Journal of Plant Protection Research | eISSN 1899-007X

ORIGINAL ARTICLE

Application of *Lantana camara* L. leaf extracts and essential oils for increasing yield and improving pest management in the production of tomato (*Solanum lycopersicum L.*) cultivar VF

Ayopo Anuoluwa Sotade[1]*, Olapeju Oluyemisi Aiyelaagbe[1],
Adefoyeke Olufunmilayo Aduramigba-Modupe[2], Isaac Oreoluwa Aiyelaagbe[3]

[1] Department of Chemistry, University of Ibadan, Ibadan. Nigeria, F106 Laboratory, Natural Products Laboratory, Ibadan, Nigeria

[2] Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria

[3] Horticulture (Fruit Science and Cropping Systems), Federal University of Agriculture, Department of Horticulture, Abeokuta, Nigeria

DOI: 10.24425/jppr.2026.158065

Received: April 06 2025
Accepted: June 12, 2025
Online publication: February 23, 2026

*Corresponding address:
drayopo16@gmail.com

Responsible Editor:
Iwona Adamska

Abstract

Tomato (*Solanum lycopersicum* L.) is the most commonly consumed vegetable in Nigeria, and synthetic pesticides are frequently used to protect tomatoes against pests and diseases. However, the environment and human health are negatively impacted by their use, prompting consideration of alternative, environmentally safe treatments. *Lantana camara* L. (commonly known as sage, family Verbenaceae), a commonly occurring plant, has shown promise as a natural alternative for controlling tomato pests and may serve as an eco-friendly substitute for synthetic pesticides. Therefore, the potential of extracts of *L. camara* and essential oils (EOs) for the production and protection of the tomato variety "Roma VF" was studied under field conditions in Ibadan, Nigeria. Fresh *L. camara* leaves were collected from plants growing on the University of Ibadan campus, Oyo State and identified at the Herbarium section, Department of Botany, University of Ibadan (UIH 23103). The leaves were air-dried, pulverized and subjected to hydrodistillation for EO extraction. The methanol and aqueous extracts of *L. camara* were obtained by maceration in methanol and water, respectively. *An in vivo* pesticidal bioassay was conducted to determine the biocidal potential of *L. camara* leaves using aqueous extract, methanolic extract, EO and water (as control) via two modes of application (spraying and drenching). The data were analysed using ANOVA and DMRT. The EO treatment gave the best control of the pests and resulted in higher fruit yield (1821 g · plant^{-1}) compared to the control (512.5 g · plant^{-1}). Thus, the EO from *L. camara* leaves demonstrated promising biocidal potential and can be effectively used to protect tomatoes against pests for increased fruit yield.

Keywords: biopesticides, drenching, hydrodistillation, romavf, spraying

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the fruit vegetables grown worldwide, whether in a pot, a kitchen garden, or on a small or large scale for commercial purposes. It is one of the most essential vegetables grown in Nigeria (Abdul *et al.* 2020). Tomato production has been dependent on synthetic pesticides, which have not provided the expected increased production due to high cost, misuse and side effects. According to Nowicki *et al.* (2013), more than 200 pests and diseases have been found in tomatoes and are either directly or indirectly responsible for product losses. The most serious threats to cereal crops and vegetables are diseases caused by fungi, nematodes, bacteria, and viruses. These have an impact not only on their nutritional value but also on people's health and the nation's economy. One of the tomato's most destructive diseases, late blight resulting from *Phytophthora infestans* infections, led to significant economic losses of 20–70% (Nowicki *et al.* 2013). These tomato pathogens continue to be a major limiting factor for tomato production and are currently causing extensive losses in field and greenhouse settings. Tomato yellow leaf curl caused by the Tomato yellow leaf curl virus (TYLCV), is another major viral disease that affects cultivated tomatoes in tropical and subtropical regions globally and has been reported to cause losses of up to 100% (Singh *et al.* 2017).

The global movement towards sustainable agriculture and environmentally safe plant disease management techniques demands a decrease in the application of synthetic chemical pesticides. The development of long-lasting, reliable, and environmentally safe biocontrol techniques for the treatment of plant diseases has been the focus of recent efforts. Natural plant products are an important source of novel agrochemicals for the management of plant diseases (Kagale *et al.* 2004). Plant extracts are components of integrated pest management initiatives and eco-friendly substitutes (Bowers and Locke 2004). For instance, Hussein *et al.* (2015) reported that lemon grass and garlic extracts significantly reduced the population density of *Tuta absoluta* in the tomato cultivar Gold Stone**.** Essential oils (EOs) are a mixture of volatile components produced by the secondary metabolism of aromatic and other types of plants (Bassolé and Juliani 2012). They are concentrated, volatile hydrophobic liquids. The most common methods of extraction of these volatile metabolites are by steam or hydrodistillation methods, and the resulting fragrant chemical mixture is referred to as EO (Regnier *et al.* 2012). Many cultures have used EOs for thousands of years for therapeutic and medicinal purposes. Due to their antibacterial and antiviral properties, EOs can serve as a source of new antimicrobial compounds and agents for food preservation (Solórzano-Santos and Miranda-Novales 2012).

Lantana camara L. (commonly known as sage), the plant investigated in this study, belongs to the family Verbenaceae and is an invasive weed. It is considered a nuisance in pastures due to its harm to ruminants, but it contains many bioactive compounds such as alkaloids, steroids, saponins, and flavonoids. It has anti-fungal effects (Bashir *et al.* 2019) and its antioxidant activities were also reported by (Nea *et al.* 2019). Sotade *et al.* (2023) also reported the chemical constituents and biological activities of EOs of *L. camara* and observed that the oil demonstrated significant antioxidant and antimicrobial activities. Sotade *et al.* (2022) reported in a short communication that *L. camara* extracts significantly enhanced the growth and fruit yield of tomatoes cultivated under field-like conditions. The population of *L. camara,* being an invasive weed, could be controlled, and its value could be enhanced by using it for pest control.

However, studies investigating the comparative effectiveness of different *L. camara* leaf extracts (aqueous, methanolic) and EOs under field conditions remain limited. Therefore, the purpose of this study was to investigate the biocidal potential of *L. camara* leaf extracts and EOs in the management of tomato pests and diseases and to evaluate their impact on the yield of tomato (*Solanum lycopersicum* L.) cultivar Roma VF under field conditions in Ibadan, Nigeria.

Materials and Methods

Plant collection, preparation and identification

Fresh leaves of *L. camara* were collected from plants growing in Ibadan, Nigeria, and identified at the Herbarium of the Department of Botany, University of Ibadan (voucher specimen number UIH 23103). The leaves were separated from the other parts, air-dried at room temperature for three weeks, and then pulverised into fine powder using a mechanical grinder. The powdered leaves were used for aqueous extraction, methanolic extraction, and EO distillation.

Preparation of *Lantana camara* leaf extracts and essential oils

Solvent extraction

Extraction of the powdered *L. camara* leaf was carried out using the cold extraction method, using distilled methanol. The pulverised *L. camara* leaves were soaked in distilled methanol (4 l) for 72 hours and filtered. The extracts were concentrated using a rotary evaporator at 58°C at a speed of 70 rpm. The extraction process was repeated once, and the extracts were stored for one week before treatment application.

Aqueous extraction

Aqueous extraction of *L. camara* leaf was performed using the hot extraction method with water. The leaf was weighed and transferred to a 5 l round-bottom flask. Boiled water (2 l) at 100°C was added to the flask. The pulverised leaf was soaked in water for 72 hours and filtered. The extracts were concentrated using a rotary evaporator, and the extracts were stored in the refrigerator at 4°C for one week before treatment application.

The yield of the extracts was determined and used to calculate the percentage yield (Formula 1):

$$\%\ \text{yield} = \frac{\text{Yield of extract}}{\text{Weight of } L. camara \text{ leaf}} \times 100\ (\%). \quad (1)$$

Essential oil extraction

The pulverised *L. camara* leaf was weighed into a 10 l round-bottom flask, and water was added until the leaves were completely immersed. The soaked sample was placed on a 10 l capacity heating mantle and fitted with a Clevenger apparatus designed according to the British Pharmacopoeia specification. The extraction was carried out for two hours. EOs were collected over water in hexane and dispensed into vial bottles, which were kept in a refrigerator at 4°C for one week before treatment application. The volume of the oil was recorded and used to calculate the percentage yield of the oil obtained (Formula 2):

$$\%\text{ yield of oil } = \frac{\text{Volume of essential oil}}{\text{Weight of } L. camara \text{ leaves}} \times 100\% \text{ (v/w \%)}. \quad (2)$$

Farmland location and seedling propagation

The research was conducted at the University of Ibadan, Department of Crop Protection and Environmental Biology Crop Garden. The tomato seeds (cultivar Roma VF) were obtained from the National Horticultural Research Institute (NIHORT) in Ibadan, Nigeria, and germinated in seedling trays for five weeks. One seed was sown per cell in the seedling trays, and one healthy seedling was transplanted into each polythene bag.

Topsoil was collected within the premises of the University of Ibadan and sieved through a 1.0 mm mesh to remove residues and pebbles, then transferred into perforated black polythene bags at 10 kg per bag. The bags were arranged on a 50 cm x 50 cm grid. Poultry manure of 0.30 kg and 100 g of oil palm bunch ash were added to every 10 kg of soil, followed by a top-dressing of 150 g of poultry manure eight weeks after transplanting (WAT).

The experiment was conducted under open field conditions from March to May 2022 in Ibadan, Oyo State, southwestern Nigeria. During this period, weather conditions were typical of the late dry to early rainy season transition, with average daily temperatures ranging from 26°C to 34°C, relative humidity between 60–80%, and moderate rainfall, especially in April and May.

Experimental design, treatment application, and data collection

A randomized complete block design with three replicates was used as the experimental design, and treatments were applied by spraying or drenching one day after transplanting. Each treatment consisted of three (3) tomato plants per replicate, resulting in 9 plants per treatment across the three replicates. A total of eight (8) treatments were applied, giving a total of 72 plants used in the experiment. All plants within each treatment plot received the respective treatment application. An overview of the treatment types, application methods, and concentrations is presented in Table 1. The EO treatment was applied once a week, while all other treatments were applied three times per week. A volume of 10 ml was initially used for both spraying and drenching, and this was increased to 15 ml as the plants grew, to ensure proper coverage. The following parameters were assessed throughout the experiment: the number of leaves, flower production, damaged leaves, damaged fruits, and fruit yield.

Table 1. Treatments and application concentrations

S/N	Mode of application	Extracts/essential oil	Concentration
1	Spraying	Essential oil	50 µl
2	Spraying	Aqueous	100 mg · ml^{-1}
3	Spraying	Aqueous	200 mg · ml^{-1}
4	Spraying	Methanol	100 mg · ml^{-1}
5	Spraying	Methanol	200 mg · ml^{-1}
6	Drenching	Aqueous	200 mg · ml^{-1}
7	Drenching	Methanolic	200 mg · ml^{-1}
8	Spraying	Blank – Water	

Leaf number was determined by direct counting and performed weekly. Flower production was recorded by counting flowers daily. Damaged leaves and fruits were assessed by visual inspection and counting of the affected plant parts daily. Fruits were harvested individually as they ripened, and fruit yield was measured per plant by weighing the harvested fruits. Fruits were harvested individually upon ripening, and total fruit yield per plant was calculated by weighing all harvested fruits. All plants per treatment (9 plants) were assessed. Data collection began immediately following transplanting, with the experiment terminated at 15 WAT (weeks after transplanting). Pests observed during the experimental period included whiteflies, and leaf spot symptoms were also recorded.

Disease incidence and severity

The number of damaged leaves was counted, and the severity was determined using the Disease Severity Rating Scale Score. All the leaves of each plant were assessed to ensure consistency and reproducibility. Data on disease severity were recorded using a 0–5 disease rating scale (Gondal *et al.* 2012), as shown in Table 2. Disease incidence on fruits was recorded and assessed

Table 2. Disease severity rating scale for evaluating leaf spots on tomatoes

Scale	Disease incidence	Description
0	0.0	Leaves free from leaf spot
1	0–5%	0–5 per cent leaf area infected and covered by spot, no spot on petiole and branches.
2	6–20%	6–20 per cent leaf area infected and covered by spot, some spots on petiole.
3	21–40%	21–40 per cent leaf area infected and covered by spot, spots also seen on petiole, branches.
4	41–70%	41–70 per cent leaf area infected and covered by spot, spots also seen on petiole, branches, stem.
5	>70%	>71 per cent leaf area infected and covered by spot, spots also seen on petiole, branch, stem, fruits.

based on the number of fruits present on plants at the time of each evaluation. All the fruits per plant were counted, and disease incidence was evaluated by visual observation. The disease incidence percentage on fruits was calculated using the formula (Formula 3) below (Hendricks *et al.* 2020):

$$\text{Disease incidence on fruits (\%)} = \\ = \frac{\text{Number of diseased fruits}}{\text{Total number of fruits}} \times 100. \quad (3)$$

Data analysis

The collected data were analysed using Microsoft Excel, and Analysis of variance (ANOVA) was determined using the Duncan Multiple Range Test (DMRT) at a significance level of $p < 0.05$. The values presented in Figures 1, 2, 3, 5, and 6 are expressed as mean and error bars.

Results

Weight and percentage yield from the extraction of *Lantana camara*

The weight and percentage yield of methanolic and aqueous extracts of *L. camara* leaves are presented in Table 3. In addition, the volume and percentage yield of EOs extracted from the leaves via hydrodistillation using a Clevenger apparatus are also shown in Table 3.

Table 3. Percentage Yield and Colour of *Lantana camara* Leaf Extracts and Essential Oil

Lantana camara leaf	Weight of plant material [g]	Yield of extract [g]/Volume of oil [ml]	% Yield	Colour of extract/oil
LCLM	1248.9	52.94	4.24	deep green
LCLAq	436.02	33.20	7.61	deep green
LCLEO	156.92	1.4	0.98	pale yellow

LCLM – *Lantana camara* leaf methanol extract
$LCLA_q$ – *Lantana camara* leaf aqueous extract
LCLEO – *Lantana camara* leaf essential oil

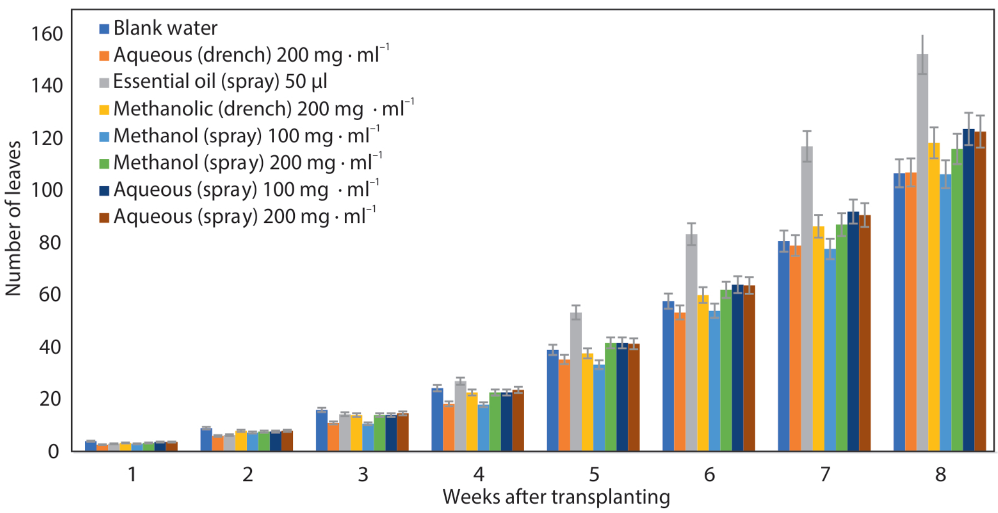

Fig. 1. Number of leaves of tomato in response to leaf extracts of *Lantana camara*

Plant growth (leaves and flower production)

The number of leaves was recorded from the first to the eighth WAT. Plants sprayed with EO produced the most leaves. The control and methanolic spray treatment (100 mg · ml^{-1}) produced the fewest leaves. Leaf extracts had no discernible effect on leaf production (Fig. 1). Flowering began in the fifth WAT and lasted until the end of the experiment. The control treatment produced the fewest flowers. At eight WAT, EO spray produced significantly more flowers ($p < 0.05$) than other extracts (Fig. 1). The effect of other extracts did not differ significantly from one another.

Damaged leaves

All plants, including those treated with extracts and the control plants, exhibited varying degrees of leaf damage. Leaf curling, chlorosis, and leaf perforation were some of the most common symptoms observed. The mines and holes observed on the leaves are typical of feeding damage by leaf-mining insects or caterpillars. The control treatment had the most damaged leaves (70%) and was followed by the methanolic spray treatment (100 mg · ml^{-1}) and methanolic drench (200 mg · ml^{-1}). The control and methanolic spray treatments were not significantly different at $p < 0.05$

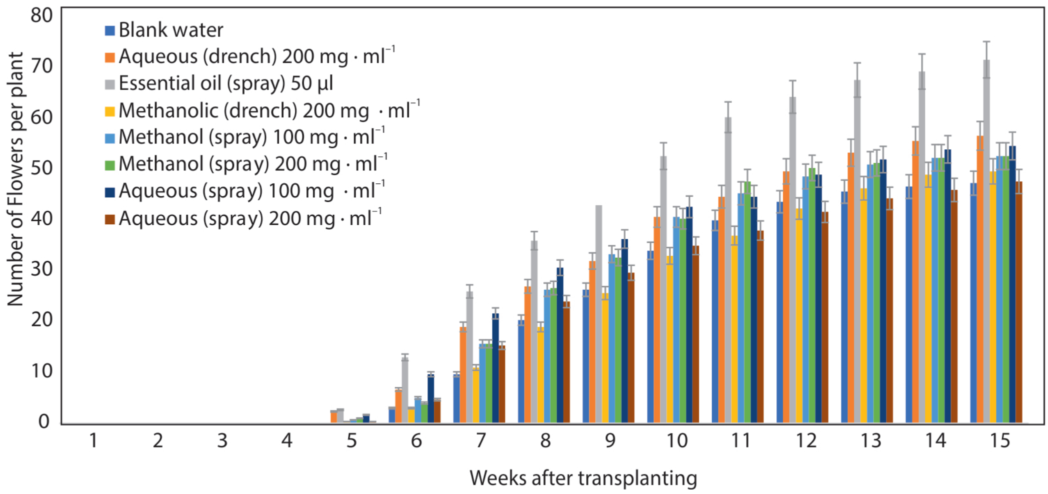

Fig. 2. Flower production of tomato in response to leaf extracts of *Lantana camara*

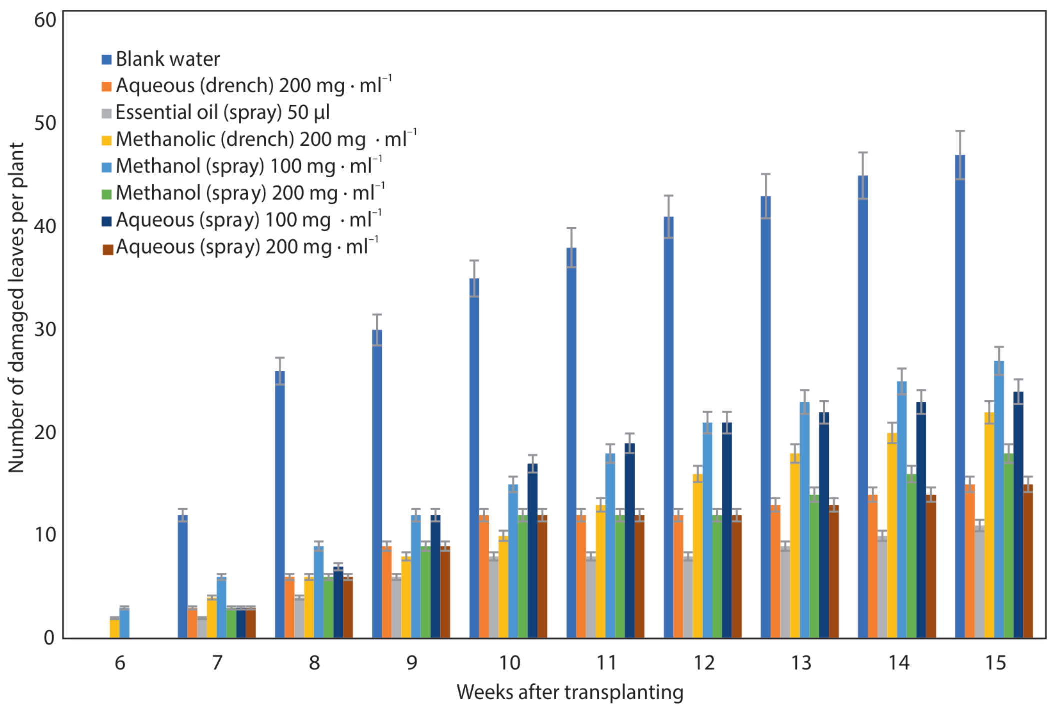

Fig. 3. Leaf damage in Roma VF tomato in response to *Lantana camara* extracts

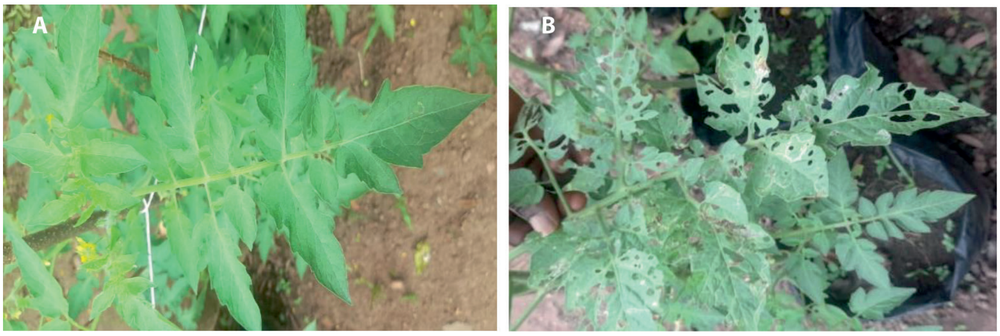

Fig. 4. Roma Vf tomato leaves from the EO-treated – A, and control plants – B

(Fig. 3). The EO treatment resulted in the fewest damaged leaves (0–5%).

Fruit damage

Figure 5 shows the progression of fruit damage over time. The control group had the highest percentage of damaged fruits (34.5%), followed by the methanolic drench treatment (18.7%). The control plot exhibited severe disease occurrence. The EO and aqueous drench treatment recorded the lowest percentage of damaged fruits at 3.2% and 5.6%, respectively. Some of the damaged fruits were attacked by rodents in the experimental plot, which affected the fruit yield. The DMRT analysis indicated that the control and aqueous drench treatment produced the highest percentage of damaged fruits, while the EO treatment produced the lowest percentage of damaged fruits. There was a significant difference ($p < 0.05$) between the EO and all other treatments applied.

Fruit yield

The EO treatment was the first to produce ripe fruit, and fruit weight was recorded immediately upon observing ripening. Tomato fruit yield is a polygenic trait influenced by a variety of internal and external factors throughout the crop growth cycle, and reflects the integration of growth, morphological, biochemical, and physiological characteristics. At 10 WAT, significant variations were observed in tomato fruit yield among *L. camara* leaf extract treatments (Fig. 6). EO applications resulted in significantly ($p < 0.05$) higher fruit yield (1821 g) compared to all other treatments. The effects of aqueous drench, aqueous spray, and methanolic spray were not significantly different. In contrast, both the control and methanolic drench resulted in the lowest fruit yields. The plants in the control treatment provided the lowest yield of tomato fruits (512.5 g), primarily due to the severe disease symptoms observed in untreated plants. The mechanism of

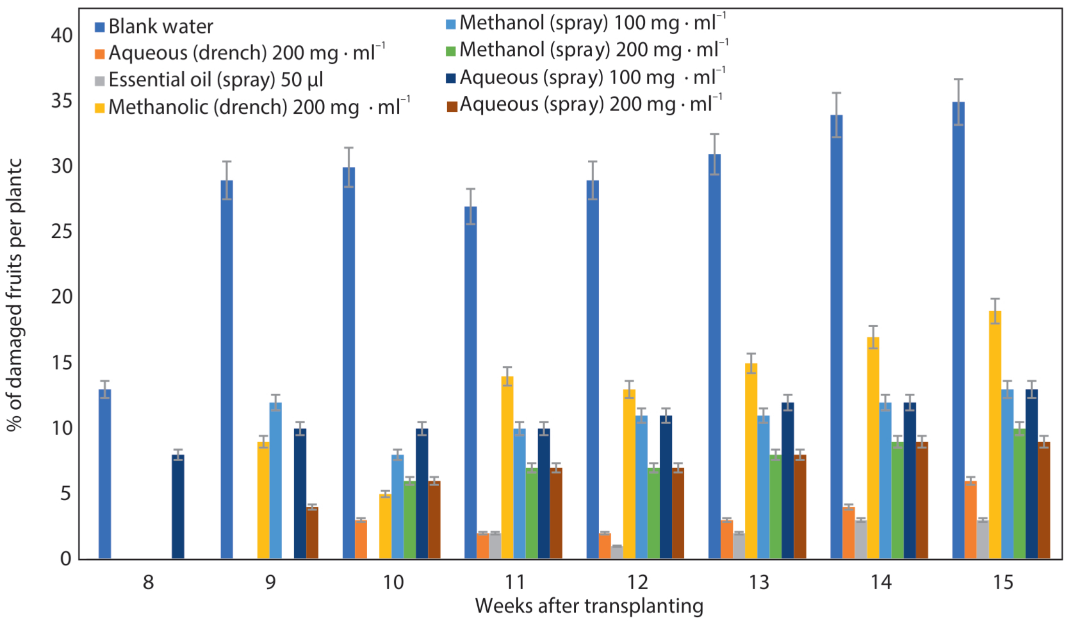

Fig. 5. Percentage of damaged fruit in Roma VF tomato in response to Lantana camara extracts

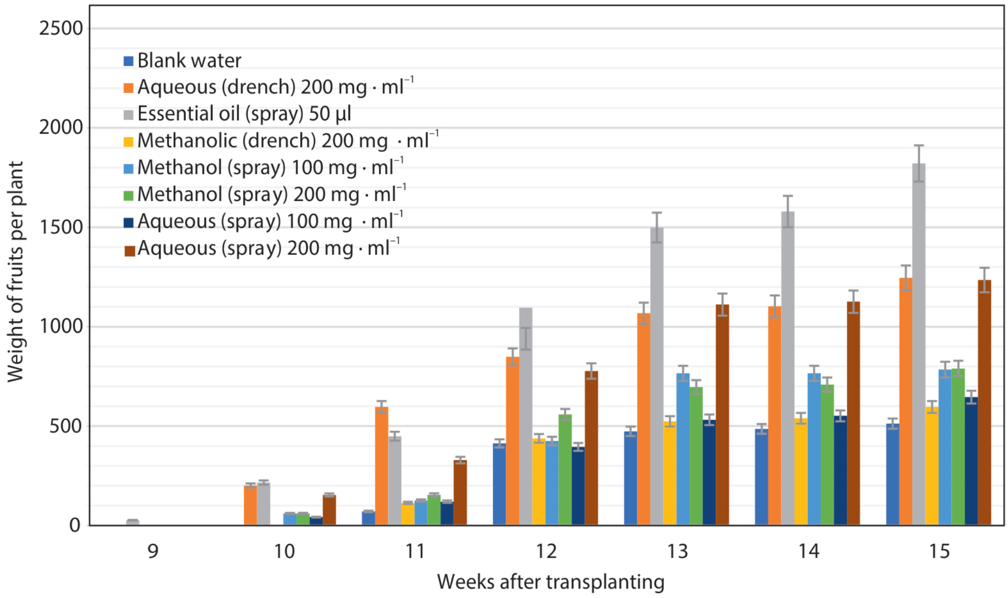

Fig. 6. Fruit yield in Roma VF tomato in response to *Lantana camara* extracts

the EO may exhibit cytoprotective properties that help maintain plant health. During the period from 12 to 15 WAT, the application of EOs produced significantly increased fruit weight ($p < 0.05$) compared to aqueous drench and all other extract treatments tested.

Discussion

Plant growth (leaves and flower production)

The higher leaves and flower production observed in the EO treatment group may be attributed to the bioactive components present in the oil, such as terpenoids and phenolics, which are known to stimulate plant physiological processes, including growth and development. Specifically, the GC-MS analysis of *L. camara* leaf EO by Sotade *et al.* (2023) revealed that the most abundant compounds include eucalyptol (35.45%), isolongifolen-9-one (12.55%), caryophyllene (10.33%), and β-pinene (7.56%). These compounds are reported to possess antioxidant and antimicrobial properties, which may have improved overall physiological efficiency, contributing to enhanced leaf production and flowering. Although the EO treatment was applied less frequently (once weekly), its higher concentration and chemical composition likely resulted in more effective stimulation of plant metabolic and hormonal pathways compared to the aqueous and methanolic extracts, which were applied more frequently (three times weekly).

In a study reported by Abo-Elyousr *et al.* (2014), it was observed that in the experiments carried out under field conditions, EOs of thyme and peppermint significantly reduced disease incidence while increasing yield (as reflected by enhanced flowering), thereby providing additional support for the use of plant-derived products in integrated disease and growth management strategies. These findings are consistent with our results, where the use of EO treatment also enhanced flower production in tomato plants. According to (Nahak and Sahu 2015), neem extract increased shoot height, number of branches, number of leaves, number of buds, number of flowers and number of fruits of tomato plants compared to different treatments. This finding supports our results, indicating that plant-based biopesticides may exert both protective and stimulatory effects on crop physiology.

Damaged leaves

The disease rating scale was used to assess leaf spots on tomatoes and determine the severity of leaf damage. Statistical analysis using Duncan's Multiple Range Test (DMRT) at $p < 0.05$ revealed no significant difference between the EO and aqueous drench treatments for the number of damaged leaves. The DMRT grouped these two treatments under the same subset, indicating statistical similarity throughout the weeks data were collected.

The EO and aqueous drench treatment effectively protected leaves from severe damage, making them less palatable to insects. We concluded that by minimizing leaf surface area loss from pest damage, photosynthesis activity remained at adequate levels, allowing for greater light interception and gas exchange processes, which resulted in better growth and higher fruit yield. Beyond commonly reported symptoms such as leaf curling, chlorosis, and perforation, mines and holes were observed on the leaves, which are characteristic signs of insect activity, particularly from *Tuta absoluta* caterpillars and other leaf-feeding pests (Zhu *et al.* 2025). The mines indicate larval feeding within the leaf tissue, while perforations are consistent with chewing damage caused by caterpillars or beetles. These observations suggest that insect pests significantly contributed to the foliar damage of the tomato plants. Although the specific severity of Figure 4 shows Roma VF tomato leaves from the EO-treated and control plants. *Tuta absoluta* infestation was not quantitatively recorded, its characteristic feeding pattern was visually confirmed in the control group, consistent with similar patterns reported in infested tomato fields. Figure 4 clearly shows extensive perforations and possible mining activity. The damage reduces photosynthetic capacity, weakens plant vigour, and increases vulnerability to secondary infections.

This protective effect is likely due to the presence of potent insecticidal compounds in the EO of *L. camara*, particularly monoterpenes like eucalyptol and sesquiterpenes like β-caryophyllene. These compounds have been reported to interfere with insect nervous systems, inhibit acetylcholinesterase, and act as antifeedants, thereby reducing foliar pest pressure (Kumar *et al.* 2024). Additionally, these phytochemicals can enhance plant resilience by limiting pest-induced oxidative stress and improving plant defence.

Fruit damage

In this study, the EO treatment resulted in the lowest fruit damage (3.4%), while the control group exhibited the highest damage (27.9%). The aqueous drench treatment also showed good efficacy with 6.7% fruit damage. Beyond these quantitative measures, qualitative analysis of fruit damage severity revealed that fruits in the control group frequently displayed deep lesions and rotting symptoms, whereas damage in treated groups, especially EO, was mostly limited to superficial blemishes or absent entirely. DMRT results confirmed that EO and aqueous drench treatments belonged to statistically distinct groups from the control ($p < 0.05$), indicating a significant reduction in fruit damage severity. While rodent activity was observed across all treatments, it did not significantly affect fruit damage data for the EO treatment. This is because most of the fruits in this treatment group appeared to be unattractive to both pests and rodents, likely due to the volatile compounds present in the EO. In contrast, fruits from the control treatment were more susceptible to both insect and rodent attacks.

Nashwa and Abo-Elyou (2012) reported that the greatest decrease in the severity of early blight disease in tomatoes was achieved by the application of *Allium sativum* and *Datura stramonium* leaf extracts, which also resulted in increased yields by 66.7% and 76.2%, respectively. In a related study, Hassanein *et al.* (2008) demonstrated that spraying tomato plants with 20% aqueous neem leaf extracts reduced disease incidence from 100% to 42.54%, while combined foliar and irrigation further reduced it to 39.49%. These findings support our result, where treatments with natural plant-based products, particularly EO and aqueous extracts of *L. camara*, significantly reduced fruit damage and improved fruit yield in tomato plants under field conditions. The efficacy of the EO treatment in our study may be attributed to the synergistic insecticidal, antimicrobial, and deterrent properties of its major components, such as eucalyptol and β-caryophyllene, which were identified in *L. camara* leaves (Sotade *et al.* 2023). These phytochemicals have been shown to repel pests effectively and inhibit fungal growth, ultimately preserving fruit quality and integrity.

Fruit yield

In the current study, the EO treatment resulted in a fruit yield of 1821 g, which was approximately 3.6 times higher than the control (512.5 g), significantly surpassing other treatments, whose yields ranged between 740 g and 1245 g. Increased fruit size observed in the EO treatment contributed substantially to this yield advantage. While EO components such as eucalyptol and β-caryophyllene likely possessed cytoprotective and growth-promoting properties, other factors may have also contributed to the enhanced fruit yield. These included improved pest suppression, lower foliar and fruit damage, and overall healthier plant physiology observed in EO-treated plants.

According to Nashwa and Abo-Elyou (2012), *Datura stramonium* and *Allium sativum* extracts applied at 5% concentrations improved tomato fruit yield by 76.2% and 66.7%, respectively, compared to the infected control. Araya *et al.* (2018) reported that *Ricinus communis* oil extract achieved 80% mortality of *Tuta absoluta*, reducing tomato fruit infestation to 29% and producing yields of 41.67 tonnes · ha^{-1}. *Azadirachta indica* leaf extract resulted in 63% mortality, 34.5% infestation, and 40 tonnes · ha^{-1} yield, outperforming the control. A previous study indicated that *L. camara* leaf extracts and EOs exhibit growth-promoting properties that could enhance the yield of environmentally friendly tomato fruits in Nigeria (Sotade *et al.* 2022).

Conclusions

This study investigated the possibilities of controlling pests and diseases of tomatoes by using EOs and aqueous extracts of *L. camara* leaves and their possible application in field experiments. One of the objectives of this study was to determine the biocidal potential of different treatments of *L. camara* extracts for pest and disease control in tomato production. The results showed that *L. camara* extracts and EO effectively controlled the pests and diseases of tomatoes. The application of EO treatment demonstrated the highest efficacy in the protection of tomato plants, leading to a significantly greater fruit yield of 1821 g compared to all other treatments, including the control group, which yielded only 512.5 g. Our data demonstrated that EO application and soil drenching of aqueous extracts of *L. camara* significantly improved growth parameters and fruit yield of tomato plants. These findings indicate that *L. camara* leaf EOs and aqueous extracts can promote increased fruit production and also be employed to formulate biopesticides, which can be used to control pests and diseases in tomato cultivation. Furthermore, these extracts show potential as a biostimulant application in organic tomato production.

Further studies are recommended to evaluate the long-term effectiveness, environmental safety, and cost-efficiency of these treatments under diverse agroecological zones. Future research should also consider the response of other tomato cultivars, explore possible synergistic effects with other plant-based biopesticides, and optimise application dosage and frequency. Comprehensive dose-response studies with varying EO concentrations of *L. camara* along with varying application frequencies are needed to determine the optimal conditions for maximizing fruit yield and efficacy. Such investigations will help validate the broader applicability and scalability of *L. camara*-based biopesticides in sustainable tomato production systems.

Abbreviations

EO	Essential oil
L. camara	*Lantana camara*
Rpm	Revolutions Per Minute
WAT	Weeks after transplanting
DMRT	Duncan's Multiple Range Test
ANOVA	Analysis of variance
GC-MS	Gas chromatography-mass spectrometry

References

Abdul I.M., Ahmed K.Y., Badamasi S. 2020. Review of the problems of tomato value chain in Nigeria: remedial option. International Journal of Agriculture, Forestry and Fisheries 8 (3): 90–95.

Abo-Elyousr K.A.M., Seleim M.A.A., Abd-El-Moneem K.M.H. 2014. Integrated effect of glomus mosseae and selected plant oils on the control of bacterial wilt disease of tomato. Crop Protection 66: 67–71. DOI: https://doi.org/10.1016/j.cropro.2014.07.022

Araya A. Abraha G., Ibrahim F., Tarekegn Y. 2018. Effectiveness of phyto-pesticidal extracts against the emerging tomato leaf miner in northern ethiopia. Journal of Hill Agriculture 9 (1): 94. DOI: http://doi.org/10.5958/2230-7338.2018.00017.4

Bashir S., Jabeen K., Iqbal S., Javed S., Naeem A. 2019. *Lantana camara*: phytochemical analysis and antifungal prospective. Planta Daninha 37: 1–7. DOI: https://doi.org/10.1590/S0100-83582019370100137

Bassolé I.H.N., Juliani H.R. 2012. Essential oils in combination and their antimicrobial properties. Molecules 17 (4): 3989–4006. DOI: https://doi.org/10.3390/molecules17043989

Bowers J.H., Locke J.C. 2004. Effect of formulated plant extracts and oils on population density of *Phytophthora nicotianae* in soil and control of *Phytophthora blight* in the greenhouse. Plant Disease 8 (1): 11–16. DOI: https://doi.org/10.1094/PDIS.2004.88.1.11

Gondal A.S., Ijaz M., Riaz K., Khan A. 2012. Effect of different doses of fungicide (mancozeb) against alternaria leaf blight of tomato in tunnel. Journal of Plant Pathology and Microbiology 03 (03): 125–131. DOI: http://doi.org/10.4172/2157-7471.1000125

Hassanein N.M., Abou Zeid M.A., Youssef K.A., Mahmoud D.A. 2008. Efficacy of leaf extracts of neem (azadirachta indica) and chinaberry (melia azedrach) against early blight and wilt diseases of tomato. Australian Journal of Basic and Applied Sciences 2 (3): 763–772.

Hendricks K.E., Christman M.C., Roberts P.D. 2020. The effect of weather and location of fruit within the tree on the incidence and severity of citrus black spot on fruit. Scientific Reports 10 (1): 1389–1400. DOI: https://doi.org/10.1038/s41598-020-58188-z

Hussein N., Hussein M., Gadel Hak S., Shaalan H., Hammad M. 2015. Effect of two plant extracts and four aromatic oils on *Tuta absoluta* population and productivity of tomato cultivar Gold Stone. Journal of Plant Protection and Pathology 6 (6): 969–985. DOI: http://doi.org/10.21608/jppp.2015.74529

Kagale S., Marimuthu T., Thayumanavan B., Nandakumar R., Samiyappan R. 2004. Antimicrobial activity and induction of systemic resistance in rice by leaf extract of datura metel against *Rhizoctonia solani* and *Xanthomonas oryzae* pv. *oryzae*. Physiological and Molecular Plant Pathology 65 (2): 91–100. DOI:m https://doi.org/10.1016/j.pmpp.2004.11.008

Kumar R., Guleria N., Deeksha M.G., Kumari N., Kumar R., Jha A. K., Parmar N., Ganguly P., de Aguiar Andrade E.H., Ferreira O.O., de Oliveira M.S., and Chandini. 2024. From an invasive weed to an insecticidal agent: exploring the potential of lantana camara in insect management strategies – a review. International Journal of Molecular Sciences 25 (23): 12788. DOI: https://doi.org/10.3390/ijms252312788

Nahak G., Sahu R.K. 2015. Biopesticidal effect of leaf extract of neem (azadirachta indica a. juss) on growth parameters and diseases of tomato. Journal of Applied and Natural Science 7 (1): 482–488. DOI: https://doi.org/10.31018/jans.v7i1.636

Nashwa S.M.A.. Abo-Elyou K.A.M. 2012. Evaluation of various plant extracts against the early blight disease of tomato plants under greenhouse and field conditions. Plant Protection Science 48 (2): 74–79. DOI: https://doi.org/10.17221/14/2011-PPS

Nea F., Tanoh E.A., Wognin E.L., Kemene K.T., Genva M., Saive M., Tonzibo Z.F., Fauconnier M. L. 2019. A new chemotype of *Lantana rhodesiensis* moldenke essential oil from Côte D'ivoire: chemical composition and biological activities. Industrial Crops and Products 141 (1): 111766. DOI: https://doi.org/10.1016/j.indcrop.2019.111766

Nowicki M., Kozik E.U., Foolad M.R. 2013. Late Blight of Tomato in Translational Genomics for Crop Breeding: Biotic

Stress. p. 241–265. Volume 1. Wiley Online Library. DOI: https://doi.org/10.1002/9781118728475.ch13

Pharmacopoeia. 1988. British Pharmacopoeia.

Regnier T., Combrinck S., Du Plooy W. 2012. Essential oils and other plant extracts as food preservatives in progress in food preservation. Wiley-Blackwell: 539–579. DOI: https://doi.org/10.1002/9781119962045.ch26

Singh V.K., Singh A.K., Kumar, A. 2017. Disease management of tomato through pgpb: current trends and future perspective. 3 Biotech 7 (1): 255–265. DOI: https://doi.org/10.1007/s13205-017-0896-1

Solórzano-Santos F., Miranda-Novales M.G. 2012. Essential oils from aromatic herbs as antimicrobial agents. Current Opinion in Biotechnology 2(2): 136–141. DOI: https://doi.org/10.1016/j.copbio.2011.08.005

Sotade A.A., Aiyelaagbe O.O., Aduramigba-Modupe A.O., Akinbuluma M.D., Aiyelaagbe I. O. O. 2022. Growth and yield response of tomato (solanum lycopersicum l.) to leaf extracts of *Lantana camara* l. African Journal of Organic Agriculture and Ecology 6: 41–47.

Sotade A.A., Ajiboye, C.O., Aiyelaagbe, O.O. 2023. Composition, antioxidant and antimicrobial activities of volatile oils from *Lantana camara* linn. ASRIC Journal on Natural Sciences 3 (1): 125–31

Zhu P., Zhang Y., Deng M., Zhang Y., Luo J., Han R., Xu L. 2025. Microplastics and nanoplastics alter the physicochemical properties of willow trees and lead to mortality in leaf beetle larvae. Plant, Cell & Environment 48 (5): 2895–2909. DOI: http://dx.doi.org/10.1111/pce.15317