such as leaf area and crown diameter. Another critical consideration in sustainable pest management is its impact on non-target organisms. Ladybird beetles (*Coccinella* spp.) serve as ecological indicators for assessing the non-target effects of pest control strategies (Cong et al., 2023). Monitoring their abundance under different pest management treatments provides insights into the environmental compatibility of *T. erecta*-based approaches.

Therefore, the aim of this study was to evaluate the potential of *T. erecta* as an environmentally friendly and sustainable pest management candidate for controlling insect pests in cabbage grown in Sri Lanka, to increase the profit margin of cabbage farming by lowering the need for synthetic chemical pesticides and to improve the eco-friendliness and human health compatibility of cabbage farming in Sri Lanka.

MATERIAL AND METHODS

Nursery Establishment

Separate ground nurseries were maintained for cabbage and marigold, adhering to recommended practices. The cabbage variety used was Green Coronet, while the marigold variety was Mandarine. Cabbage seedlings were raised for 21 days, whereas marigold seedlings were grown for over a 28-day period in nurseries.

Experimental site

The study was conducted at the Research and Teaching Farm at Mahailuppallama Sub-Campus, Faculty of Agriculture, University of Peradeniya, Sri Lanka, from December 2023 to March 2024. This site is situated in the

Low-country Dry Zone of the country and is predominantly characterized by Reddish Brown Earth (RBE) soil (Dassanayake et al., 2020). The area receives an annual rainfall of 1750 mm and has temperatures around 27 °C (Punyawardena, 2010).

Experimental design, field layout and treatments

The study employed a RCBD with three blocks, each comprising five plots for five treatments. These treatments included: cabbage sole crop (T_1 control), cabbage sole crop + synthetic insecticides (T_2), cabbage sole crop + marigold water extract (T_3), cabbage + marigold additive intercropping (T_4) and cabbage + marigold replacement intercropping (T_5). Each plot measured 4 × 4 m, with 1.5 m spacing within and between blocks, maintained as buffer strips composed of cabbage plants (Figure 1).

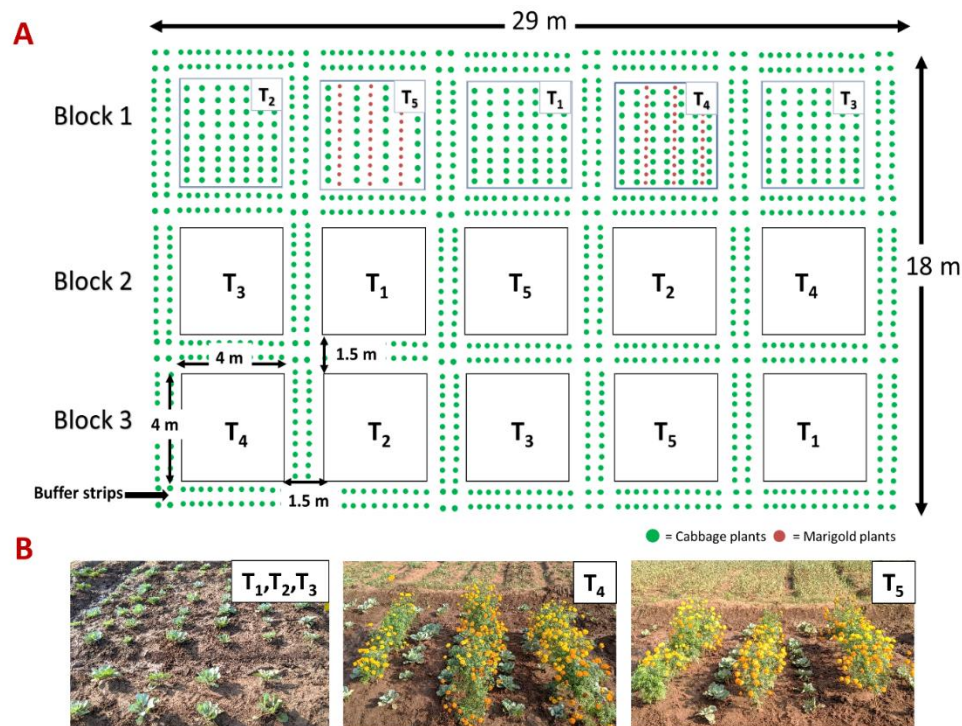


Figure 1. A - Field layout and B - Crop arrangement in treatments (T_1 - cabbage sole crop as control; T_2 - cabbage sole crop + synthetic insecticides; T_3 - cabbage sole crop + marigold extract; T_4 - additive intercropping and T_5 - replacement intercropping)

In the replacement intercropping treatment (T_5), three cabbage rows were replaced by marigold and therefore the cabbage plant count per plot was 36, whereas in all other treatments it was 63 per plot, following the recommended spacing standards provided by the DOA, Sri Lanka (Figure 1). To balance the marigold's repellent effect against insect pests between T_4 and T_5 , the marigold plant count in both treatments was kept at 36 per plot, ensuring that any observed differences are attributed to the planting arrangement rather than plant density.

Treatment imposition

The treatments were implemented as follows:

- T_1 : Cabbage sole crop was planted at 50 x 40 cm spacing (Sri Lanka DOA recommendation), with no additional treatments.
- T_2 : Cabbage sole crop was planted according to DOA recommendation and treated with synthetic chemical insecticides at fortnightly intervals. A polythene barrier was used during application to prevent the drift to adjacent plots. The chemicals applied were Thiamethoxam 25% (w/w) and Emamectin Benzoate 5% (w/w).
- T_3 : Cabbage sole crop was planted at recommended spacing and treated weekly with marigold extract as a foliar spray in the concentration of 50 g of fresh plant material (entire plant) per 1 liter of water. A polythene barrier was used during application to prevent drift effect.

T₄: The recommended cabbage plant density was maintained, while marigolds were planted in single rows for every two rows of cabbage. No chemical insecticide or marigold extract were applied.

T₅: Three cabbage rows were replaced by marigold plants. No chemical insecticide or marigold extract were applied.

Crop management

Irrigation and fertilizer application were carried out following standard practices based on Sri Lanka DOA recommendations. No disease attacks were reported during the study. Synthetic insecticides were applied only in the positive control (T₂). Manual weed management was carried out whenever required. For African marigold, no specific management practices were followed apart from pinching, which was carried out at the stage of 6 WAP.

Preparation of marigold water extract

Marigold extract was prepared using 50 g of fresh marigold plant material. Plants were uprooted and soil was washed off. The whole plant was then ground using an electric blender. The ground material was then blended with water for 5 minutes and then filtered using a stainless strainer to remove residues. The extract was applied as a foliar spray immediately after preparation.

Data collection and measurements

With the exception of larval and ladybird counts, all data were recorded from ten randomly selected cabbage plants per plot. Larvae of Diamond Back Moth (*Plutella xylostella*), Tobacco Cutworm (*S. litura*), Webworm (*H. undalis*), Cabbage Semi-Looper (*C. eriosoma*), Cabbage Cluster Caterpillar (*C. binotalis*), along with ladybirds (*Coccinella* spp.), which appeared on the surfaces of cabbage leaves, were counted from all plants in each plot on a weekly basis for eight weeks, from December 2023 to February 2024. Identification was carried out using Sri Lanka DOA official website and advisories (DOA, 2017, 2023b). Cabbage leaf area measurements were recorded fortnightly using the Easy Leaf Area Mobile Application (Easlon and Bloom, 2014). The average diameter of the cabbage crowns was measured in two perpendicular directions using a measuring tape.

Statistical analysis

All data were analyzed using SAS OnDemand for Academics. The larval counts and ladybird counts were analyzed using GENMOD with a Poisson distribution and log link function in SAS. This method was selected because insect count was discrete, often skewed, and did not follow a normal distribution. The leaf area and the cabbage crown diameter data were analyzed using ANOVA, with mean separation performed using the LSD method at a 0.05 significance level.

RESULTS AND DISCUSSION

Variation in larval abundance among treatments

Maximum likelihood parameter estimates (MLPEs) (Table 1) show how each treatment affects insect abundance compared to the control, using a log scale. These values can be exponentiated to indicate the proportion of insects relative to the control. This allows the treatment effects to be clearly interpreted in terms of percentage reduction. For example, an estimate of -2.89 indicates a reduction of 94.44% in larval abundance compared to the control. Accordingly, significant reductions in larval abundance were observed under treatments T₂, T₄ and T₅.

Table 1. Variation in larval abundance among treatments relative to the control

Treatment	Cumulative Count of larvae across 8 weeks	Maximum Likelihood Parameter Estimates (Log scale)	Percentage change (Natural scale; %)
T ₁ (control)	54	0.00(reference) ^b	0.00(reference)
T ₂ (synthetic insecticides)	3	-2.89 ^a	-94.44
T ₃ (marigold water extract)	57	0.05 ^b	+5.13
T ₄ (marigold additive intercropping)	3	-2.89 ^a	-94.44
T ₅ (marigold replacement intercropping)	9	-1.79 ^a	-83.30

Legend: Different lowercase letters indicate significant differences in MLPEs for larval counts among treatments at the P<0.05 level, as determined by Tukey-Kramer adjustment for multiple comparisons.

Additive intercropping of marigold with cabbage (T_4) exhibited similar results as in standard synthetic chemical insecticides (T_2), where the larval abundance was reduced by 94% compared to the control ([Table 1](#)). Replacement intercropping treatment (T_5) also showed significant reductions in larval abundance compared to the control (T_1). The observed decline in larval abundance in intercropped plots may be explained by several mechanisms, including decreased herbivore colonization, increased natural enemy populations and disruption of pests' ability to find hosts ([Huss et al., 2022](#)). These findings are consistent with John Vandermeer's "disruptive crop hypothesis" (1989), which proposes that vegetative diversity can influence herbivore populations by limiting their ability to discover and colonize host plants ([Banks and Ekbom, 1999](#)).

However, the results reveal that the marigold water extract treatment (T_3) was not effective in reducing larval abundance in cabbage ([Table 1](#)). This ineffectiveness may stem from the water-based extraction process, as the active compounds responsible for insecticidal and repellent properties in marigold, such as terpenoids and their derivatives, are insoluble in water ([Nahak and Sahu, 2017](#); [Marouf, 2022](#)). Furthermore, certain phytochemicals, such as linalool and limonene, are susceptible to photodegradation and volatilization, leading to reduced persistence under open-field conditions.

The superiority of marigold intercropping over its water extract identified during this experiment suggests a more viable strategy for pest management. Therefore, it is recommended to use *T. erecta* as an intercrop rather than a water extract.

Even though marigold replacement intercropping (T_5) provided promising advantages in reducing larval abundance, it can be economically less beneficial compared to additive intercropping. This is because replacement intercropping lowers the density of the cash crop (cabbage), reducing the overall potential crop yield. In contrast, the additive method maintains the cabbage plant density as the sole crop, ensuring better yield. Accordingly, these findings indicate that additive intercropping with marigold provides the optimal balance of pest control efficacy, crop productivity and economic viability.

Temporal variation in larval species abundance at the study site

During the observed weeks, the composition of larval species varied among different treatment plots, showing that cabbage has a sequential infestation pattern throughout its growth cycle. As cabbage develops phenologically, its palatability changes, inviting diverse insect species successively ([Andaloro et al., 1983](#)). During the first five weeks after planting, four larval species were recorded in the experimental plots ([Figure 2](#)). However, after the fifth week, only *S. litura* species was identified until the 8 WAP stage ([Figure 3](#)).

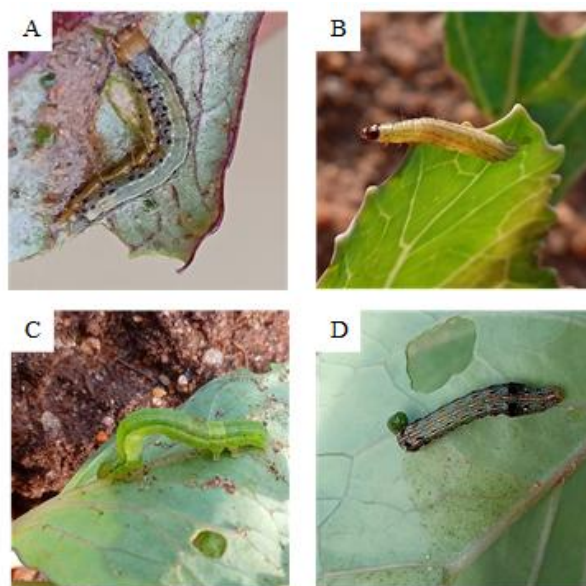


Figure 2. Different species of larval pests reported at the experimental site:
A - *Crocidolomia binotalis*; B - *Hellulla undalis*; C - *Chrysodeixis eriosoma*; D - *Spodoptera litura*

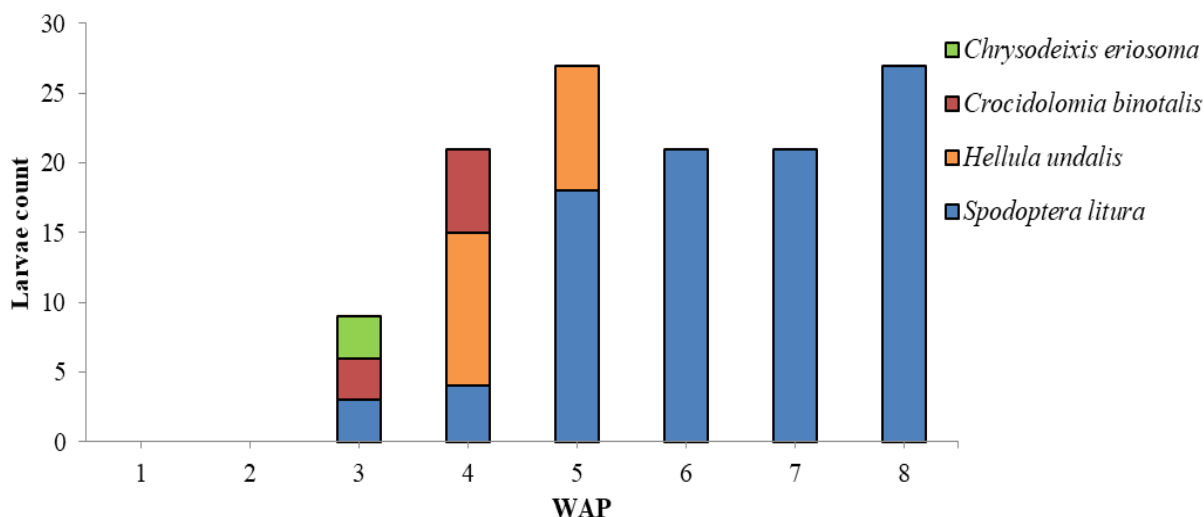


Figure 3. Temporal variation in larval pest species abundance at weekly intervals (WAP - weeks after planting).

Once the crop achieves maturity, it experiences less damage from non-economic pests such as aphids. Nonetheless, *S. litura* was continuously observed throughout the monitoring period, potentially indicating its adaptability to different phenological stages of cabbage and its prolonged field persistence.

Variation in ladybird abundance among treatments

Bioindicators are living organisms (including plants, animals, microbes) that can be used to screen the health and integrity of ecosystems (Siddig et al., 2016; Chowdhury et al., 2023). Their presence or absence, density increase or decrease can provide important clues about the health of the environment (Burger, 2006). Ladybird beetles (*Coccinella* spp.) are widely used as bioindicator species for assessing the non-target impacts of pest management strategies. They are highly sensitive to pesticide exposure and possess several practical advantages, including wide distribution, high abundance, ease of sampling and identification and limited mobility (Cotes et al., 2009; Schmuck et al., 1997; Cong et al., 2023).

MLPEs (Table 2) summarize the effects of the treatments on ladybird (*Coccinella* spp.) abundance, using the same log-scale interpretation method described earlier for larval counts. The results showed no significant differences in ladybird abundance between the marigold extract treatment and the control treatment. However, both marigold additive intercropping and replacement intercropping significantly increased ladybird abundance by 100% and 95.23%, respectively. In contrast, synthetic insecticide treatment drastically reduced ladybird abundance by 95.24%. These findings suggest that marigold intercropping creates a more favorable environment for ladybirds, while synthetic insecticides have a strong negative impact on their populations.

Table 2. Variation in ladybird abundance among treatments

Treatment	Cumulative Count of ladybirds across 8 weeks	Maximum Likelihood Parameter Estimates (Log scale)	Percentage change (Natural scale; %)
T ₁ (control)	21	0.00(reference) ^b	0.00(reference)
T ₂ (synthetic insecticides)	1	-3.04 ^c	-95.24
T ₃ (marigold water extract)	17	-0.21 ^b	-19.05
T ₄ (marigold additive intercropping)	42	0.69 ^a	+100.00
T ₅ (marigold replacement intercropping)	41	0.67 ^a	+95.23

Legend: Different lowercase letters indicate significant differences in MLPEs for ladybird counts between treatments at the $P < 0.05$ level, as determined by Tukey-Kramer adjustment for multiple comparisons.

Confirming the findings of Alhadidi et al. (2018) on harmful effects of synthetic pesticides on beneficial insects such as ladybirds, the present study also recorded a significant reduction in ladybird abundance (Table 2) that could be attributed to harmful effects of the synthetic insecticides on non-target organisms. In contrast, integration of marigold

into the cabbage farming significantly increased ladybird abundance compared to the control. Observations made during the experiment clearly indicated that different life cycle stages of the ladybird beetle were frequently found on added marigold plants (Figure 4).

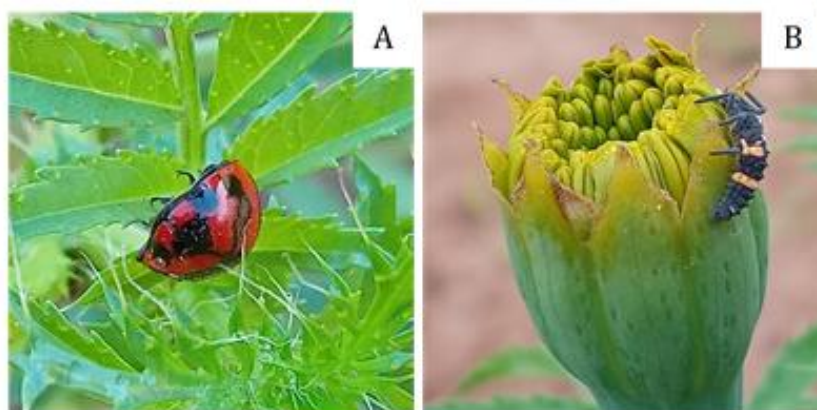


Figure 4. *Coccinella* spp. adult stage (A) and larval stage (B) reported at the experimental site

Previous research has shown the beneficial impacts of marigold on insects (Singh and Prakash, 2022). Marigold offers both food and shelter, attracting and sustaining natural enemies. They also influence the microclimate around crops, providing an extra habitat and refuge for beneficial insects. The results of this study indicate that, although synthetic insecticides can efficiently control pests, they also drastically diminish the abundance of non-target organisms such as ladybirds. In contrast, marigold-based intercropping appears to be more compatible with the maintenance of ladybird populations.

Variation in cabbage plant diameter and ground cover among treatments

In practice, pest management strategies are adopted depending not only on their technical effectiveness but also on their ability to maintain or enhance crop profitability (BIRTHAL et al., 2000). To evaluate this, it is essential to assess crop growth parameters that relate to harvest. In this study, growth measures indicated no significant differences ($P < 0.05$) among the treatments in terms of cabbage plant diameter and leaf area (Table 3). This shows that neither the application of chemical insecticides nor marigold water extract or incorporation of marigold as an intercrop had a negative impact on cabbage plant growth.

Table 3. Variations in cabbage growth parameters between treatments at 08 weeks after planting

Treatment	Plant diameter (cm)	Leaf Area (cm ²)
T ₁ (control)	15.21±0.92 ^a	57.92±9.72 ^a
T ₂ (synthetic insecticides)	13.81±0.90 ^a	40.50±9.93 ^a
T ₃ (marigold water extract)	14.23±0.85 ^a	52.81±9.30 ^a
T ₄ (marigold additive intercropping)	15.41±1.01 ^a	55.41±9.73 ^a
T ₅ (marigold replacement intercropping)	14.12±0.95 ^a	32.83±9.06 ^a

Legend: Different lowercase letters indicate differences in plant diameter and leaf area between treatments at the $P < 0.05$ level, as determined by LSD mean separation.

The results show that additive intercropping does not significantly impede growth, contrary to the common assumption that intercropping (particularly additives) reduce main crop yields. This finding can be supported by several studies. For example, Iverson et al. (2014) reported that well-designed polycultures can produce win-win outcomes, enhancing both per-plant and per-unit area primary crop productivity, as well as biocontrol services. One potential factor contributing to the sustained cabbage growth in additive intercropping systems is improved weed control. Studies have shown that the rapid growth and better canopy coverage of intercrops can hinder weed development by blocking sunlight, which may compensate for any yield reductions caused by interspecific competition (Kumar et al., 2003; Pandey et al., 2003; Dhima et al., 2007). In addition, by raising humidity beneath the foliage canopy shading, marigold can help reduce the rate of transpiration from cabbage leaves, conserving water within the plant and thereby reducing the abiotic stresses. This can be particularly beneficial for cabbage in dry

conditions or periods of drought. Moreover, canopy shading can help stabilize soil temperature, which supports root development and nutrient uptake. These factors can create a more favorable microclimate for cabbage, leading to improved growth and yield (Huss et al, 2022). Thus, intercropping marigold with cabbage is potentially a viable strategy for achieving better pest control while managing the economic yield and enhancing micro-climate conditions. The results reveal that marigold can be a complementary intercrop for cabbage, showing its importance in companion cropping systems without compromising overall yield. Complementary intercrops demand different forms and quantities of nutrients, enabling coexistence with minimal competition (Li et al., 2020).

CONCLUSION

This study demonstrated the potential of marigold intercropping, rather than marigold water-based extract, as a crucial strategy in managing cabbage insect pests. In terms of larval counts, synthetic insecticides effectively reduced pest populations, but also negatively impacted non-target organisms, as indicated by the decline in coccinellid population. In contrast, marigold water extract showed no significant difference compared to the control in reducing larval abundance, indicating ineffectiveness of this treatment as an alternative pest control measure. Both additive and replacement intercropping methods significantly reduced larval abundance, demonstrating effectiveness equivalent to synthetic insecticides. Furthermore, additive intercropping maintained cabbage crop density, ensuring better economic outcomes compared to replacement intercropping, which reduces cabbage crop density. Regarding ladybird (*Coccinella* spp.) abundance, synthetic insecticides drastically reduced their populations, whereas marigold water extract showed no significant difference from the control. Both additive and replacement intercropping methods increased ladybird abundance. Overall, additive intercropping with marigold was the most effective and economically beneficial method, promoting pest reduction and supporting beneficial insect populations without compromising crop yield. This study was conducted as a one-season, small-plot experiment, providing valuable preliminary insights into the effectiveness of marigold intercropping. Expanding the research across multiple seasons and larger field plots would enhance the applicability of marigold-based pest management strategies in tropical cabbage farming systems. Building on these findings, future studies should explore the integration of additive intercropping with reduced synthetic insecticide use and assess different intercropping patterns with different marigold plant densities.

Authors' Contribution: Conceptualization: LMR and HHPN; Methodology: LMR, HHPN, LDBS and SS; Software: SS, SHNPDS, and HHPN; Validation: LMR and SHNPDS; Formal Analysis: HHPN; Investigation: HHPN; Resources: LMR, WHJ, and RHGR; Data Curation: HHPN; Writing – Original Draft Preparation: HHPN; Writing – Review & Editing: LMR, RHGR, SHNPDS, and LDBS; Visualization: HHPN; Supervision: LMR, HHPN, SHNPDS, RHGR, and WHJ; Project Administration: LMR. All authors have read and agreed to the published version of the manuscript.

Data availability statement: The data presented in this study are available upon request from the authors.

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Conflict of interest: The authors declare that they have no conflict of interest.

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