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ORIGINAL ARTICLE

A PRELIMINARY STUDY ON THE COMPARATIVE EVALUATION OF PATH-AWAY® ORGANIC AND CYPERMETHRIN ON GROWTH AND PEST MANAGEMENT OF TOMATO (*Solanum lycopersicum* L.) PRODUCTION IN LAFIA, NASARAWA STATE

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ABSTRACT
The study compared the effects of Path-Away® Organic (PAO) biopesticide at three concentrations (5 ml, 10 ml and 15 ml per 1.5 L of water) and Cypermethrin on the growth, pest control efficiency, and yield performance of tomato (Solanum lycopersicum L.) under field conditions in Lafia, Nasarawa State, Nigeria. Results indicated that Cypermethrin consistently enhanced plant height, leaf production, flower formation and fruit yield. At week 12, cypemethrin-treated plants attained the highest plant height of 42.13 cm and produced the highest number of leaves (183.67), flower (4.27) and fruit yield of 1.40 kg per plot (equivalent to 1.20 kg ha^{-1}). PAO at 5 ml significantly improved vegetative growth, with plant height reaching 41.13 cm, number of leaves at 146.33, and fruit weight of 1.07 kg per plot, yielding 0.67 kg ha^{-1}. PAO at 10 ml offered moderate pest suppression, with 37.73 cm plant height and 2.73 flowers, but had slightly reduced growth compared to the 5 ml treatment. PAO at 15 ml resulted in the lowest performance among treated plots, with 22.40 cm plant height and 0.47 kg fruit weight, likely due to phytotoxic effects. The untreated control recorded the poorest results across all parameters, with only 20.87 cm plant height and no fruit production. The findings suggest that while Cypermethrin remains highly effective, PAO at 5 ml presents a promising eco-friendly alternative, offering significant growth and yield benefits with reduced environmental risks.
KEYWORDS*: Path-Away® Organic, tomato, Cypermethrin, biopesticide, growth enhancement, yield improvement.*

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) remains one of the most economically and nutritionally important horticultural crops globally and in Nigeria, contributing significantly to food security, employment and income generation for smallholder farmers (USAID, 2020). Its cultivation spans diverse agro-ecological zones across the country, including the Guinea Savanna belt where Nasarawa State is located (Muoghalu *et al.*, 2021). Tomatoes are rich in essential vitamins, minerals, and antioxidants, making them a vital component of diets and an important cash crop for rural households (Adeboye *et al.*, 2024). Despite its economic relevance, tomato production in Nigeria faces considerable challenges, particularly from insect pest infestations that negatively affect plant growth, yield quality and quantity (Akoroba *et al.*, 2021). Common pests such as whiteflies, aphids, fruit borers and mites attack tomatoes throughout the growing period, reducing productivity and compromising market value (Mitchell, 2004; Mailafiya *et al.*, 2014).

Effective pest management is thus central to improving tomato yields and ensuring sustainable production systems. Conventional pest management in tomato farming largely relies on synthetic pesticides such as Cypermethrin, which have proven effective but pose risks of environmental pollution, pest resistance development, and potential health hazards to farmers and consumers (Ullah *et al*., 2018; Boudh and Singh, 2018). These concerns have stimulated interest in eco-friendly, sustainable pest management alternatives, particularly bio-pesticides derived from plant-based or microbial sources (Kumar *et al*., 2021). Path-Away® Organic (PAO), a bio-pesticide formulated from natural organic compounds such as citric acid and Neem extract offers potential as a safer, environmentally friendly alternative to synthetic chemicals (Microbac, 2020; Akhte *et al*., 2023; Adesakin *et al*., 2025). Moreover, sustainable cultivation practices such as crop rotation, organic manure application, and integrated pest management (IPM) are recommended to improve tomato yield and reduce environmental impact. Modern tomato varieties such as Roma VF, Tropimech, UC82B and Money Maker, which are widely cultivated in Nigeria, offer desirable traits such as early maturity and resistance to common pests and diseases (Binuomote, 2021).

The use of PAO a newly introduced biopesticide (Microbac, 2020) needs to be evaluated empirically to establish its efficacy under local agronomic conditions, particularly in the Guinea Savannah regions like Lafia, Nasarawa State. This study, therefore, seeks to evaluate the agronomic performances of PAO at varying concentrations alongside one synthetic insecticide, cypermethrin and untreated control. The objectives are to assess the effects of PAO on insect pest suppression, vegetative growth and yield parameters of tomato, thereby contributing to integrated pest management (IPM) strategies suitable for sustainable tomato production in Nasarawa State and similar agro-ecological zones.

MATERIALS AND METHODS

Study Location

The experiment was conducted at the Teaching and Research Farm of the Faculty of Agriculture (Shabu Lafia Campus), Nasarawa State University, Keffi, Nasarawa State, Nigeria. The site is located within the southern Guinea savanna ecological zone, between latitude 8°33'N and longitude 8°32'E. The area experiences a tropical climate with distinct wet and dry seasons, average annual rainfall of approximately 1,300 mm and a temperature range of 24°C - 34°C. (Abubakar *et al*., 2019).

Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with five treatments and three replications. The treatments were as follows:

T_1: Path-Away® Organic (PAO) 5 ml/1.5 litres of water
T_2: Path-Away® Organic (PAO) 10 ml/1.5 litres of water
T_3: Path-Away® Organic (bio-pesticide) 15 ml/1.5 litres of water
T_4: Cypermethrin (synthetic insecticide) at recommended rate.
T_5: Control (no pesticide application)

Each plot measured 3 m x 2 m, with 1 m spacing between plots and 1.5 m spacing between blocks to minimize interference. Ten tomato plants of UC82B variety were transplanted per plot at a spacing of 50 x 50 cm.

Field Preparation and Planting

The field was cleared manually, ploughed and ridged. Tomato seeds were first raised in a nursery for three weeks before transplanting. Transplanting was done in the early morning hours to minimize transplant shock. Irrigation was provided immediately after transplanting and subsequently at 2 - 3 day intervals, depending on rainfall.

Pesticides Application
Pest management practices were applied using a knapsack sprayer at three critical stages:
Two weeks after transplanting (WAT)
At 50% flowering
At 50% fruit setting
PAO treatments were applied at the designated concentrations, while cypermethrin was applied at 2 ml per litre of water i.e., the recommended rate. Control plots received no pesticide application.

Data collection
Five randomly selected tomato plants per plots were tagged for data collection at 4, 6, 8 10 and 12 weeks after transplanting. The following parameters were recorded:
Plant height (cm)
Number of leaves
Number of affected leaves (due to pests)
Number of flowers and affected flowers
Number of Fruit bud formation
Number of harvested fruits (converted to kg^{-1}).

Data Analysis
All data were subjected to Analysis of variance (ANOVA) using Statistix 10.0 software (2018). Severity of infestation and effectiveness of Path-Away® Organic biopesticide and synthetic insecticide (Cypermethrin) was measured according to the methods of FAO (2006) and Pedigo and Rice (2014). Severity ratings for pest infestation and the effectiveness of Path-Away® Organic biopesticide and Cypermethrin were derived using the 1–5 scale described by FAO (2006) and Pedigo and Rice (2014), where:1 = No visible damage, 2 = Slight damage (1–25% of plant parts affected), 3 = Moderate damage (26–50%), 4 = Severe damage (51–75%), and 5 = Very severe damage (>75%). Effectiveness was assessed based on observable reductions in pest populations, visual recovery of plant parts, and consistency across replicated treatments. Treatment means were compared using Least Significant Difference (LSD) at a 5% probability level.

RESULTS

Effect of Bio-Pesticide and Synthetic Pesticide on Plant Height across Growth Stages
Table 1 presents the results on plant height of tomato across five growth stages (4, 6, 8, 10 and 12 weeks after transplanting). At Week 4 PAO at 5 ml (12.47 cm) and Cypermethrin (12.00 cm) produced significantly taller plants compared to PAO 15 ml (8.43 cm) and the control (8.13 cm), were statistically different ($P \leq 0.05$) when compared with each other. At Week 6, PAO at 5 ml recorded the highest plant height (25.60 cm), followed by Cypermethrin (23.00 cm), while the control had the lowest height (12.47 cm). Differences between PAO 5 ml and the control were significant ($P \leq 0.05$). At Week 8, Cypermethrin produced the tallest plants (37.93 cm), followed by PAO 10 ml (34.07 cm) and PAO 5 ml (31.30 cm). The control (17.40 cm) and PAO 15 ml (19.13 cm) were significantly shorter. The difference between

Cypermethrin and the control was highly significant (P≤0.05). By Week 10, Cypermethrin maintained the tallest height (41.47 cm), which was slightly higher than PAO 5 ml (41.00 cm). PAO 15 ml (22.27 cm) and the control (20.60 cm) again recorded the lowest heights. At Week 12, Cypermethrin remained highest (42.13 cm), closely followed by PAO 5 ml (41.13 cm). The control (20.87 cm) and PAO 15 ml (22.40 cm) were significantly lower. The growth advantage of PAO 5 ml and Cypermethrin over control was statistically significant (P≤0.05).

Table 1: Effect of Path-Away® bio-pesticide and Cypermethrin synthetic pesticide on plant height across growth stages

Plant height (cm) across growth stages					
Treatment	**Weeks**				
Bio-pesticide	**4**	**6**	**8**	**10**	**12**
PAO 5 ml	12.47	25.60	31.30	41.00	41.13
PAO 10 ml	11.27	21.47	34.07	37.73	37.73
PAO 15 ml	8.43	14.67	19.13	22.27	22.40
Cypermethrin	12.00	23.00	37.93	41.47	42.13
Control	8.13	12.47	17.40	20.60	20.87
Grand mean	10.50	19.47	27.97	32.61	32.85
C.V	33.19	38.30	44.32	45.15	49.28
SE±	2.85	6.09	11.25	12.02	11.89
LSD	0.44	0.25	0.34	0.30	0.28

Effect of Bio-Pesticide and Synthetic Pesticide on Number of Leaves and Number of Leaves Infected with insect pest across Growth Stages

Table 2: Number of Leaves (NL) at Week 4, PAO 5 ml had the highest leaf number (29.13), followed by Cypermethrin (25.53) and PAO 10 ml (23.13). Control and PAO 15 ml had the lowest (18.00 and 18.07, respectively).

Table 2: Effect of Path-Away® bio-pesticide and Cypermethrin synthetic pesticide on number of leaves and number of leaves infested with insect pests across growth Stages

	NL					**NOLI**				
Treatment	**Weeks**					**Weeks**				
Biopesticide	**4**	**6**	**8**	**10**	**12**	**4**		**8**	**10**	**12**
PAO 5 ml	29.13	88.47	116.67	146.13	146.33	1.80	11.27	13.30	13.00	49.20
PAO 10 ml	23.13	80.00	122.20	142.47	142.67	1.00	9.50	10.40	14.80	37.33
PAO 15 ml	18.07	50.00	69.27	88.20	88.53	3.67	6.87	7.47	12.53	25.27
Cypermethrin	25.53	72.40	161.87	178.13	183.67	1.87	7.53	9.67	15.47	52.47
Control	18.00	31.87	49.00	66.93	66.93	1.60	4.07	5.04	11.73	18.80
Grand mean	22.77	64.55	103.80	124.37	125.63	1.99	7.85	9.18	13.51	36.51
C.V	38.82	49.68	63.73	54.24	52.22	7.22	77.35	70.94	27.90	66.38
SE±	7.22	26.18	54.01	55.09	53.56	1.16	4.96	5.32	3.08	19.84
LSD	0.51	0.27	0.32	0.33	0.2	0.29	0.67	0.62	0.72	0.42

Number of Leaves (NL), Number of Leaves Infested (NOLI)

The differences between PAO 5 ml, Cypermethrin and control are statistically significant. PAO 5 ml (88.47) at Week 6 significantly outperformed all other treatments. Cypermethrin (72.40) and PAO 10 ml (80.00) were close but statistically different (P≤0.05) from the control (31.87). Week 8, Cypermethrin recorded the highest NL (161.87), followed by PAO 10 ml (122.20) and PAO 5 ml (116.67). Control had only 49.00 leaves. All the treated plots were significantly (P≤0.05) different from the control.

Week 10 and 12 showed that Cypermethrin remained highest with 178.13 and 183.67, PAO 5 ml and 10 ml followed closely with treatments with PAO 5 ml (146.13, 146.33); PAO 10 ml (142.47, 142.67). Control had 66.93 leaves in both weeks. The differences between treated and control plots were statistically significant (P≤0.05). At Week 4, the Table 2 shows that the lowest NOLI was recorded in PAO 10 ml (1.00) and PAO 5 ml (1.80), while PAO 15 ml had the highest (3.67). PAO at 10 ml had significantly fewer infested leaves than PAO at 15 ml and the control. At weeks 6 and 12, Cypermethrin and PAO at 10 ml consistently had fewer infested leaves than PAO at 15 ml and the control. At Week 12, Cypermethrin (52.47), PAO 10 ml (37.33) and the control (18.80) were significantly different from each other (P≤0.05). Despite lower NOLI in the control, the interpretation must consider overall leaf count as control had very few leaves produced and hence the infestation percentage was high. Table 3 shows the level of inferences made on number of leaves infested and the effectiveness of the use of PAO and Cypermethrin.

Table 3: Identification of insect pest, pest infestation range and pesticide effectiveness across growth stages

Insect Pest Common Name	Scientific Name	Infestation Severity (Ranging 1 - 5)	Effectiveness of Path-way	Effectiveness of Cypermethrin
White flies	*Bemisia tabaci*	5	Moderate to Good (Repellent and population control, but not a quick knockdown	High (Quick knockdown.
Aphids.	*Aphids* spp.	4	Good (Repellent and anti-feeding properties)	High (Rapid reduction in population)
Tomato Fruit Worm	*Helicoverpa armigera*	5	Moderate(It reduced larval feeding but less effectiveness on area of heavy infestation)	Very high (Highly effective against larvae)
Leafminers	*Liriomyza spp.*	3	Moderate (Deters adult laying eggs, but less active on leavae inside leaves)	High (Effective especially when it helped in larvae exposed)
Thrips	*Thrips tabaci*	4	Good (Repels, reduces population, virus spread risk)	High (Quick reduction but may harm beneficial insects)
Cutworms	*Agrotis spp.*	3	Low to Moderate (limited effect on larvae in the soil	High (Effective against exposed larvae)
Stink Bugs	*Nezara viridula*	3	Moderate (Repellent but poor knockdown)	Moderate to high (Effective upon direct contact)

Assessment following the methods of FAO (2006), Pedigo and Rice, (2014).

Effect of Path-Away® bio-pesticide and Cypermethrin synthetic pesticide on number of flower and number of flower infested with insect pest across growth stages

At week 6 (Table 4), the result shows that cypermethrin consistently produced high number of flowers (NOF) compared to all other treatments across the weeks of growth. PAO at 5 ml had highest flowering (1.20), followed by PAO 10 ml (0.80), while PAO 15 ml and control had no flowering. There was significant difference (P≤0.05) between PAO application at 5 ml and the control. At Week 8, Cypermethrin recorded highest NOF (4.20), PAO 5 ml followed with 2.93, PAO 10 ml with 2.60. Control had 0.00 and these were significantly (P≤0.05) differences between the treatments and the control. Week 10 and 12 showed that Cypermethrin out-performed (1.93 and 4.27), while PAO 5 ml followed closely (1.67, 3.73). These were not significantly different from each other (P≥0.05) Differences between PAO 10 ml and PAO 15 ml were not statistically different from each other ((P=0.05)) and were significantly different from the control that produced low number of flowers.

Number of Flowers Infested (NOFI) showed that PAO 10 ml had the least flower damaged at Weeks 6 and 12. At Week 12, PAO applied at 10 ml had 1.40 number of flowers infested while Cypermethrin had 2.87. PAO 5 ml had 2.87 and Control had 0.33 (due to almost no flowers) and PAO 10 ml significantly (P≤0.05) protected flowers produced than others.

Table 4: Effect of Path-Away® bio-pesticide and Cypermethrin synthetic pesticide on number of Flower and number of flowers infested with insect pests across growth stages

	NOF					NOFI				
Treatment	**Weeks**					**Weeks**				
Biopesticide	**4**	**6**	**8**	**10**	**12**	**4**	**6**	**8**	**10**	**12**
PAO 5 ml	0.00	1.20	2.93	1.67	3.73	0.00	0.33	0.80	1.67	2.87
PAO 10 ml	0.00	0.80	2.60	0.73	2.73	0.00	0.00	0.13	0.73	1.40
PAO 15 ml	0.00	00.00	0.00	1.27	1.20	0.00	0.00	0.33	1.27	0.73
Cypermethrin	0.00	0.53	4.20	1.93	4.27	0.00	0.13	1.87	1.93	2.87
Control	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.33
Grand mean	0.00	0.50	2.15	1.12	2.49	0.00	0.09	0.63	1.12	1.64
C.V	0.00	11.21	109.00	70.83	79.35	0.00	271.105	135.15	70.83	80.37
SE±	0.00	0.46	1.91	0.65	1.62	0.00	0.21	0.69	0.65	1.80
LSD	0.00	0.12	0.29	0.09	0.19	0.00	0.46	0.14	0.09	0.13

Number of flower (NF), Number of flower infested (NOFI)

Effect of Path-Away® bio-pesticide and Cypermethrin synthetic pesticide on fruit weight/plot and fruit yield (kg/ha) across growth stages

Table 5 shows that fruit weights (Kg/plot) was significantly (P<0.05) produced among the treatments with the use of Path-Away organic, and Cypermethrin more than the production in the control treatments throughout the period of observations. At Week 8 (early reproductive stage), Cypermethrin produced the highest fruit weight per plot (1.27 kg) confirming its early positive impact on fruit development. Path-Away bio-pesticide at 5 and 10 ml followed closely with (1.20 kg) per plot, indicating that the use of PAO bio-pesticide at optimized concentrations can support early fruit formation and development. Path-Away bio-pesticide used at 15 ml shows that the fruit weight per plot reduced (0.93 kg), likely due to negative effects of higher PAO bio-pesticide concentration while the control treatment produced low fruit weights (0.13 kg). The differences between the control treatment and treated plots were statistically significant (P≤0.05) when compared between the treatments.

At 10 Week PAO at 10 ml recorded the highest fruit weight per plot (2.07 kg), which was significantly ($P \leq 0.05$) higher than the untreated control and PAO used at 15 ml producing 1.53 kg Cypermethrin surprisingly dropped to 0.27 kg, and control slightly rose to 1.13 kg due to late fruiting. Path-Away organic at 10 ml produced 2.07 kg which were statistically similar ($P=0.05$) to PAO 5 ml producing 1.73 kg but produced slightly lower fruit weights than PAO 10 ml. The low performance of PAO at 15 ml was significantly lower, possibly due to phytotoxic effects of excessive PAO biopesticide concentration. There were no fruit production in the control plots, thus, the treatments were significantly different from all treated plots throughout the period of observation. At Week 12, Cypermethrin produced the highest fruit weight per plot (1.40 kg), and this was significantly different from all other treatments. PAO at 5 ml recorded fruit weight of 1.07 kg which were significantly higher ($P \leq 0.05$) than those recorded in PAO at10 and 15 ml (0.60 kg and 0.47 kg, respectively than the Control (0.00 kg).

Table 5 also shows the production of tomatoes in Kg ha^{-1}. At week 10, PAO at 5 ml produced the highest number of harvested fruit yield (0.93 kg ha^{-1}), indicating its effectiveness in supporting early fruit development, which was significantly higher than the untreated control (0.00) and PAO at 15 ml (0.27 kg/ha) . Cypermethrin and PAO at 10 ml had statistically similar yields (0.80 kg ha^{-1}) to PAO at 5 ml. PAO at 15 ml (0.27 kg/ha) produced significantly fewer harvested fruits, indicating reduced effectiveness at higher bio-pesticide concentration. The control treatment did not produce any fruit, and this was significantly lower than fruit production in all treated plots. At week 12, the use of cypermethrin (1.20 kg/ha) significantly outperformed all treatments in the weight of harvested fruits.), PAO 5 ml yielded 0.67, while PAO 10 ml and 15 ml were both at 0.33. Control remained at 0.00. LSD = 0.18, confirming significant treatment effects.

Table 5: **Effect of Path-Away® organic bio-pesticide and Cypermethrin synthetic pesticide on Fruit weight/plot and Fruit Yield kg ha^{-1} across Growth Stages**

	Fruit Weight (kg/plot)			Harvested Fruits (kg [000]) ha^{-1})	
Treatment			**Weeks**		
Bio-pesticide	**8**	**10**	**12**	**10**	**12**
PAO 5 ml	1.20	1.73	1.07	0.93	0.67
PAO 10 ml	1.20	2.07	0.60	0.80	0.33
PAO 15 ml	0.93	1.53	0.47	0.27	0.33
Cypermethrin	1.27	0.27	1.40	0.80	1.20
Control	0.13	1.13	0.00	0.00	0.00
Grand mean	0.95	1.35	0.74	0.56	0.51
C.V	90.58	87.93	104.95	96.27	109.06
SE±	0.70	0.93	0.61	0.44	0.45
LSD	5.02	0.15	0.26	0.24	0.18

DISCUSSION

This study evaluated the comparative effectiveness of Path-Away® Organic (PAO) biopesticide at three concentrations (5 ml, 10 ml, and 15 ml), Cypermethrin, and an untreated control on tomato growth, pest suppression, and yield under field conditions. The results showed clear variation in agronomic performance based on the treatment type and concentration. These results align with findings by Beelagi *et al.*, (2023) and Hossain *et al*., (2022), who reported that Cypermethrin enhances growth through effective insect pest suppression. And the use of some biopesticides have been reported to enhance growth of vegetables when used to control pests (Ayilara *et al*., 2023). As has been suggested by Nikolopoulos (2025) the availability of some plant hormones such as auxins, cytokinins, abscisic acid, ethylene and gibberellins could be a factor that enhances the growth of the tomatoes as applied. Particularly, PAO has been reported to contain citric acid as a base in its formulation. Regarding pest suppression, cypermethrin and PAO at 10 ml significantly reduced the number of infested leaves. The deceptively low pest damage in control was due to low leaf production, not low pest activity. These results support earlier suggestions by Farag *et al*. (2021) and Butu *et al*. (2020) who emphasized the need to optimize bio-pesticide dosage for maximum effectiveness. The results is in consonance with Ayilara *et al*. (2023) that showed that the use of some plant biopesticides reduces the ability of insects to colonize the plant host thus reducing pest infestation.

In terms of reproductive traits, these results agree with the findings of Akhter *et al*. (2023) on the role of optimized botanical pesticides in enhancing reproductive success in tomato. The application of cypermethrin-treated plots had the highest fruit weight per plots followed by PAO at 5 and 10 ml, while the control produced no fruit. This affirms earlier studies by Balog *et al*. (2017) and Essiedu *et al.* (2020) who demonstrated the potential of integrating bio-pesticides into IPM systems to maintain productivity and reduce synthetic inputs. Although, cypermethrin remains superior in pest control and crop performance, environmental concerns such as toxicity to non-target organisms, ecological disruption, and pest resistance (Boudh and Singh, 2018; Ullah *et al*., 2018) suggest a need for alternatives. PAO derived from natural components such as citric acid (Microbac, 2020), showed promising eco-friendly results. At 5 ml, it offered a balance between pest suppression and plant growth, aligning with findings by Tadesse *et al.* (2025) and Kumar *et al*. (2021), and is therefore recommended for sustainable tomato production in integrated systems.

CONCLUSION AND RECOMMENDATIONS

The findings confirm that cypermethrin remains an effective tool for tomato pest management and growth enhancement. However, environmental concerns associated with its use necessitate the exploration of alternatives. Path-Away® Organic at 5 ml offers a promising eco-friendly option with moderate pest control and growth-promoting potential, particularly suitable for integration into Integrated Pest Management (IPM) programs. This study is a preliminary study and hence, showed that the Path-Away® Organic biopesticide can be adopted if used at optimized dose within IPM frameworks to reduce dependence on synthetic pesticides, enhance environmental sustainability and maintain productivity in tomato production. Further research is encouraged to assess long-term field performances, pest resistance dynamics and economic viability of biopesticide-based pest management strategies.

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