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Evaluating the Effectiveness of Marigold as a Trap Crop for Aphid Management in Tomato (*Solanum lycopersicum Cultivation*)

[1] **Mambwe Kasonta,** [2] **Mwenya Silombe**
[1, 2] Department of Agriculture and Environmental Sciences, Information and Communications University, Zambia Research and Development Center, Zambia

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Corresponding Author: **Mambwe Kasonta**

Abstract

The study investigated the use of marigold (*Tagetes spp.*) as a trap crop for managing aphids in tomato (*Solanum lycopersicum*) production in Maposa, Luanshya District. Using an RCBD with four treatments and three replications, aphid population, damage incidence, and yield were monitored over 12 weeks. Results showed that aphid numbers were highest in the control and lowest in the two-marigolds-per-plant treatment, which also recorded less than 10% damage and the highest yield of 33.2 fruits per plant. In contrast, the control had over 70% damage and only 15.4 fruits per plant. Overall, marigold especially at high planting density proved effective for reducing aphid infestation and increasing tomato yield. The study recommends its inclusion in Integrated Pest Management (IPM) for smallholder farmers in Zambia.

Keywords: Marigold, Aphids, Trap Cropping, Tomato Yield

Introduction

Tomato (*Solanum lycopersicum*) is one of the most widely grown vegetable crops and an important source of income and nutrition for many smallholder farmers in Zambia. However, its production is seriously threatened by aphid infestations, which cause direct feeding damage and transmit several viral diseases. Many farmers rely heavily on chemical pesticides, but these are often expensive, environmentally unsustainable, and may lead to pest resistance over time (Sarkar *et al*., 2018; Panwar, Devi & Singh, 2019) [14, 12]. As a result, there is growing interest in environmentally friendly pest management approaches such as trap cropping.

Trap cropping involves planting a more attractive species near the main crop to divert pests away, reducing the need for chemical sprays (Shelton & Badenes-Perez, 2016) [16]. Marigold (*Tagetes erecta*) has shown strong potential in this role because of its bright flowers and volatile compounds that attract aphids and other insect pests. Recent studies have reported that intercropping marigold with tomato not only lowers pest numbers but also improves yields by reducing aphid damage and enhancing natural enemy populations (Dikr & Abayechaw, 2021; Géniaux *et al*., 2024) [4, 6]. Despite this, little research has been carried out in Zambia to test how different marigold arrangements can affect aphid control and tomato yield under local field conditions. Thus, this study was undertaken at Maposa, Luanshya District, Zambia, using the tomato variety Tengero to evaluate the effectiveness of marigold as a trap crop for aphid management under small-holder production conditions.

Problem statement

Tomato production in Zambia suffers major yield losses due to aphid infestations, which can reduce output by 30–70% and spread damaging viral diseases (Mwanaumo *et al*., 2021) [11]. To manage these pests, most farmers rely heavily on synthetic pesticides, but long-term use has created serious problems. Overapplication has led to resistance, making pest control increasingly difficult and expensive (Mumbwa *et al*., 2022) [10]. Continuous pesticide use also harms soil health by disrupting beneficial microbial populations essential for nutrient cycling (Kasonde *et al*., 2021) [8]. Environmental contamination is another concern, with an estimated 25% of pesticide use in Sub-Saharan Africa affecting non-target ecosystems, including water bodies and soils (FAO, 2020) [5]. Human health risks are significant as well; poor handling, lack of protective equipment, and excessive application expose farmers and consumers to harmful residues. Globally, pesticide poisoning affects millions each year (WHO, 2021) [17], and in Zambia, 60% of smallholder vegetable farmers report symptoms linked to pesticide exposure such as headaches, breathing difficulties, and skin irritation (Mumbwa *et al*., 2022) [10].

Research Objective

To evaluate the effectiveness of marigold (*Tagetes spp*.) as a trap crop in controlling aphid (*Aphididae)* infestations and improving tomato (*Solanum lycopersicum*) yield in Zambia.

Specific Objectives

1. To determine the effect of marigold as a trap crop on aphid population density.
2. To Investigate the optimal planting density of marigold for effective aphid management.
3. To evaluate the effect of different marigold spatial arrangements on aphid population density in tomato.

Hypothesis

Null Hypothesis (H_0):

The use of marigold as a trap crop has no significant effect on aphid population density.

Alternative Hypothesis (H_1):

The use of marigold as a trap crop has a significant effect on aphid population density.

Experimental Site

The experiment was conducted in Maposa, Luanshya District, Copperbelt Province, Zambia, to evaluate the effectiveness of marigold (*Tagetes spp*.) as a trap crop in managing aphid (*Aphididae*) populations in tomato (Solanum lycopersicum) production. Maposa is located within agro-ecological zone III, 13.1367° S latitude and 28.4166° E longitude characterized by high annual rainfall averaging 1,200mm, with peak precipitation occurring between December and February. The region has clay loam soils with moderate fertility and good moisture retention, making it suitable for vegetable production. Average daily temperatures range from 18-26°C, conditions that influence both aphid population dynamics and marigold growth performance.

Source: Researcher, 2025

Fig 1: Showing study site

Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. This design is chosen to account for field variability and to ensure the accuracy and reliability of the results. RCBD helps minimize the effect of environmental heterogeneity such as soil texture, slope, and fertility differences across the experimental site.

Each treatment was randomly assigned within each block, and the layout consisted of uniform plot sizes with standardized spacing between tomato plants and marigold rows.

Plot size per treatment: 3 m × 2 m

Pathways between plots: 1m

Spacing: Tomato plants spaced at 60 cm × 45 cm; marigolds at 30 cm spacing (depending on treatment)

Land Preparation

The land preparation process was carefully conducted to create optimal conditions for the cultivation of tomato (Solanum lycopersicum) and marigold (Tagetes spp.) as part of an Integrated Pest Management (IPM) strategy for aphid control. Fifteen (15) days before Transplanting, the experimental field was ploughed manually using hoes to break up the soil and improve aeration. This was followed by harrowing, also done using hoes, to ensure a fine and uniform seedbed suitable for root establishment. The removal of tree stumps, weed residues, and crop debris was also performed before ploughing to minimize weed competition and eliminate any pest reservoirs that could interfere with the study. To enhance soil fertility and ensure proper seedling establishment, Compound D fertilizer (10:20:10 NPK) was applied as a basal dressing at a rate of 300 kg/ha two weeks before planting (MoALD, 2020) [9]. This provided essential nutrients, particularly nitrogen, phosphorus, and potassium, necessary for early crop development.

For planting, rows measuring 3 meters in length were carefully marked using a hoe. Within these rows, 3-4 cm deep planting holes were created using a pointed stick in all experimental units. This planting layout was strategically designed to accommodate both tomato and marigold trap crops, ensuring effective pest attraction and management. Each hole received one seedling, with a plant-to-plant spacing of 20 cm and a row-to-row spacing of 75 cm to promote adequate aeration, light penetration, and pest control. This structured approach to land preparation ensured a favorable growing environment for both tomato and marigold, enhancing soil fertility, water retention, and overall crop health, which is crucial for evaluating the effectiveness of marigold as a trap crop in aphid management.

Fertilizer Application

A balanced fertilization plan was utilized to encourage the healthy growth of tomatoes and enhance the attractiveness of marigold plants as a trap crop.

Basal Fertilizer Application

Compound D (10:20:10 NPK) fertilizer was used at 300 kg/ha as a basal dressing. It was added to soil one weeks after transplanting to supply the seedlings with nutrients required for establishment.

Top Dressing Fertilizer Application

Urea (46% N) was used at 200 kg/ha in two applications:

First application: Three weeks after planting, when the crops had 3–4 true leaves.

Second use: At six weeks from transplanting, at the initial flowering stage to promote fruit set and yield.

Weed Control

Effective weed control is necessary to minimize competition for water, nutrients, and sunlight between the weeds and the tomato and marigold plants. Unchecked weed growth also serves as a substitute shelter for insects like aphids, which would reduce the efficacy of the marigold trap crop.

Weed Management Strategies

A blend of mechanical, cultural, and manual weed control practices were utilized across the course of the experiment to provide a weed-free environment with minimal adverse effects on crop development and beneficial insects.

1. Pre-Planting Weed Control

Land Preparation: Pre-planting, the field was plowed and harrowed with hoes to destroy existing weeds and loosen compacted soil.

2. Manual and Mechanical Weed Control

Hand Weeding: Weeds were pulled out manually by hoes at fortnightly intervals during the first six weeks of crop growth. This reduced root disturbance in the crop.

3. Mulching as a Cultural Control Practice

Organic mulch (dry grass) was applied surrounding the tomato and marigold plants for retarding weed development, water conservation, and regulation of soil temperature.

4. Monitoring and Adjustments

Regular field inspections were conducted to assess weed emergence and adjust the weed management approach as needed.

Data Collection

Systematic data collection was conducted during the experiment to evaluate the effectiveness of marigold (*Tagetes spp*.) as a trap crop in managing aphid (*Aphididae*) infestation in tomato (*Solanum lycopersicum*) production. The data focused on aphid population density, tomato plant growth and health, yield performance. The objective of this study was mainly to determine if marigold effectively keeps aphids away from tomato plants and consequently reduces impact on tomato quality and yield. To achieve this, the aphid populations was monitored each week using a standardized sampling regime. Weekly measurements of the population of aphids were taken from third week after transplanting through to the final harvest. The leaf count method was used to determine the density of aphids. Five tomato plants were selected randomly per treatment plot, and three leaves per plant, one from the top, one in the middle, and one from the bottom canopy, were examined for aphids. The number of aphids per leaf were counted, averaged, and contrasted among the different treatments. Data was analyzed based on comparing density of aphid on marigold and tomato plants using Analysis of Variance (ANOVA) to reveal significant differences across treatments.

Tomato Plant Vigor and Growth Parameters

In order to grasp how aphid infestation affects plant vigor, growth parameters of tomato plants were measured at periodic intervals. They are plant height, number of leaves. Measurements of plant height was recorded from third week after transplanting to 12th week after transplanting. Five plants in each plot were selected at random and measured with a measuring tape from the stem base to the growing apical tip. Plant height monitoring offered insights into how pest pressure impacts tomato growth rates. Leaf number per plant was enumerated at each sampling date to measure plant growth on various treatments. Incidence of aphid damage was measured by visually evaluating leaves for presence of symptoms like curling, wilting, and yellowing that reflect aphid feeding.

Data Analysis

Data obtained from the experiment was analyzed statistically to determine the effectiveness of marigold (*Tagetes spp*.) as a trap crop in the management of aphids in tomato (*Solanum lycopersicum*) production. Inferential statistical analysis was employed for easier interpretation and confirmation of findings.

To determine whether differences observed in aphid population and tomato yield among the different treatments are statistically significant, inferential statistical tests was employed. Analysis of Variance (ANOVA) was applied to test the data and compare mean differences among the different treatment groups. The data was processed using statistical software R.

Number of Aphids Per Plant

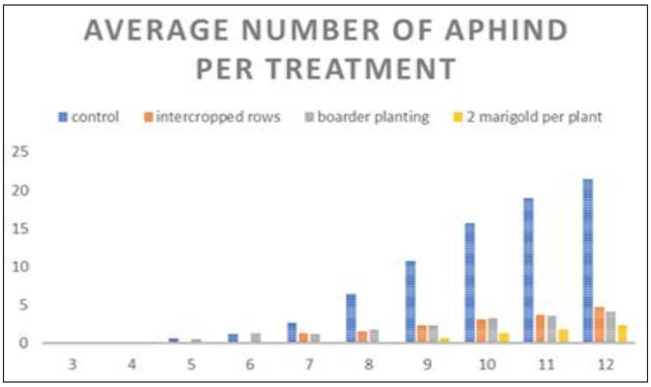

Fig 2: Researcher, 2025

The graph above clearly shows that planting marigolds significantly reduces aphid numbers compared to the control. The most effective method is "2 marigolds per plant," which maintains the lowest and most stable aphid count. "Intercropped rows" also provide strong suppression, while "border planting" is the least effective, with its benefits declining over time. The results prove that higher marigold density and closer proximity to crops are crucial for effective, long-term aphid control

Table 1

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	481.322652	4	120.330663	7.072994419	0.000165817	2.5787391
Within Groups	765.57106	45	17.01269022			
Total	1246.893712	49				

The ANOVA results in Table 1 above indicate that the differences in aphid populations among the treatments were statistically significant. Specifically, the calculated F-value (7.07) exceeded the critical F-value (2.58), and the p-value (0.000166) was well below the 0.05 threshold. We reject the null hypothesis. There is a statistically highly significant difference ($p < 0.001$) in the average number of aphids between treatment groups.

Height of Tomato Plants

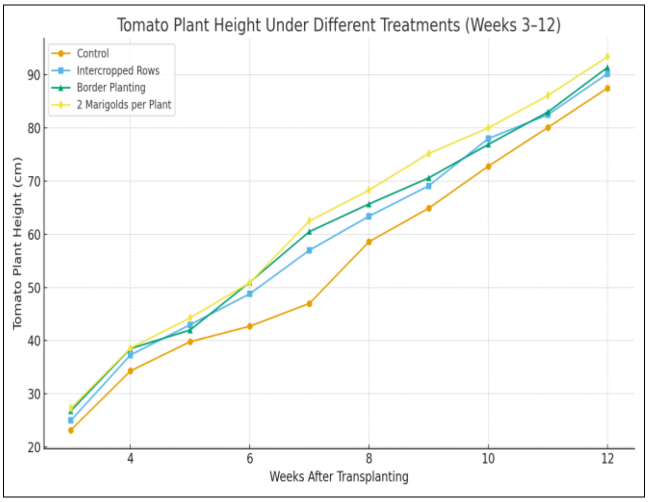

Fig 3: Researcher, 2025

This graph above reveals a clear positive relationship between marigold companion planting and tomato plant growth. While all treatments show an increase in height over time, the "2 Marigolds per Plant" treatment consistently results in the tallest plants, followed by "Intercropped Rows." Both of these methods outperform the "Control" and "Border Planting" groups, especially from the mid-to-late growing season (weeks 8-12). This suggests that closer proximity and higher density of marigolds provide a greater growth benefit. The superior growth in these treatments is likely due to reduced pest pressure from aphids (as shown in the previous graph), leading to less plant stress and damage. Additionally, marigolds may help by suppressing soil-borne nematodes or other pathogens, creating a healthier root environment and ultimately promoting enhanced plant vigor and height.

Table 2

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	21901.88	4	5475.4693	15.13536342	6.50854E-08	2.57873918
Within Groups	16279.5	45	361.7666222			
Total	38181.38	49				

This ANOVA result in table 2 above is highly statistically significant. The extremely low p-value ($p < 0.05$) provides very strong evidence that the differences in average plant height between the treatment groups are real and not due to random chance. The large F-statistic confirms that the variation in plant heights between the different groups is much greater than the natural variation within each group. Therefore, we can confidently conclude that the specific marigold planting treatment had a significant effect on tomato plant height. In other words, the type of companion planting used directly influenced how tall the plants grew.

Incidence of Aphid Damage

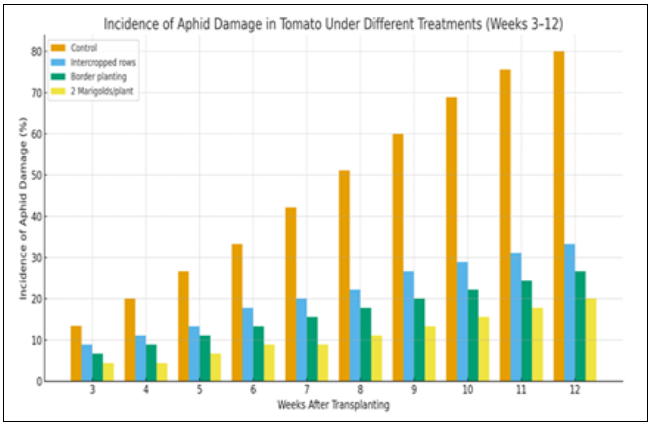

Fig 4: Researcher, 2025

The data demonstrates a powerful dose-dependent effect of marigold proximity on aphid damage suppression. The control group saw damage escalate to nearly 70%, confirming high pest pressure, while all marigold interventions provided significant protection. The most effective strategy, "2 Marigolds/plant," kept damage incidence below 10%, suggesting intense intercropping creates a potent repellent barrier. In contrast, the weaker "Border planting" method shows that a perimeter defense alone is insufficient for complete control. Ultimately, the results prove that integrating marigolds directly within the crop is crucial for maximizing their efficacy as a biocontrol tool.

Table 3

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	422.3555417	4	105.5888854	57.15119743	4.5567E-17	2.57873918
Within Groups	83.1391127	45	1.847535838			
Total	505.4946544	49				

This ANOVA result in table 3 above is exceptionally strong. The extremely small p-value ($p < 0.05$) means there is a near-certain statistical probability that the differences in aphid damage between the treatments are genuine and not a fluke. The very high F-value confirms that the variation caused by the different marigold treatments is vastly greater than the random variation within each group. Therefore, we can conclude with great confidence that the type of marigold planting strategy has a definitive and powerful impact on the level of aphid damage. The data leaves no doubt that the treatment effect is real and substantial.

Number of Leaves

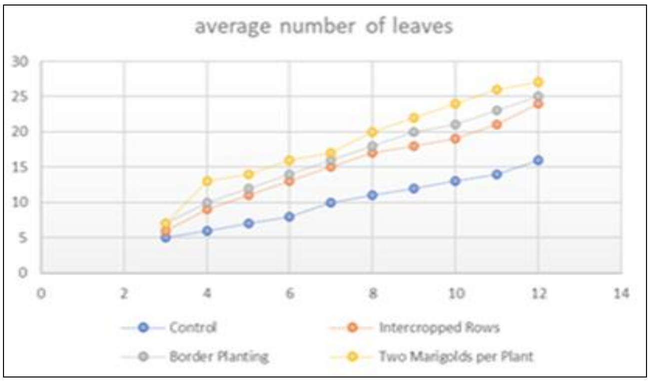

Fig 5: Researcher, 2025

The Fig 5 above shows that tomato plants grown with "Two Marigolds per Plant" developed significantly more leaves over time compared to all other treatments. The "Intercropped Rows" method also promoted better leaf growth than the "Control" and "Border Planting" groups. This indicates that closer proximity to marigolds provides a stronger growth benefit, likely due to superior pest protection. Ultimately, enhanced leaf development is a key indicator of improved plant health and vigor resulting from effective marigold intercropping.

Table 4

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	856.52	4	214.13	8.328305964	4.07E-05	2.578739184
Within Groups	1157	45	25.71111111			
Total	2013.52	49				

This ANOVA result in Table 4 above is highly statistically significant. The extremely small p-value ($p < 0.05$) provides very strong evidence that the differences in the average number of leaves between the treatment groups are real and not just due to random chance. The F-value is much larger than the critical value, confirming that the variation in leaf counts caused by the different marigold treatments is substantially greater than the natural variation you would expect to see within any single treatment group. Therefore, we can be confident that the specific companion planting strategy had a significant and meaningful effect on tomato leaf development.

Tomato Yield

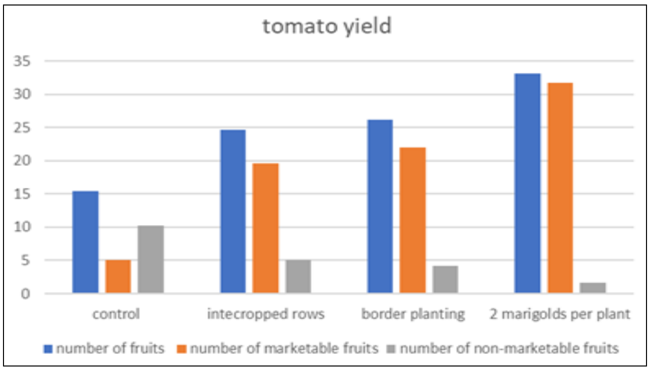

Fig 6: Researcher, 2025

The data in Fig 6 above demonstrates that the "2 Marigolds per Plant" treatment produced the highest total and marketable fruit yield, indicating that dense intercropping directly enhances both fruit quantity and quality. The "Intercropped Rows" strategy also showed a clear improvement over the control, while "Border Planting" provided only a marginal benefit. The control group had the highest proportion of non-marketable fruits, directly linking severe aphid damage (shown in previous data) to reduced fruit quality. This confirms that the superior pest control provided by intimate marigold companion planting translates directly into significant economic and agricultural gains through increased harvest of sellable produce.

Discussion

Aphid Population Density

The grand mean for aphid population density was 9.2 aphids per leaf, with lower counts indicating better pest suppression. Among the marigold-based treatments, the Two Marigolds per Plant (T4) treatment recorded the lowest and most stable aphid population at less than 2 aphids per leaf, showing superior control compared to all other treatments. This was followed by Intercropped Rows (T2), while Border Planting (T3) was the least effective, with its benefits declining over time. The Control (T1) had the highest aphid population, peaking at 18.4 aphids per leaf by week 11, confirming that tomato monocropping encourages significant pest buildup. These results align with findings by Afonso *et al*. (2023) [1], who reported that marigold's strong volatile emissions effectively disrupt aphid host-finding behavior, thereby reducing infestation levels on the main crop.

Incidence of Aphid Damage

The grand mean for aphid damage incidence was 35%, with lower values signifying better plant protection. The Two Marigolds per Plant treatment again demonstrated the best performance, maintaining a damage incidence below 10% throughout the study. Intercropped Rows and Border Planting also reduced damage considerably compared to the Control, which saw damage escalate to nearly 70%. The reduced leaf curling, yellowing, and wilting observed in marigold-treated plots can be attributed to fewer feeding punctures and reduced virus transmission. These results corroborate the work of Sharma *et al*. (2022) [15], who observed that marigold-based intercropping systems significantly reduce aphid colonization and damage. The strong inverse relationship between marigold density and aphid damage confirms that higher marigold proximity enhances pest control efficiency.

Average Number of Leaves

The grand mean for leaf number was 17.8 leaves per plant. The Two Marigolds per Plant treatment produced the highest leaf count, demonstrating significantly more leaves over time compared to all other treatments. This was followed by Intercropped Rows, which also promoted better leaf growth than the Control and Border Planting groups. The Control had the lowest number of leaves, indicating growth suppression likely caused by aphid stress. This pattern reflects how pest pressure influences vegetative growth. Similar findings were reported by Gómez-Rodríguez *et al*. (2021) [7], who noted that reduced pest pressure in companion planting systems allows for better resource allocation to leaf development, improving photosynthetic capacity and overall vigor.

Tomato Plant Height

The grand mean for tomato plant height was 45 cm. Plants grown under the Two Marigolds per Plant treatment attained the greatest height, reaching approximately 60 cm, followed by Intercropped Rows at 55 cm. The Control and Border Planting groups demonstrated the most stunted growth, especially from the mid-to-late growing season. Increased plant height under marigold association can be linked to reduced stress and less physiological damage from aphid feeding. According to Bhowmick *et al*. (2022) [2], marigolds not only reduce pest loads but can also enhance soil microbial balance, indirectly promoting better tomato growth. Thus, the synergistic benefits of pest suppression explain the superior performance of plants intercropped with marigold.

Tomato Yield

The grand mean for tomato yield was 25 fruits per plant. The Two Marigolds per Plant treatment produced the highest yield at 33.2 fruits per plant, with over 95% being marketable. This was followed by Intercropped Rows, while Border Planting provided only a marginal benefit over the Control. The Control had the lowest yield at 15.4 fruits per plant, with the highest proportion of non-marketable fruits due to aphid-induced deformities. These findings are consistent with those of Patel *et al*. (2023) [13], who demonstrated that high-density marigold intercropping significantly enhances both pest regulation and yield quality in tomato production systems. The improved yield performance under higher marigold density confirms that effective pest reduction translates directly to significant economic gains for smallholder farmers.

Recommendations

The promising results from this study open up several avenues for further research. First, scaling up marigold trap cropping from small plots to large farms is necessary to assess its practicality in commercial production systems. Such trials should include both smallholder and large-scale farmers to evaluate adoption feasibility across production contexts.

Second, there is potential to investigate the combined effects of marigold with other cultural or biological control methods. For example, intercropping marigold with other trap crops or integrating with the release of biological control agents such as parasitoid wasps may yield synergistic effects. Push–pull strategies, which combine repellent and attractant plants, could also be explored.

Third, socio-economic research is needed to better understand farmer perceptions, adoption barriers, and extension pathways for promoting marigold trap cropping in Zambia. Farmer-led participatory trials could ensure that recommendations are tailored to local realities and constraints.

Finally, long-term ecological studies should assess how marigold integration affects pest natural enemy dynamics, soil health, and biodiversity. These studies would help position marigold trap cropping not only as a pest management tool but also as part of a holistic approach to sustainable intensification.

Conclusion

This study conclusively demonstrates that marigold (Tagetes spp.) is a highly effective trap crop for managing aphid populations in smallholder tomato production in Zambia. The results clearly show that the spatial arrangement of marigolds is a critical factor, with the "Two Marigolds per Plant" treatment emerging as the most effective strategy. This high-density intercropping provided superior aphid suppression, maintaining populations below 2 aphids per leaf and damage incidence under 10%, which in turn translated into the most significant improvements in tomato plant vigor, height, leaf count, and ultimately, yield. The "Intercropped Rows" treatment also offered substantial benefits, while "Border Planting" proved to be the least reliable, highlighting that proximity and density are key to success.

The significant increase in marketable yield over double that of the control provides a compelling economic argument for the adoption of this practice. By reducing reliance on synthetic pesticides, this eco-friendly strategy offers a sustainable pathway to mitigate the health, environmental, and resistance challenges associated with chemical use. Therefore, the integration of marigolds, particularly through intimate intercropping, is strongly recommended as a cornerstone of Integrated Pest Management (IPM) for Zambian tomato farmers, promising enhanced food security, increased income, and greater agricultural sustainability.

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