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Assesing the Efficacy of Tobacco and Chili-Based Biopesticide Against Tuta Absoluta and Their Influence on Tomato Growth and Yield Performance

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Abstract

The continuous reliance on chemical insecticides for controlling tomato pests has led to concerns regarding pesticide resistance, environmental pollution, and human health risks due to chemical residues. This study aimed to assess the efficacy of tobacco and chili-based biopesticide against tuta absoluta and their influence on tomato growth and yield performance. The experiment used a randomized complete block design (RCBD) with five treatments: control (T1), chili extract (T2), tobacco extract (T3), synthetic pesticide (T4), and a tobacco-chili mixture (T5), each replicated three times across three blocks. Results revealed that both tobacco and chili extracts significantly reduced pest damage compared to the control group, with lower leaf

damage severity scores. However, these treatments did not outperform synthetic pesticides in terms of plant growth, with the pesticide treatment showing the highest plant height (124 cm) and fruit weight (620 g). The combination of tobacco and chili showed a potential synergistic effect, resulting in the least damage in some plots. While tobacco and chili extracts demonstrated pest control potential, further research is necessary to optimize their application and ensure their effectiveness in integrated pest management strategies, as their growth-promoting effects were not as strong as synthetic pesticides. The findings highlight the need for more sustainable pest control methods in agriculture.

Keywords: Tobacco Extract, Chili Extract, Tuta Absoluta, Sustainable Agriculture Synthetic Pesticide, Natural Pest Control, Environmental Sustainability

Introduction

Tomato is scientifically called *Solanum lycopersicon* belonging to a Solanaceae family also known as the nightshade family, (Gasparini *et al.*, 2024) ^[12]. This family consist of vegetables like potato, eggplant, bell pepper and chili pepper. The tomato fruit is egg-shaped with an attractive skin, (Tamakloe and Vincent, 2023). Global tomato production is estimated at more than 171million tons from an area of five million hectares of arable land, with the main producers being China, USA, Turkey, Egypt and India (Suleiman *et al.*, 2024) ^[30]. Trend analysis conducted in 2014 and 2017 shows that Egypt remains the leading tomato producer in Africa, followed by Nigeria in second place. Africa contributes 11.8% to the total global tomato production (Ivan *et al.*, 2023) ^[14]. According to (Syed *et al.*, 2024), tomatoes are one of the most important vegetable crops grown worldwide and are second to potatoes in terms of acreage, but top in terms of processed crops, as stated by (Bhatkar *et al.*, 2021) ^[4], it is nutrient-rich and contains essential vitamins and minerals that are beneficial to human health. The expansion of the tomato cultivation area and the increase in consumption levels have led to greater demands from consumers for higher quality, nutritional content, and taste in tomatoes. However, increased diseases and insects, as well as poor soil quality, result in reduced tomato production, (Gatahi, 2020) ^[13].

Tomatoes are vulnerable to a large number of insect pests from the time the plants first emerge in the seedbed until harvest, (Roberts *et al.*, 2023) ^[25]. All parts of the plant provide food, shelter, and breeding grounds for insects. Therefore, all parts of the plant, that is; leaves, stems, flowers and fruits, can be susceptible to attack, (Gatahi, 2020) ^[13]. Tomato fruit borers, aphids, stink bugs, tomato leaf borers, leaf-footed stinkbugs, hornworms, silver leaf worms, and whiteflies mainly attack tomatoes.

Among these invasive pests of tomato, *Tuta Absoluta* is the major concern for tomato production. It infests young plants by borrowing into the buds and stems. As the plant grows, larvae mines the leaves and reduce the plant's ability to photosynthesize.

In the northwestern China in 2017, *Tuta absoluta* emerged after which it rapidly spread to more than 150 counties in 10 provinces by 2021 (Zhang *et al.*, 2020). It established itself as the most invasive species, which led to serious crop damage, yield losses, and compromised tomato production in those regions, (Wang *et al.*, 2021).

The mid hills of Nepal, tomatoes were threatened by various pest among them include *Tuta absoluta*. It affected the tomato quality because it bore through fruit thereby, reducing both quality and quantity, (Upreti *et al.*, 2020). Field survey also articulated that farmers have been using different preventive measures like insecticides and various cultural methods to protect the tomatoes from damage, despite none of them shown significant solution of the problem, (Iamsal, *et al.*, 2018) [17].

In the Eastern region of Africa, tomato production is vital as it drives a sustainable livelihood and food security especially for small-scale farmers, (Ddamulira *et al.*, 2021) [9]. Tomato production in Kenya accounts for about 14% of the total vegetable production, while in Ethiopia, Tanzania, Sudan and Uganda it provides 40% to rural livelihood, (Kathimba *et al.*, 2021). However, the invasion and wide spread impacts of *Tuta Absoluta* has constrained tomato production in the region, (Pascal *et al.*, 2019) [23]. For instance, about 98% of the farmers in Kenya highlighted several problems of *Tuta Absoluta* and the average seasonal loss was estimated at 114,000 tones, (Pascal *et al.*, 2019) [23]. In Zambia, both commercial and small -scale farmer grow tomatoes for home consumption, fresh market, export and processing. The yield of tomato were low in 2018 about 5 tons per hectare and these low yield were contributed by both abiotic and biotic factors, among the biotic factor *Tuta Absoluta* was inclusive, (Charlse *et al.*, 2022) [7]. The tomato farmers lost 57% of their produce to *Tuta Absoluta* and spent US\$9.4/Ha on pesticides per household (Ivan *et al.*, 2023) [14]. In cases where the chemicals are used, chemicals are expensive and hazardous to the environment, while in the absence of any control measure put in place, 100 % of crop damage can be recorded. (Ivan *et al.*, 2023) [14].

The economic impact of *Tuta absoluta* is far-reaching, resulting in significantly global expenditures for the control and mitigation measures aimed at minimizing crop losses, (Vivekanandhan *et al.*, 2024). For instance, Turkey's outlay on *Tuta absoluta* amounts to \$183.7 million USD annually on *Tuta absoluta* control, While Nepal reported crop losses totaling \$19.7 million in the first year of the invasion (Acharya *et al.*, 2023) [1]. These losses have significant socio-economic implications, including a notable 32% increase in tomato prices, which exacerbates food insecurity and places a significant burden on households and the economy, (Vivekanandhan *et al.*, 2024).

The main method for managing *Tuta Absoluta* is the application of synthetic insecticides, (Roberts *et al.*, 2023) [25]. Cartap and Abametin are some of the synthetic insecticides used in tomato fields that have developed resistance, (Maureen *et al.*, 2023) [19]. However, the escalated usage of insecticides for the management of *Tuta Absoluta* has consequently lead to resistance and target site

insensitivity to different classes of insecticides such as organophosphates, carbamates, synthetic pyrethroids, (Maureen *et al.*, 2023) [19]. Synthetic insecticides harm beneficial arthropods by both sub-lethal and direct acute toxicity. Overuse of pesticides against arthropods can have unpredictably high and low yields as well as short- and long-term consequences, (Khan *et al.*, 2023) [16].

Currently, there is a growing global interest in the utilization of biopesticides as a more safer and sustainable approach to pest management, due to their eco-compatible nature and reduced likelihood of resistance, (Chakraborty *et al.*, 2023) [6]. Many studies have demonstrated that entopathogenic fungi are effective in controlling populations of *Tuta Absoluta*, with notable examples including *Beauveria bassiana* and *Metarhizium anisopliae* (Mohamed *et al.*, 2021). Similarly, botanical biopesticides such as *Azadirachtin indica* (Neem), *B. bassiana* (Bio-power), *M. anisopliae* (Biomagic) and *V. lecanii* (Bio-catch) have demonstrated considerable potential for the management and control of *Tuta Absoluta* populations, (Mazimba *et al.*, 2022) [10].

In view of the potential management of *Tuta Absoluta* by biopesticides, the current study evaluated the effectiveness of tobacco and Chili on *Tuta Absoluta* in tomato.

Problem Statement

Zambia recorded 57% tomato loses to *Tuta absoluta* with a mean seasonal production loss of 10,700 tones equivalent to US \$ 8.7 million, (Ivan *et al.*, 2023) [14]. It posed a great threat to the Zambian tomato industry, as tomato is one of most important vegetable crops that accounts 86% of the total value of fresh fruits and vegetables sales within the smallholder sector. Zambia's Plant Quarantine and Phytosanitary Services (PQPS) initiated a detection surveillance of the pest reported in some areas and established Phytosanitary import conditions for tomato confirmation and drafted the legislation to regulate movement of tomatoes, (MS *et al.*, 2019). The main method for managing *T. absoluta* is the application of synthetic insecticides like Cartap, Abametin, and some other alternative management strategies for instance, cultural and biological methods, (Roberts *et al.*, 2023) [25]. These management strategies are not 100% effective and due to escalated usage of insecticides for the management of *Tuta absoluta*, some chemicals have developed resistances over the years, (Maureen *et al.*, 2023) [19]. Additionally, chemical insecticides cause adverse environmental effects including water pollution, eradication of beneficial wildlife and human health problems due to chemical residues in food (Ali *et al.*, 2021). Pesticides can contaminate surface and groundwater through runoff, leaching, drift or direct use. Pesticides and their residues go to water sources over large geographic areas, posing risks to drinking water supplies and aquatic ecosystems, (Myungheon *et al.*, 2024) [22]. Pesticides can affect the nervous system, skin or eye irritation, cause cancer, or disrupt the endocrine system, (Garud *et al.*, 2024) [11]. Exposure to synthetic pesticides can cause acute or chronic effects, depending on the dose, duration and frequency of exposure as well as individual sensitivity and health status, (Kanyika *et al.*, 2025). It is against this background that the researcher embarked to find more safe and sustainable methods to eradicate tomato insect pest.

Research objectives

Main objectives

To assess the efficacy of tobacco and chili-based biopesticide against *Tuta absoluta* and their influence on tomato growth and yield performance.

Specific objectives

1. To determine the effects of tobacco and chili –based pest management on tomato growth (plant height, leaf area, fruit weight, number of fruits).
2. To determine the severity of damage of chili-based biopesticide against *Tuta absoluta* on tomato.
3. To determine the severity of damage of tobacco-based biopesticide against *Tuta absoluta* on tomato.
4. To compare the efficacy of tobacco and chili-based biopesticide against *Tuta absoluta* and on tomato.

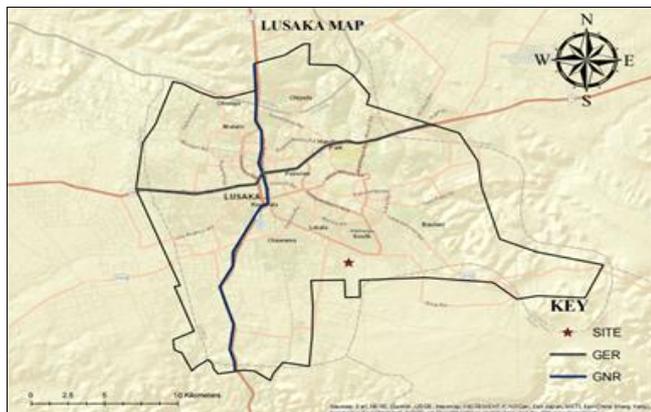
Hypothesis

H₀: Tobacco and chili-based biopesticide against *Tuta absoluta* has influence on tomato growth and yield performance.

H_{alt}: Tobacco and chili-based biopesticide against *Tuta absoluta* does not have influence on tomato growth and yield performance.

Experimental site

The study was carried out in agro ecological zone II in Lusaka – jack compound, at information and communications university demo – plot located at latitude -10.1732000° S and longitude 31.3694200° E, elevation above sea level: 1382 m = 4534 ft. High rainfall and warm temperatures characterize the climate of this zone. Annual average rainfall ranges from 900 -1000mm with warm temperature ranging from 22.4°C to 34°C. Soil types range from slightly acidic to alkaline, soil texture is sandy loam.



Source: Researcher, 2025

Fig 2: Map showing research site

Experimental material

The study utilized Tengru tomato seeds, and compound D fertilizer, snow beast (synthetic pesticide) from Lusaka agro junction. The researcher obtained tobacco and chili from local framers.

Experimental design

The experiment followed a randomized complete block design with five treatments each replicated three times in three blocks except for the control treatment. Treatment one (T1) control, treatment two (T2) was sprayed with chili

extract, treatment three (T3) tobacco extract, treatment four (T4) synthetic pesticide, treatment five (T5) tobacco and chili mixture.

Land preparation

It takes careful planning and execution to prepare the soil for tomato growing in order to produce the ideal conditions for root development, seed germination, and overall plant growth. Using a hoe, machete, and rake, we first cleared the study site of plant debris, weeds, and residue from prior crops to prepare the planting surface. To increase aeration, break up compacted soil layers, and facilitate root penetration, we employed a hoe. In order to enrich the soil and supply the nutrients required for tomato growth, chicken manure was added. To guarantee even water distribution and lessen runoff, we then used a rake to level the soil. To create a nursery, we prepared a flat seedbed and dug furrows that were 0.5 cm deep and 5 cm apart.

Nursery establishment

The researcher used a rake and a machete to clear the seedbed. A flatbed was made by tilling the land and building up the sides to improve soil drainage. Seeds were sown into furrows that were 0.5 cm deep and 5 cm apart on 6 March 2024. To shield the seeds from birds and sunlight, we mulched with leftovers from fresh maize stalks. We used a watering can to irrigate the nursery bed every two days. A week before being transplanted, the seedlings were hardened off.

Transplanting

The main experimental field was first demarcated into three plots, each separated from the next by a 2 m buffer zone to minimize any treatment overlap or edge-effects between plots. Within each plot, twenty flat beds were established, with each bed separated from the next by a 1 m pathway to facilitate access, movement and management without trampling adjacent plants. On 2 May, the seedlings were ere transplanted into the main field. Within each bed, plants were spaced at 30 cm apart (center-to-center) to ensure adequate inter-plant distance for growth, light interception and air circulation. The rows within each bed were aligned such that uniform spacing was maintained and each bed held the same number of plants. The transplanting was carried out carefully to minimize root disturbance seedlings were lifted from the nursery beds with a trowel, planted at the same depth they had in the nursery, firmed in and watered immediately after transplanting. After transplanting, beds were labelled according to treatment.

Fertilization

Fertilization was carried out three times using a compound mineral fertilizer formulated as NPK (15:9:20 + micro-elements), with each dose applied at a rate of 4 g per plant. The first dose was administered one week after transplanting, followed by the second two weeks after transplanting, and the third at the flowering stage of the tomato plants. This schedule aligns with the crop's shifting nutrient needs from early vegetative growth through to reproductive development. In addition, an organic amendment of chicken manure at 3 kg per meter bed and a supplementary application of "compound D" were applied one month after transplanting, once the plants had become established in the field.

Staking and pruning

To support the tomato plants, we positioned wooden poles in each bed. In order to keep the tomatoes from leaning on nearby plants, which could cause competition for sunlight and encourage the growth of pathogens, we tied them horizontally to the poles every 20 cm as they grew. To keep the plants healthy and in shape, we cut them with sharp scissors.

Weeding

The researcher removed weeds manually between the planting rows using a hoe, which helped to break up weed competition and improve access for harvesting and pest management. To further suppress weed germination and maintain soil health, the researcher then covered the soil surface between the rows with a layer of grass mulch. This mulch acted to block light from reaching emerging weed seeds and seedlings, conserve soil moisture, moderate temperature fluctuations, and reduce soil splash on lower foliage all of which support healthier crop growth and reduced weed pressure.

Pest and disease management

The researcher regularly monitored the tomato crop for signs of pests and diseases by conducting systematic field checks, enabling early detection of problems. Based on each bed's assigned treatment, the researcher then applied the appropriate pesticides responsibly using the right product, dosage and timing to manage pest or disease pressure while minimizing non-target impacts and ensuring valid treatment comparisons.

Preparation of plant material

Preparation of tobacco extract

The researcher collected 1 kg of clean – dry, healthy tobacco leaves and soaked them in a bucket containing 2 liters of water overnight, allowing the active compounds from the leaves to leach into the solution. After the soaking period, the mixture was filtered through a fine strainer (or muslin cloth), thereby separating the leaf debris from the clear extract, which can then be used as a crude biopesticide base.

Preparation of chili extract

The researcher weighed 500 g of dried chili and placed the chili into a bucket. They then added 1 liters of water and left the mixture to soak overnight. After the soaking period, the researcher poured the liquid through a strainer to remove the solid chili particles and obtain a clear chili-infused extract for use as a biopesticide.

Preparation of the combined mixture of tobacco and chili

Weigh 500g of tobacco on scale; soak in 1liter of water in a bucket overnight. In the morning, Strain the tobacco water on a strainer, dilute the tobacco with 1liters of tap water. In a separate bucket add 500g of chili and add 1 liters of water then leave it soak overnight too. Afterwards, strain the chili using a strainer. Combine tobacco and chili filtrate in the same container. After the tomatoes establish in the main field, put the chili mixture in a knapsack at a ratio of 250ml/L of water sprayer and spray T2, after use we rinsed the sprayer with water and add tobacco extract dilute at a ratio of 250ml/L of water and spray T3. Clean the sprayer,

dilute snow beast (synthetic pesticides), at ratio of 2ml/L of water and spray in T4. In the same manner, clean the sprayer, add 250ml/L of water of chili-tobacco mixture, and spray T5. We sprayed once every week. Note that T1 was not sprayed with any chemical because it was a control treatment.

Sampling strategy

The researcher randomly selected five damaged leaves from each plant in each treatment and counted the number of damaged leaves per plant. The damage on each plant was then scored using the leaf damage scale from 1 to 9, following which the plants were rated based on the number of leaves damaged and the severity of the damage according to this scale.

Table 1: Showing the leaf damage scale

Number of leaves attacked	Percentage of the leaf area attacked
1	No damage or less than 5% of leaf area attacked
2	5% to 10% of leaf area attacked
3	10% to 20% of leaf area attacked
4	20% to 30% of leaf area attacked
5	30% to 40% of leaf area attacked
6	40% to 50% of leaf area attacked
7	50% to 60% of leaf area attacked
8	60% to 80% of leaf area attacked
9	More than 80% of leaf area attacked

Data collection

We used the experimental field trial data collection method and direct and indirect insect sampling technique. The plant height was measured using a measuring tape from the bottom to the tip of the tomato randomly in each treatment at different growth stages. The leaf area was measured by getting 1 largest leaves in each treatment, press dried and tracing it on a grid. The researcher recorded the number of leaves that were damaged by *Tuta absoluta* using agronomic disc scale.

The tomato plants' yield was evaluated based on the size, quantity, and quality of their fruits. Weighing the fruits in each treatment using an electronic scale enabled us to determine the weight of the fruits. By counting the number of fruits per plant in each treatment, the number of fruits in each treatment was determined. Following harvest, the tomato fruits were sorted to eliminate any rotten or damaged ones. The fruits that are in decent condition were marketable tomatoes, while the damaged and rotten ones were discard.

Data analysis

The data collected were analyzed using an analysis of variance (ANOVA) technique at a 5% level of significance ($\alpha = 0.05$), meaning that differences between treatments were considered statistically significant if the p-value was ≤ 0.05 . In addition to inferential testing, descriptive statistics (specifically the mean and standard deviation) were computed for each treatment group to summarize central tendency and variability of measurements. Moreover, the software Microsoft Excel was used both for calculating these descriptive statistics and for organizing/comparing treatment-means outputs from the ANOVA analysis, thereby facilitating interpretation of results across treatments.

Results and Discussion

Plant Height

Plant height data under different treatments of the experiment indicate variability due to tobacco and chili extracts. The synthetic pest control treatment grew the tallest plants (124 cm) in Plot 1, followed by those of tobacco (110 cm) and chili (110 cm). Tobacco and chili combination grew 117 cm tall plant. The greatest growth in Plot 2 was exhibited by the treatment of tobacco (122 cm) followed by synthetic pest control (117 cm) and control (118 cm). The control plants (125 cm) grew to be the tallest in Plot 3 followed by those of tobacco (121 cm) and chili (118 cm). The synthetic pest control treatment for Plot 3 made it grow to be the shortest (96 cm). From these results, the control treatment grew some of the tallest plants, especially in Plot 3, and exhibited variable responses to tobacco and chili although synthetic pest control treatments grew comparatively tall plants.

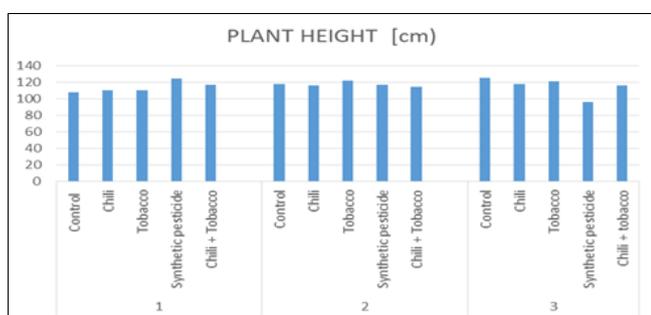


Fig 1: Plant height of tomato plants in the distinct treatment groups of the three replication

Number of Fruits

There is a significant difference in number of fruits produced by plants due to treatment was observed. The most number of fruits (44) were produced in synthetic-treated plants in Plot 1, whereas (35) fruits were produced in tobacco-treated plants. In Plot 2, most fruits (52) were produced in once-treated plants with tobacco, whereas (40) fruits were produced in synthetic pesticides-treated plants. The most number of fruits (49) were produced in synthetic pesticides in Plot 3, whereas (15) and (37) fruits were produced in treatment of tobacco and chili + tobacco, respectively. Control results were inconsistent, 25, 43, and 20 fruits being observed in each of these plots, respectively. Although results differed from one plot to another, these results clearly indicate those treatments in which tobacco and synthetic pesticides were included had a tendency to have increased production of fruits.

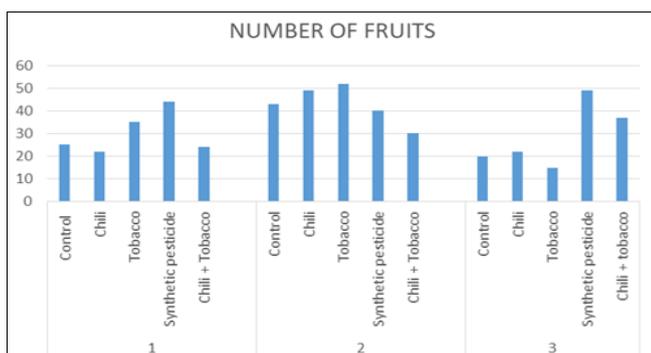


Fig 2: Number of fruits of tomato plants in the distinct treatment groups of the three replication

Sample fruit weight

The data on sample fruit weight of tomato under different treatment shows large variation across plots. In Plot 1, plants receiving treatment of tobacco had the highest mean sample fruit weight at 660 g, and chili treatment had 650 g. Synthetic pesticide treatment had 620 g, and chili + tobacco treatment had 645 g. In Plot 2, chili + tobacco treatment had the highest sample fruit weight at 695 g, and control plants had 765 g, synthetic pesticide treatment had 647 g, and tobacco and chili treatment had 630 g and 635 g, respectively. In Plot 3, synthetic pesticide treatment had fruits of highest weight at 600 g, followed by tobacco (525 g), chili (510 g), and chili + tobacco (567 g). The control treatment had 460 g fruits. These results suggest that, despite tobacco and chili treatment having relatively high weights in certain plots, synthetic pesticide generally had heavier fruits in certain cases. The heaviest obtained fruits (600 g) were those obtained by synthetic pesticide treatment in Plot 3, followed by 525 g obtained by tobacco, 510 g obtained by chili, and 567 g obtained by chili + tobacco. 460 g of fruits were obtained by control treatment. These data suggests that, based on these research results, synthetic pesticide commonly had heavier fruits in certain cases, but in other plots, tobacco and chili treatment had relatively high weights.

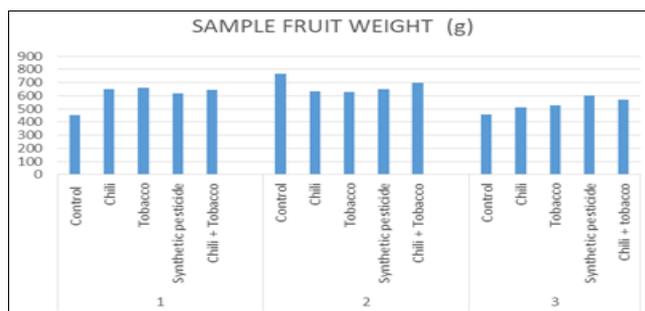


Fig 3: Sample fruit weight of tomato plants in the distinct treatment groups of the three replication

Leaf Area

There was significant variation in leaf area of tomato plants from various treatments. Control from Plot 1 had maximum leaf area (73.92 cm²) followed by the treatments with chili (41.53 cm²) and tobacco (49.35 cm²). Minimum leaf area was found in artificial pesticide-treated plants (33.6 cm²), and minimum leaf area was found in tobacco and chili combination-treated plants (32.48 cm²). Chili-treated plants were possessing broad leaves (65.03 cm²) in Plot 2, while the control was possessing respective broader leaf area (26.52 cm²). Leaf area of the tobacco-treated plants was 41.54 cm², of the synthetic pesticide-treated plants 43.92 cm², and of the plants treated with both chili and tobacco was 19.95 cm². Chili-treated plants in Plot 3 had leaves of size 42.56 cm², whereas control plants had leaves of size 31.2 cm². The plants treated with tobacco had diameter of 28 cm², the plants treated with synthetic pesticide had diameter of 46.2 cm², and those treated with chili and tobacco both had diameter of 33.93 cm². According to these results, tobacco treatment and synthetic pesticide treatment both had minimum leaf area, whereas control and chili treatment had maximum leaf area. Chili and tobacco treatment both exhibited uniformly minimum leaf area.

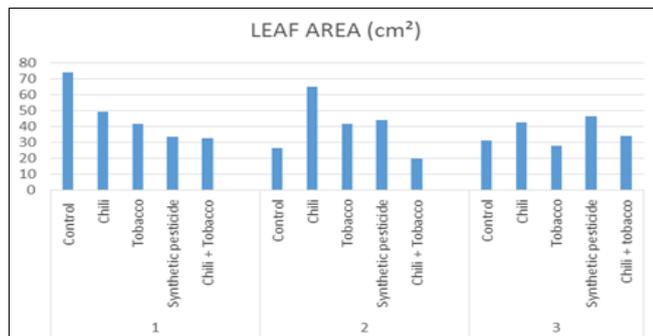


Fig 4: Leaf area of tomato plants in the distinct treatment groups of the three replication

Severity of leaf damage

The leaf damage caused by Tuta absoluta was rated on a 1-9 scale where 1 is no damage and 9 is maximum damage. Plot 1 control group showed maximum damage rating (6), followed by synthetic pesticide (3), tobacco (4), and chili (3). In addition, the chili + tobacco treatment was given a rating of 3. Tobacco, chili, and synthetic pesticide damage scores were all 4 for Plot 2, with the maximum damage being that of the control group (5). The lowest damage rating went to tobacco + chili. The control had the lowest damage rating in Plot 3 (four), highest in tobacco and chili treatments (five), and lowest in synthetic pesticide and chili + tobacco treatments (four and three, respectively). The control generally registered the greatest amount of damage at all times while tobacco and chili treatments, particularly when in combination, registered less damage.

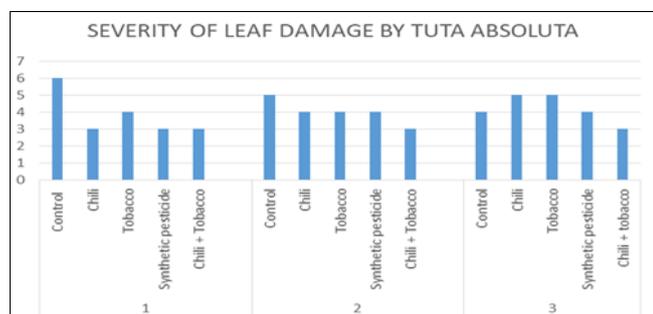


Fig 5: Severity of leaf damage caused by Tuta absoluta of tomato plants in the distinct treatment groups of the three replication

Analysis of variance

Treatment differences are exemplified in the total of 45 and mean of 3 of the treatment category. Low plot number variation is exemplified in the mean of 2 of the plot number category. Whereas 9-scale refers to further experimental grouping or classifying for analysis, the findings on plant height (mean of 115.47 cm), number of fruits (33.8 per plant), fruit weight (603.93 g), and leaf area (40.65 cm²) also reveal how the plants responded to treatment conditions. Variance values indicate highly diverse variance on fruit weight and leaf area, which implies that treatment would have highly changed these parameters. These impacts can have resulted from pest management or other treatment regimens, e.g., efficacy of chili and tobacco to suppress Tuta absoluta.

Table 2: Descriptive statistics summary

SUMMARY					
Groups	Count	Sum	Average	Variance	
TREATMENT	15	45	3	2.1428	
PLOTNUMBER	15	30	2	0.7142	
PLANTHEIGHT	15	1732	115.466667	53.69	
NUMBEROFF	15	507	33.8	145.88	
FRUITWEIGHTS	15	9059	603.933333	7556.4	
LEAFAREA(cm	15	609.73	40.6486667	204.48	
LEAFATTACK	15	60	4	0.8571	

The following is the ANOVA result of the analysis of variance on the effectiveness of the tobacco and chili treatments on Tuta absoluta study. There are two types of sources of variation, which are between groups and within groups. The sum of squares (SS) of the between-group variation is 4,332,163.83, significantly higher than that of the within-group variation (111,499.83). This indicates that the treatment groups are quite different from each other. "Between Groups" possesses six degrees of freedom (df), and "Within Groups" possesses 98. "Between Groups" possesses a mean square (MS) value of 722,027.30 and "Within Groups" possesses 1,137.75. Because the p-value is 4.58×10^{-77} , the F-ratio is 634.61 and this is very much greater than the critical value (F crit = 2.19). The low p-value is a guarantee that the treatments (chili and tobacco) significantly influenced the measured values and that the variations between groups are very statistically significant.

Discussion

Plant height is an indicator marker for the determination of commercial tomato yield potential and an essential marker of general plant health. Depending on the cultivar and growing conditions, commercially mature tomato plants average anywhere from 40 to 80 cm in height. This experiment's use of synthetic pesticides was appropriate to produce heights within or exceeding this commercially normal range, showing efficacy for optimizing plant height in highly controlled pest management. Yet, in the case of Plot 3 specifically, though, neither the chili nor the tobacco treatments were any more than or larger than the commercial benchmark for height, although some benefit did accrue, particularly through diminished pest damage. This disparity implies that further optimization would be necessary to provide reliability and efficacy of such natural products for agriculture, although they could be added to an integrated pest management scheme. Additional study is needed to better utilize their efficacy against pests and promotion of plant growth by establishing maximum application rates and synergism between tobacco and chili.

Plant height

Pest control efficacy and potential plant response to the treatments are accountable for treatment variations in plant height. Faster growth of the plants in the case of the synthetic pesticide could have been a result of decrease in Tuta absoluta infestation. Synthetic pesticides, through reduction of pest damage, can be instrumental in maximizing plant height, as revealed in previous studies, (Agbor *et al*, 2022)^[2]. This enables the plant to invest more

energy in growth than defense against insect pest. The chemical treatment with synthetic pesticide resulted in the shortest plant (96 cm) in Plot 3. Constrained growth under chemical treatment could have been caused by factors such as pesticides' toxicity or impact on plant physiology, (Zhang and Yang, 2024). The intricacy of pesticide activity is also evident in variation in plant height among plots, where side effects and efficacy could be influenced by application rates and environmental conditions. Tobacco and chili treatment impacts were not entirely in harmony in Plot 2 (122 cm), potentially by its ability to off-set pest stress. Tobacco was found to enhance the overall health and growth of plants by increasing the damage to various insect pests, (Cai *et al.*, 2018) [5]. Chili with capsaicin is a pest irritant and would reduce pressure from pests considerably but would affect plant growth less than tobacco. As seen by the 118-cm plant height in Plot 3, chili would have inflicted occasional mild stresses to the plants that would have resulted in moderate growth reactions in the plants. In addition, tobacco-chili association failed to significantly enhance plant height, suggesting that their action might not be synergistic and could result in phytotoxicity or nutrition deficiency, so suggested other research should study on how plants respond to mixed natural treatments.

Pesticidal action of chili and tobacco is due to the fact that tobacco has alkaloids and chili has capsaicinoids. The fairly high mean plant height of 115.47 cm shows that plant growth was not negatively impacted by the treatments at hand. This is supported by studies such as those done by Sankar and Sitaraman (2017) [26], in which it was found that natural pest control chemicals such as tobacco did not impact plant growth such as that of tomatoes. This is welcome news for plant-based pest controls as opposed to chemical pesticides, and this is welcome news for sustainable agriculture. Fruit weight and number of fruits per plant are good measures of the effectiveness of pest control.

The average fruit weight of 603.93 g and number of fruits per plant of 33.8 of this research can be interpreted as indicators of an effective well-balanced pest control program that supports plant growth and optimizes fruiting. Shrestha *et al.* (2016) state that the crops could be cultivated without damaging them by employing integrated pest management (IPM) techniques that entail combining natural repellents like tobacco and chili with other methods of applying insecticides. The variation in the weights of the fruits indicates that although the treatments overall were favorable, the impacts may have been affected by certain environmental or biological conditions. Further investigation can explore how soil or weather conditions affect such treatments in order to further optimize pest control activities. Leaf area is also a critical measure of plant health with a mean of 40.65 cm².

Greater leaf area is typically related to higher growth and photosynthesis. Since *Tuta absoluta* eats and destroys tomato leaves, leaf area variability values tell us that pest control was quite efficient (González *et al.*, 2019). More complex studies might be needed to identify the precise mechanisms, but relatively little leaf area variation between treatments can be proof of the consistent efficacy of tobacco and chili treatments against leaf cover. The efficacy of such treatments is also supported by the fact that the nine (9) scale utilized in analysis can be a severity scale or intensity of the infestation of the pests. Collectively, the results

establish the feasibility of sustainable control of the pests to stimulate the yield of the crops and offer a strong method to manage *Tuta absoluta* through the application of these natural therapies (Sreedharan *et al.*, 2020) [29]. The very low p-value of (4.58×10^{-76}) demonstrates statistically significant group differences, ascertaining that the tobacco and chili treatments actually significantly affected various plant growth and yield parameters. This is in alignment with results of research on other means of controlling pests. A study discovered, chili and tobacco treatments were highly suppressive of pest infestations but still conducive to plant health, meaning that they can be future non-synthetic drivers of pest control, (Zaytseva *et al.*, 2021).

Null hypothesis of no difference in the treatment groups is rejected at very high confidence as the F-ratio of 634.61 is far greater than the critical value of 2.19. It confirms the suspicion that the impacts of the tobacco and chili treatments on plant health and control of the pests were measurable. Between and Within Treatment Group Variability: The enormous sum of "Within Groups" squares (111,499.83) against "Between Groups" (4,332,163.83) tells us that the difference between the different treatment groups is much more than within any single group. This means that the treatments were indeed capable of causing different results. The relatively low "Within Groups" variance indicates that the plants in the same treatment group responded similarly to one another, which would also confirm the reliability of tobacco and chili's pest-repellent property. Yet, any other variable, normally not controlled in field experiments, like environmental conditions, plant genetic factors, or plot-specific factors, could be responsible for some variability.

Number of fruits

Variability of fruit yields is most probably a measure of the relative effectiveness of every treatment to prevent *Tuta absoluta* damage because of its special ability to detect and mitigate pest damage, the synthetic pesticide consistently recorded the highest yield of fruit, especially Plot 3, which outclassed all the other treatments by far. The tobacco treatment did, nonetheless, realize promising harvests, particularly in Plot 2, with the highest number of fruits. In such a case, tobacco would have also adequately assisted in reducing infestation by pests because it has nicotine, which can be used as an effective insecticide too. Nonetheless, comparatively to the use of tobacco alone, the chili + tobacco treatment did not always fare better. This may perhaps be due to a potential antagonistic action or suboptimal application rates. Fruit yields are among the most significant measurements in commercial tomato cropping; based on variety and culture, marketable yields will range from 30 to 50 fruit per plant. The chili and control treatments underperformed in particular plots, demonstrating a possible vulnerability to infestation by pests, particularly *Tuta absoluta*, but the tobacco and synthetic pesticide treatments were able to perform at or above such commercial levels. It may also be that the low fruit numbers of the control and chili were due to the fact that the control group had no adequate control over pests and the chili had no adequate control over pests. Though effective in repelling insects, in Costa Rican research, it has been concluded that chili is not as effective in fruit deterring as synthetic pesticides, which have been formulated to kill pests in a simpler and more efficient manner.

The research thus illustrates that synthetic pesticides remain on top of natural alternatives such as chili and tobacco in fruit production even when the latter is capable of eliciting some form of beneficial influence. This is supported by the findings of other researchers, which show that synthetic pesticides avoid damage that would otherwise decimate fruit production by effectively managing pest populations, (Helvacı, M., 2022).

Fruit weight

The effect of the insecticide and plant health treatment by the various treatments is more likely than not accountable for the variation in the sample fruit weight. Insect feeding damage and insect stress were most likely minimized through the synthetic application of pesticides, whose purpose was to control such pests as *Tuta absoluta*. As a result, the plants were able to put more energy into fruiting, with the outcome of which was evident in Plot 3 having heavier fruit (600 g) and almost equally heavy in all other positions, but somewhat less. The pesticides will reduce the rivalry between the fruits and the pests over resources, one of the factors influencing the size and weight of the fruit. In contrast to the synthetic pesticide, the natural pesticides with tobacco and chili, though efficient in controlling pests, could not influence the number of the pests as much, and thus the weights of the fruits were relatively lesser. Both the chemicals of tobacco and chili, nicotine and capsaicin, respectively, are insecticidal and repellent. Since tobacco contains the toxic pesticide nicotine, tobacco has the potential of being highly effective against certain pests, e.g., *Tuta absoluta*. Higher fruit weights in Plot 1's tobacco treatment and Plot 2's chili + tobacco treatment can be attributed to this, but because chemically in nature as they are, tobacco and chili also stress plants, which may cause the fruit to mature in a less-than-ideal state, but they can slow pest damage to a certain degree. Moreover, owing to phytotoxicity or nutrient imbalance, among other factors, the combined treatment of tobacco and chili might have produced a synergistic effect responsible for the lowered positive impact on plant growth and fruit weight (Kanmani *et al.* 2021) [15]. This might explain the unpredictable trend in the combined treatment alongside the heterogeneous fruit weights achieved in the plots. The findings of this study reveal that while market fruit weight—typically ranging from 150 to 250 grams per fruit—is a critical determinant of tomato marketability, the observed mean fruit weights in this experiment were substantially higher due to the inclusion of multiple fruits per sample. Although large mean weights, such as the 765 g recorded in the control plot of Plot 2, exceed typical single-fruit standards and may imply an increased risk of cracking or pest infestation, they also reflect vigorous plant growth and enhanced productivity.

These results align with previous studies such as those by Rahi *et al.*, (2021) [24], who reported that higher fruit weights are often associated with improved nutrient uptake and photosynthetic efficiency, particularly under favorable agronomic conditions. Similarly, Ngegb *et al.*, (2022) observed that organic and botanical treatments, including those derived from chili and tobacco, can promote comparable yield performance to synthetic pesticides, while maintaining environmental and soil health benefits. This suggests that the comparable fruit weights obtained from natural treatments in the present study are consistent with

earlier research indicating that botanically based pest management can sustain both productivity and fruit quality.

Leaf area

Variation in leaf area between the treatments is due to the reaction of the plants to the treatments and the effect of pest management. The typically maximum leaf area of the control plants indicates that the plants can potentially invest resources for the production of leaves when there is no interference by pests. *Tuta absoluta* could have reduced the leaf area of the tobacco and synthetic pesticide-treated plants significantly, however. Similar to previous studies, upon plant mobilization to defense, infestation by pests will lead to arrested leaf growth (Clarke, 2022). Pesticide-exposed plants can have limited leaf area due to phytotoxicity or chemical stress triggered by chemicals that can cause arrested leaf growth regardless of sustained pest pressure (Ibrahim *et al.*, 2020). Although not as effective as chemical pesticides, spraying with tobacco and chili was perhaps as good at both lowering stress and pest numbers, slowly, with some plots still having tiny leaves. Both. Chili and tobacco each have bioactive molecules that repel pests, but together perhaps also stress the plant. Capsaicin, the plant's natural insect repellent in chili, reduces pest pressure but also slows plant growth by inducing poor physiological stress. While nicotine in tobacco is insecticidal, excessive nicotine also affects plant growth (Kanmani *et al.* 2021) [15]. The very low leaf area of Plot 2 chili + tobacco treatment (19.95 cm²) indicates that chili + tobacco could have exacerbated this stress. These findings are a measure of the synergistic risk of the combination of these compounds, which could have antagonistic action to suppress leaf growth and affect total plant health than with single applications.

Larger leaves tend to be associated with increased photosynthetic capacity and potential yield, leaf area is a useful measure of crop plant vigor. In order to achieve maximum photosynthesis and fruit yield, commercial practices in tomato focus on having strong, established leaves. The two experiment treatments from tobacco and chili were not sufficiently effective in replacing the expected leaf area, especially when used in combination. The reduction in leaf area recorded with the pesticide and tobacco treatment indicates possible adverse effects of such chemicals, although healthy leaves developed in control plants. Especially, the registered reduction in leaf area after the application of synthetic pesticides may be due to adverse chemical compound side effects, which are not suitable for sustainable agriculture. These findings support previous studies that indicated chili and tobacco are instances of natural pest control mechanisms which can limit pest damage but, if unchecked, do not necessarily enhance maximum plant growth. The evidence suggests that depending on what treatment was applied *Tuta absoluta* inflicted varying levels of damage on the leaves. Because the pest infested uncontrollably, the maximum damage scores were obtained in the control plots in all the plots across. Fact that *Tuta absoluta* feeds on leaves and fruits means that it is capable of inflicting huge damage to tomatoes without action against the pest. This is bound to interfere with photosynthesis and general well-being of the plant (Kanmani *et al.* 2021) [15]. This outcome agrees with that which is found concerning the impact that pest stress

may lead to reduced plant performance and potential yield when pest control is not present, (Tonnang *et al.* 2022) [34]. Treatment efficacy to reduce the intensity of leaf damage can be used to score their performance.

Severity of damage

Leaf damage inflicted by *Tuta absoluta* was effectively controlled by the insecticidal and repellent activity of tobacco and chili. In particular, the damage ratings were lowest for the combination of chili-tobacco, and this may be a pointer to an occurrence of a synergistic effect. Capsaicin, the bioactive constituent of chili, is an insect repellent, and the insecticidal activity of tobacco nicotine has the capability to interfere with the pest's nervous system, (Arya *et al.*, 2025) [3]. The combination would have reduced the extent of damage on the plants through the enhancement of *Tuta absoluta* deterrence. The combined treatment was not necessarily superior to the individual treatments in all cases, however, which may suggest that tobacco and chili do not function synergistically at all or that the pest has developed a tolerance to some of the chemicals over time. Whereas chemically potent at managing *Tuta absoluta*, chemical pesticides inflicting moderate harm in the present study ranged from three to four per plot. This indicates that the pesticide treatment could be effective in fewer insects and residual activity or insufficient complete cover would have done a minimum amount of harm to the plant. While highly potent in reducing pest pressure, pesticides at times can result in harmful effects on plants, such as phytotoxicity, which can also serve as a causative agent for the harm noted. This suggests how difficult it is to attain balance between minimizing plant damage because of pesticide application and pest damage avoidance. Minimization of leaf damage is central in commercial tomato crop production of crop with a function of attaining maximum potential yield and maximization of plant. Leaf damage lowers the capability of the plant to carry out photosynthesis, while large damage leads to inferior fruit development and yields (Wang *et al.*, 2019) [35]. Commercial growers have an incentive to keep leaf injury below some level in order to keep plant productivity up. Natural crops such as chili and tobacco might thus be a greener, more sustainable option compared to chemical pesticides, which in most cases are specifically designed to suppress pest pressure at the lowest. Though meeting industry requirements for a minimum of leaf damage, nature regulating measures such as tobacco and chili would need to be applied in conjunction with other integrated pest management strategies since the results indicate. Natural remedies would need to be proven to be effective in the long term and to be easy to prepare by additional research to guarantee that they are indeed suitable for industrial farmers.

ANOVA

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Recommendations

1. To maximize the effectiveness of tobacco and chili extracts in controlling *Tuta absoluta*, future research could examine the most appropriate concentration and mode of application. Application with different formulas, manner of application, and blending with other natural repellents or insecticides can be part of the study. Research can also determine whether climatic conditions such as soil type, temperature, and humidity affect the impact of tobacco and chili.
2. The result of this experiment on tobacco-chili mixture was not always consistent. Such potential synergistic or antagonistic interaction between these two plant remedies must be explored in future research, especially with regard to effect on plant health as well as pest control generally. Enhanced understanding of such interactions could result in enhanced effectiveness of integrated pest management practices.
3. Long-term efficacy of tobacco and chili as insecticides will have to be assessed in future research, though short-term efficacy was covered in this test. Future research can trace treatments through how long they remain effective in the field, how they influence build-up of resistance over time, and how they influence subsequent crop seasons' plant quality and yield.
4. Additional research can examine the impact of non-target organisms, water and soil quality, among others. Economic evaluation should also experiment whether it is cost-effective for farmers to apply tobacco and chili as integrated pest management against chemical pesticides on short- and long-term farmer returns.
5. Future research must also determine other natural insecticides or biocontrol products that will replace or supplement chemical pesticides, e.g., pepper and tobacco. Further use of sustainable pest management in tomato production could be increased by researching other plant-based insecticides, e.g., garlic or neem.

Conclusion

Through this study, invaluable information on how well tobacco and chili repel *Tuta absoluta* and affect tomato yields and growth has been supplied. The findings show that although tobacco as well as chili will cut down pest infestation, their effectiveness is not necessarily quite so powerful as synthetic pesticides. Tobacco and chili treatments that were always of low damage severity on leaves (scores 3 and 4, respectively) were found in all the plots, whereas control plots always had the highest severity of leaf damage with scores 4 to 6. Moreover, between the leaf damage, none of the tobacco or chili treatment dominated the other significantly; however, in most of the plots, the combination of both left little damage, and therefore there can be a synergistic effect. Synthetic pesticide application brought back the highest sample fruit weight and plant height in all treatments of plant growth and yields. For example, relative to other treatments, Plot 1 synthetic pesticide application had significantly higher sample fruit weight of 620 g and mean plant height of 124 cm. While both the tobacco and chili treatments were ineffective in both instances, they did at plant sizes of approximately 110 cm and fruit weights of 600-650 g demonstrate some potential for raising tomato yields above control with neither of these treatments implemented. They indicate that chili and tobacco can be utilized to a certain

degree in the control of pests, but are not so effective in inducing healthy plant growth as man-made pesticides. Therefore, although natural controls may reduce the extent of pest damage, further research must be initiated to further develop the use of such controls so that in integrated pest management programs, they are as effective and sustainable as man-made chemicals.

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