

Controlling *Tuta absoluta* (Meyrick) by Selected Crude Plant Extracts in the Laboratory and in the Screen House

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Abstract: Effects of *Commiphora swynnertonii*, *Synadenium glaucescens* and *Allium sativum* extracts on the tomato leaf miner, *Tuta absoluta* (Meyrick) were evaluated on the adults and in screen house conditions. The adult stage was involved with 30 adults that were reared in an insectarium, the experimental design was a completely randomized design (plant extracts from three plants species × three doses of 2%, 4% and 8%). In the screen house, experimental dispositive was a completely randomized block design (two varieties of tomatoes × three plants extracts). Larval counts were performed after 0, 1, 2, 3 and 7 d of treatment, 40 tomato leaves (10 × 4 replicates) were randomly taken from each treatment. The mean percentage mortality of adults was recorded daily for 5 d. Results indicated that, each plant extract caused significant mortality to adults of *T. absoluta* after 5 d in comparison to the control. Leaf dipping against adult of *T. absoluta* proved to be the most effective for all plant extracts at 30%-100%. *Commiphora* resulted in the adults' mortality of 100%. In the screen house *Commiphora* showed the high reduction of infestation for Tanya and Cal J varieties. Treatment with this plant extract resulted in the highest fruit yield and the lowest yield loss compared to all the plant extracts. *C. swynnertonii* extract is recommended into integrated pest management strategies for the control of *T. absoluta*.

Key words: Plant pesticide, insect control, tomato, *Tuta absoluta*.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the world's major vegetables. It is a good source of nutrients and some secondary metabolites like folate, potassium, vitamins C and E, flavonoids, β-carotene and lycopene are essential for human health [1]. In Tanzania, among others vegetables crops, tomato production is higher with a total annual production estimation of 235,000 t [2]. Survey results in Morogoro Region, show that under current management practices, the yields vary from 2.2 t/ha to 16.5 t/ha [3] which is below the world average of 27.5 t/ha [2]. Many constraints prevent farmers from

achieving potential yield. Some constraint are abiotic stresses like salinity, drought, declining soil fertility, poor crop management etc. and on the other hand biotic stress like pests and diseases [4]. The tomato leaf miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a pest that originates from South America and devastates tomato plants [5]. This pest has invaded in Tanzania [6]; there are no official records of this pest in Tanzania; but the main concern is that it can cause serious yield losses of 50% to 100% [7]. *T. absoluta* has become a major threat to the sustainability of the production. Its control is a challenge as it rapidly develops resistance towards conventional insecticides [8]. The presence of *T. absoluta* in Tanzania also affects the export trade as the productivity is reduced and the local price of tomato soars. In 2015, tomato prices in the country

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rose by 375% in just a month, resulting from the tomato leaf miner outbreak [9].

Chemical control has been the main method used against *T. absoluta* in South America, the low efficiency of the active ingredients against the insect was reported since the 1990s [10]. In Tanzania the use of pesticide to control pests is high, with different combination of pesticides probably because farmers assume that the only solution to pest problems is to spray more frequently and use different types of pesticides [11]. Furthermore the use of synthetic pesticides poses a threat to the environment and health of tomato consumers [12] and increases production costs [13]. Thus, there is need to look for alternative technique that will improve the yields while safeguarding the environment and human health. Some higher plants are known to have broad spectrum activity and exhibit antibacterial, antifungal and insecticidal properties under laboratory and field tests [8]. Further, while resistance development continues to be an issue for many synthetic pesticides, it is likely that resistance will develop more slowly to plant-based pesticides owing to the complex mixtures of constituents that characterize many plants [14].

Three plants namely *Synadenium glaucescens*, *Commiphora swynnertonii* and *Allium sativum* were tested. These plants have been used in Tanzania traditional medicine [15, 16]. Previous findings show that these plants have a broad spectrum activity against common pathogen in human and animals [15, 16]. The exudates of *C. swynnertonii* have been used traditionally to cleanse bladder and kill insects such as ticks, lice, bed bugs and mange mite [16]. Garlic oil which is an oviposition deterrent, has been found to be highly toxic to eggs of *Plutella xylostella* [17, 18]. Stem branches and buds of *S. glaucescens* have insecticidal and repellent properties against aphids, grasshoppers and mosquitoes [19].

The overall objective of this study was the development of alternative method of plant extracts to use synthetic pesticides in controlling *T. absoluta* in

tomatoes in Morogoro, Tanzania. Specifically,

- To determine the *in vitro* effectiveness of *C. swynnertonii*, *S. glaucescens* and *A. sativum* plant extracts against adults of *T. absoluta*;
- To assess the *in vitro* effective concentration of the plant extracts against adults of *T. absoluta* on adults;
- To determine the effectiveness of the plant extracts on the tomato leaf miner in the screen house.

The aim of this study was the screening of different medicinal plants at appropriate doses against *T. absoluta* under laboratory and screen house conditions.

2. Materials and Methods

The experiment was conducted at Sokoine University of Agriculture Morogoro, Tanzania located at 6.822° S and 37.661° E. The experiment was conducted under laboratory from January 2016 to June 2016, in the screen house from June to September.

The laboratory work of preparation of plant extracts was done at the Department of Veterinary Medicine and Public Health, while rearing and monitoring of *T. absoluta* were conducted at the Horticulture Unit. Thirty adults *T. absoluta* were placed in boxes (5 cm × 10 cm × 10 cm). After 1, 2, 3, 4 and 5 d of exposure, *T. absoluta* adults were observed in each treatment to assess mortality.

Roots of *S. glaucescens* were collected from Gairo district in Morogoro Region, while bulbs of *A. sativum* were purchased from the Mawenzi market in Morogoro municipality. Extract of *C. swynnertonii* was obtained from Natural Product Laboratory in the Department of Veterinary Medicine and Public Health.

The design of the laboratory experiments consisted of a 3 × 3 factorial (plant extracts from three plant species × three plant doses of 2%, 4% and 8%) arranged in a completely randomized block design with three replications. In these experiments a synthetic insecticide BELT flubendiamide was used as

positive control. These insecticides belong to the chemical family of substituted phthalic acid diamides that have a very broad lepidoptera spectrum. For the tomato leaf miner the preparation is done by mixing 10-15 mL in 100 L of water, whereas sterile distilled water (SDW) containing 0.1% Tween® 20 was used as negative control. The insecticide was used following the manufacturer's recommendations. The plant parts that were used in the experiment included: root bark (*S. glaucensens*), resin (*C. swynnertonii*) and bulb (*A. sativum*). The plant materials were packed into polyethylene bags, transported to the laboratory within 24 h after collection. The plant materials were cleaned of debris using running tap water. The bark material was first peeled from root stumps and chopped into small pieces before sun drying. For *A. sativum*, preparation of powder was carried out according to method described by Mahmood [20]. After cleaning, the bulbs were aseptically cut into small pieces with a knife and then dried in the shade for 7 d at 32-35 °C. The semi-dried pieces were then blended using pestle and mortar, and left to dry in the shade at room temperature for further 7 d. The materials were thereafter finely powdered with the help of a mixer-grinder and then stored in airtight bags in a cool dry room until when they were used. The resin was just kept in airtight bottle in the fridge until when it was used.

Solvent extraction was carried out according to the method described by Parekh and Chanda [21] with some modification. Each elite plant powder (resin) was separately extracted in ethanol (99.8%). Exactly 100 g of ground plant material was soaked in 500 mL of ethanol in a conical flask plugged with aluminium foil and kept for 72 h in a dark place at room temperature. The total yield for *Commiphora* resin was 90% while for *Synadenium* 20% and *A. sativum* 18%. The extracts, were filtered with Whatman filter paper 1 and the filtrate was concentrated using a rotary evaporator until all the solvent was cleared. The extracts were weighed to determine the percentage of

paste in the dry material and then were stored at 4 °C in airtight bottles until use. The serial dilution method was used to prepare the working solutions at the three different concentrations of 2%, 4% and 8%. In the laboratory the experiment was performed on the adult of *T. absoluta* using 2%, 4% and 8% concentrations of each plant extract. To maintain turgor of the petiole of each leaf, they were wrapped in humid cotton wool. Petri-dishes were maintained at conditions of the insectariums at 24 ± 2 °C. The positive and negative control treatments were also included. Each treatment was replicated three times. The number of live and dead adults of each treatment as well as control was recorded daily for 5 d.

3. Bioassay under Screen House Conditions

To evaluate the effect of the treatment on *T. absoluta* population, naturally infested tomato plants of the two varieties (Tanya and Cal J) were grown in a screen house at the Crop Museum (SUA). Plants of the two varieties Tanya and Cal J planted in separate rows were used. The screen house had not been sprayed with any pesticide. Pre-treatment larval count was carried out by sampling 40 leaves randomly taken from each plot as four replicates of 10 each. The three different plants extracts were applied at 4%. Treatments were applied by spraying the extract solution on the plant to run-off, using a hand held sprayer. To minimize cross infestation the plants were sprayed in the morning since *T. absoluta* is a nocturnal insect. The positive control treatments were sprayed with BELT at the concentration of 0.2 mL/L, while the negative control was sprayed with 0.1% Tween® 20 in SDW.

Larval counts were performed after 0, 1, 2, 3 and 7 d of treatment, 40 tomato leaves (10 × 4 replicates) were randomly taken from each treatment. On each day, these 40 leaves were taken from the different treatments and brought to the laboratory for examination under a binocular microscope (Leica MZ 12.5). The number of larvae of *T. absoluta* present on

the leaves was counted and recorded. In screen house, for both varieties the incidence was equal, thus destructive sampling was used to calculate the reduction of the infestation within the treatment. The percentages of infestation reduction were calculated according to Henderson and Tilton's equation [22] as follows:

$$\text{Reduction \%} = 1 - (a/b \times c/d) \quad (1)$$

whereas a = population in treatment after spraying; b = population in treatment before spraying; c = population in check untreated (control) before spraying; d = population in check untreated after spraying.

Reduction percentages were calculated after 1, 2, 3 and 7 d after treatment for the larvae.

3.1 Data Collection

The yield of the tomato plants of the two varieties was assessed in term of number of fruits per plant, fruit size, marketable and non-marketable fruits. The number of fruits per plant was assessed by counting the fruits of all trusses for the different treatments. Fruits size was measured by weighing the fruits from each treatment using an electronic balance.

After harvesting, all tomato fruits were sorted and graded into marketable and non-marketable fruits and weighted separately on a balance. Marketable fruit yield constituted of only fresh, non-damaged fruits suitable for selling while non-marketable fruit yield was made up of fruits damaged by pests. The total fruit yield was the sum of weights of marketable and non-marketable fruits yields. Yield loss was calculated using the following formula:

$$\text{Yield losses} = [\text{Non-marketable}/(\text{Marketable} + \text{Non-marketable})] \times 100 \quad (2)$$

3.2 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using GenStat version 8.1, at a difference declared significance of 5% level. In the laboratory the experiment was done in a triplicate,

and two-way ANOVA was used with concentration (three levels) and plant extract (three levels) as source of variation. In the screen house, the experiment was done in quadruplicate using two-way ANOVA with plant extract and varieties as factors. Descriptive statistics (mean, standard error of mean and coefficient of variation) were generated using GenStat procedures. Multiple means comparison was done using Turkey GenStat tool at 5% level of significance. The determination of the lethal dose 50 of each plant extract was done by probit regression dose-response analysis using MedCalc software version 17.6.

4. Results

4.1 Effect of Plant Extracts on the Mortality of Adults of *T. absoluta*

Results on the effects of the treatments on the adult stage of *T. absoluta* under laboratory conditions are presented in Fig. 1. The results showed that mortality of 10% occurred in the negative group within the test durations. Adult's mortality level under the laboratory conditions was significantly different among the treatments. *Commiphora* extracts caused the highest mortality of *T. absoluta* adults. The mortality caused ranged from 75.5% on day 1 to about 94% on day 5. *Synadenium* extract caused the 2nd highest mortality, while garlic extracts and the conventional insecticides caused comparable mortality of about 63% to 64%. This was significantly higher than the mortality caused by the negative control.

Results of the dose-response of each plant extract at different concentrations on adult mortality's of *T. absoluta* are presented in Fig. 2. The three different plant extracts show their effectiveness in controlling *T. absoluta* at the adult stage.

4.2 Bio-Efficacy of Pesticides against Larvae of *T. absoluta* on Two Tomato Varieties

Two varieties of tomato namely Cal J and Tanya

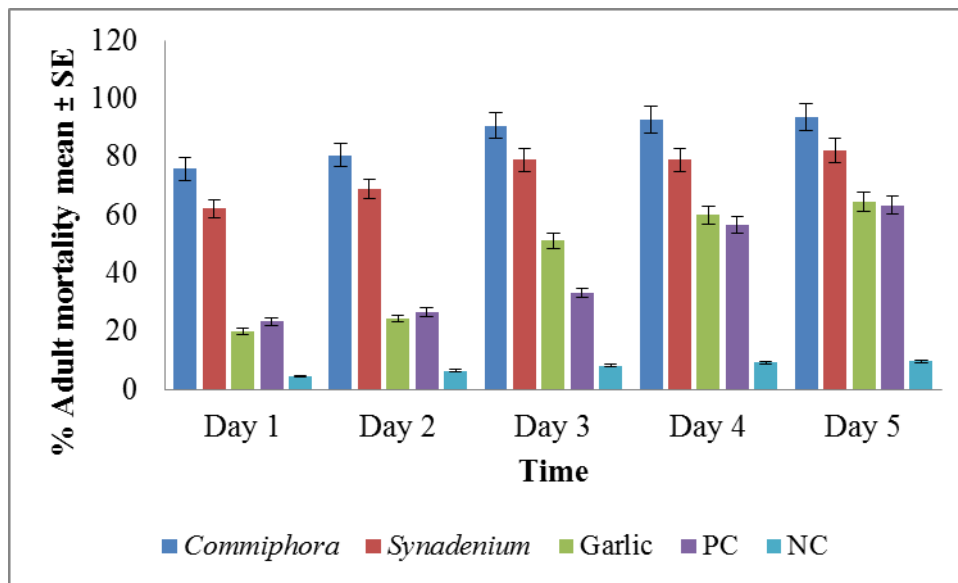


Fig. 1 Effect of plant extracts on the adult mortality of *Tuta absoluta*.

PC: positive control; NC: negative control.

were evaluated in this study to see the effectiveness of the plant extracts.

The results for variety Cal J are presented in Table 1 and for Tanya in Table 2. The results show that reduction percentage of *T. absoluta* infestation on tomato leaves with the different tested plant extracts for the two varieties of tomatoes ranged between 19.3%-80.1% for Cal J and 22.7%-79.1% for Tanya after 7 d from application (Tables 1 and 2, respectively). There was no significant difference in the reduction of *T. absoluta* ($p > 0.05$) between the two varieties, while different plant extracts showed significant differences ($p < 0.05$). Generally, *Commiphora* was more effective at 80.1% for Cal J and 79.1% for Tanya in controlling *T. absoluta* than the positive control with 55.4% for Cal J and 54.2% for Tanya. *Commiphora* exhibited the highest effect on *T. absoluta* after 3 d followed by the positive control in both varieties. *Synadenium* showed the lowest reduction (22.7% for Tanya and 19.3% for Cal J). In general, population of *T. absoluta* was significantly higher in negative treatment than other

treatments. Under screen house conditions, the highest effects of the tested plant extracts against *T. absoluta* were observed after 3 d of treatment for *Commiphora*, when 87.7% and 89.1% on Cal J and Tanya, respectively. The positive control caused reduction of 64% and 63.2% for Cal J and Tanya, respectively. On the 7th day the effect of the pesticide had decreased. The results are attributed to the fact that *T. absoluta* was more sensitive to some of the tested plant extracts after 2-3 d. Thereafter, the effect of the plant extract decreased and pest population increased.

4.3 Effect of the Treatments on the Yield of Tomato

Commiphora extract gave the highest yield of 1,200 g and 1,100 g for Cal J and Tanya, respectively. *Commiphora* was followed by positive control and garlic (Fig. 3). There were no significant differences between the varieties. Negative control and *Synadenium* gave the lowest yield for both varieties. There were no significant differences between varieties and treatment on the total yield of the tomatoes.

Controlling *Tuta absoluta* (Meyrick) by Selected Crude Plants Extracts in the Laboratory and in the Screen House

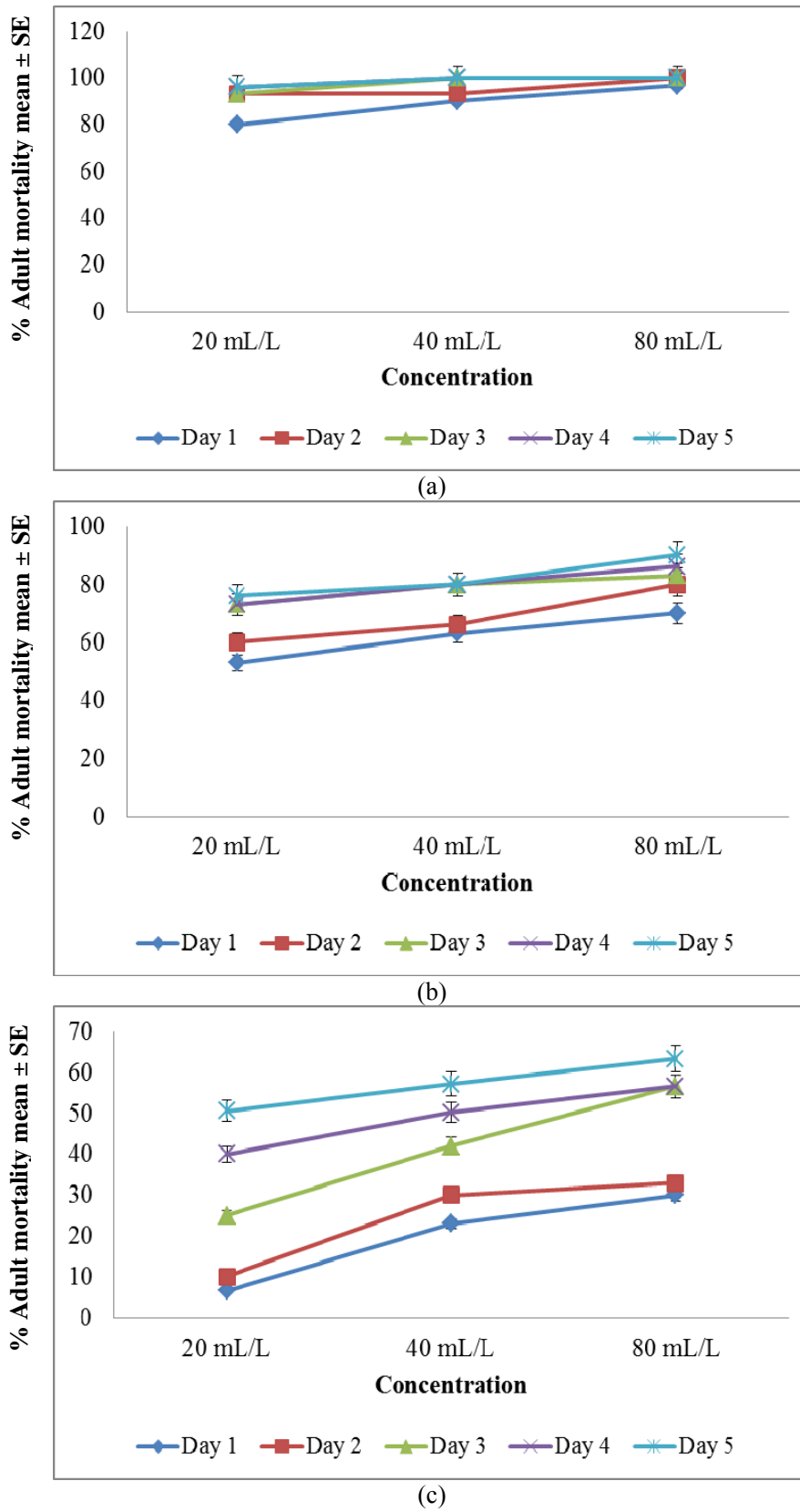


Fig. 2 Dose-response curve of each plant extract on adults mortality: (a) *Commiphora*; (b) *Synadenium*; (c) garlic.

Table 1 Effectiveness of the treatments on larvae of tomato leaf miner (*Tuta absoluta* (Meyrick)) on variety Cal J under screen house conditions.

Plant extracts	Pre-spray	Average No. of surviving larvae				Reduction percent (%)			
		1 d	2 d	3 d	7 d	1 d	2 d	3 d	7 d
<i>Commiphora</i>	32	27	19	12	11	37.59a	65.3a	87.7a	80.1a
<i>Synadenium</i>	29	30	27	32	35	4.6c	28.4d	26.8d	19.03d
Garlic	35	27	28	15	23	24.3b	36.5c	34c	27.08c
PC	40	33	21	13	18	36.50a	55.6b	64b	55.4b
NC	31	34	38	43	47				
<i>p</i>						0.004	0.0003	0.001	0.001
CV						18.2	6.8	11.8	8.8
SE ±						7.843	4.419	5.992	4.535

Means followed by the same letter are not significantly different at $p < 0.05$. PC: positive control; NC: negative control.

Table 2 Effectiveness of the treatments on larvae of tomato leaf miner (*T. absoluta* (Meyrick)) on variety Tanya under screen house conditions.

Plant extracts	Pre-spray	Average No. of surviving larvae				Reduction percent (%)			
		1 d	2 d	3 d	7 d	1 d	2 d	3 d	7 d
<i>Commiphora</i>	25	25	14	9	8	34.6a	65.9a	89.4a	79.1a
<i>Synadenium</i>	31	28	27	29	34	6.3d	23.7d	31.43d	22.7d
Garlic	31	30	24	25	29	20.4c	36.9c	40.79c	23.6c
PC	25	30	17	14	18	31.75b	48.9b	63.2b	54.2b
NC	28	30	35	38	44				
<i>p</i>						0.001	0.0003	0.001	0.0002
CV						13.6	6.5	6	3.5
SE ±						2.144	4.592	7.33	3.463

Means followed by the same letter are not significantly different at $p < 0.05$. PC: positive control; NC: negative control.

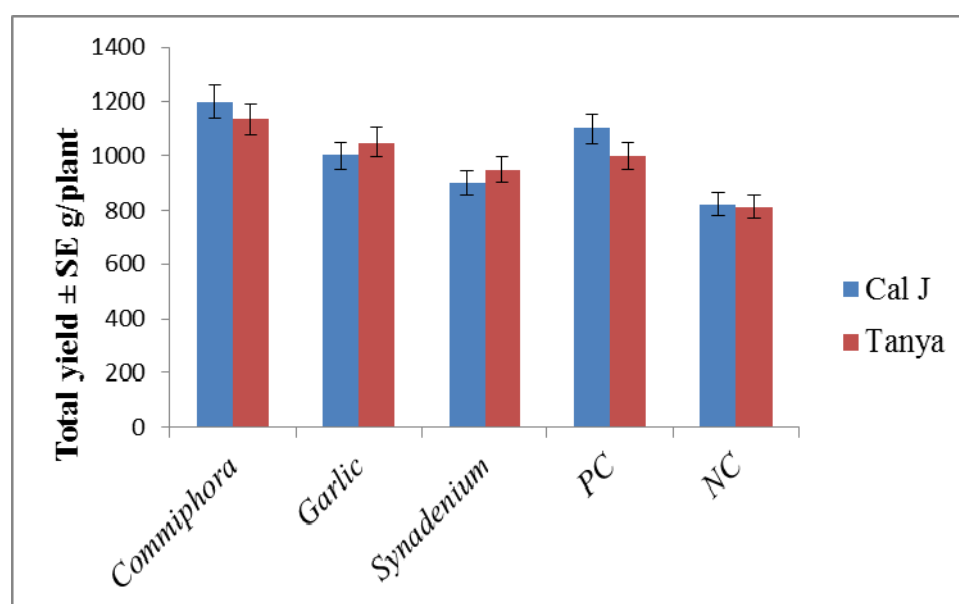


Fig. 3 Total yield of Cal J and Tanya in different treatments.

PC: positive control; NC: negative control.

Controlling *Tuta absoluta* (Meyrick) by Selected Crude Plants Extracts in the Laboratory and in the Screen House

4.3.1 Yield in Number of Fruits per Plant

There were no significant differences in number of fruits per plant between the two varieties (Cal J and Tanya) (Fig. 4). Results show that marketable and non-marketable fruit yields significantly differed ($p < 0.05$) among plants extracts (Fig. 5). *Commiphora* and positive control had the highest number of marketable fruits. However, no significant differences were observed in number of marketable fruits between *Synadenium*, garlic and negative control. Neither there were no

significant differences in number of non-marketable fruits between positive control, *Synadenium* and garlic.

4.3.2 Yield Loss of Different Varieties of Tomato

Results on tomato fruit weight losses are presented in Fig. 6. The treatments affected significantly the total loss. *Commiphora* extract led to the lowest percent of fruit yield loss with the extend of yield. The highest yield loss percent of 72.7% and 83.1% for Cal J and Tanya, respectively, which were recorded from the negative control treatment.

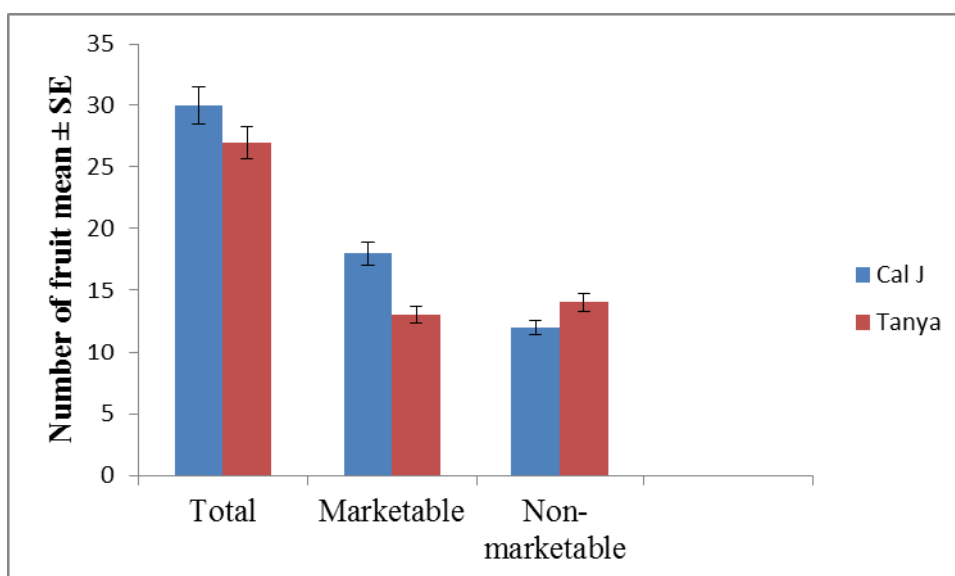


Fig. 4 Effect of varieties on the number of fruits.

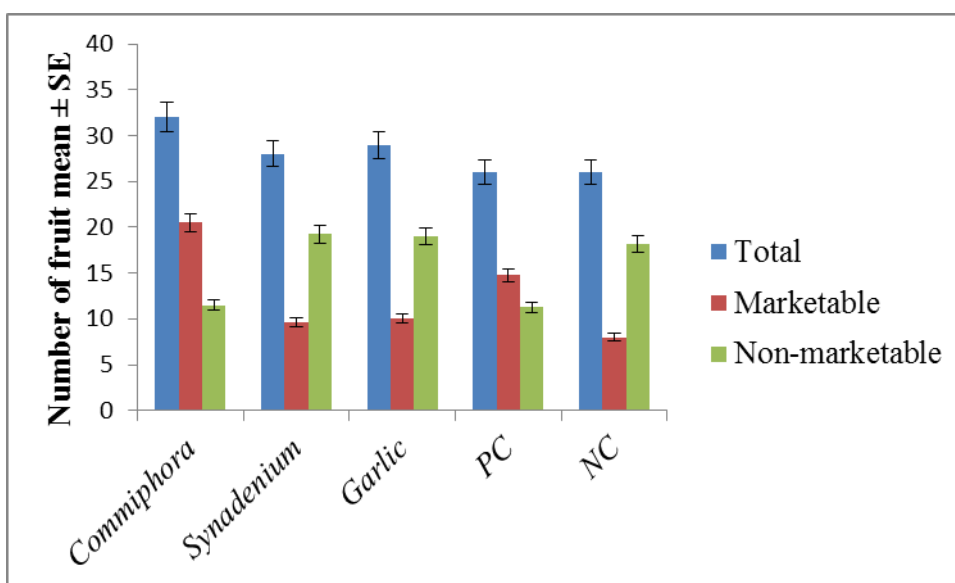


Fig. 5 Effect of different plant extracts on the number of fruit.

PC: positive control; NC: negative control.

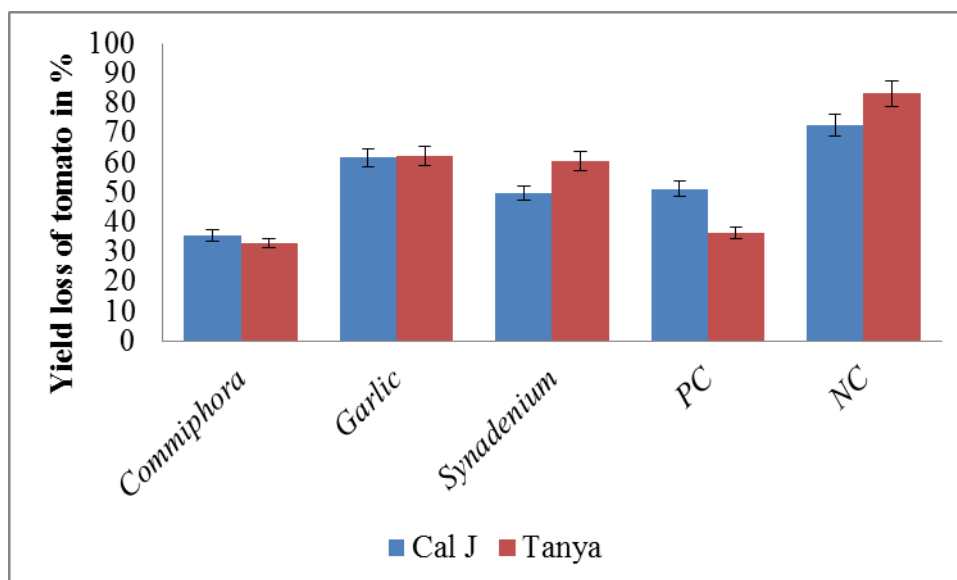


Fig. 6 Total yield loss of two varieties of tomato in different treatments.

PC: positive control; NC: negative control.

5. Discussion

All plant extracts caused mortality on the adult of *T. absoluta*, garlic extracts and the conventional insecticides caused comparable mortality of about 63% to 64% while the high mortality was recorded by *Commiphora* extract.

Many previous studies reported effective larval control of *T. absoluta* with botanical materials. Nadia *et al.* [23] reported that application of four concentrations of neem (*Azadirachta indica*) seeds ethanolic extract and *Jatropha* (*Jatropha curcas*) seeds petroleum ether extract on young larvae of *T. absoluta* resulted in larval mortalities that ranged between 33%-46.7% and 23.5%-48.5%, respectively, obtained after 24 h. Also, higher larval mortalities, up to 100%, were obtained with the two extracts after 4 d of treatments. Moreno *et al.* [8] tested the bioactivity of hexane and ethanol extracts of 23 plants against *T. absoluta* larvae. Their results showed that, hexane extract of *Acomella oleracea* was the most active against *T. absoluta* larvae. Nilahyane *et al.* [24] applied extracts of seven plants against *T. absoluta* larvae; their results showed that, the extracts had varying levels of toxicity for the larvae. The most effective was that of *Thymus vulgaris* (95%), followed

by *Ricinus communis* (58%). In a similar laboratory study, Ghanim and Abdel [25] used five plant extracts against 2nd instars larvae of *T. absoluta*. Their results showed that, chinaberry caused the highest effects on *T. absoluta* larvae, followed by geranium, onion and garlic. Essential constituents of most of the plant extracts in this study are primarily lipophilic compounds that act as toxins, feeding deterrents and oviposition deterrents to a wide variety of pests. Insecticidal properties of several plant extracts to the housefly, red flour beetle and southern corn root-worm were reported [26]. Although many plant extracts have insecticidal properties, the degree of toxicity of different compounds to one species differs considerably.

Repeated modes of action of Azadirachtin included induced cessation in feeding (antifeeding) and growth inhibition [27-29]. Studies showed that they reduced moulting and caused deformations in pupae and decreased fecundity of females [30]. The antifeedant effects of azadirachtin are partly due to sensory detection and avoidance by insects [31].

The insecticidal activity of *Commiphora* exudate parallels other findings. For instance essential oils of *Commiphora* leaves repelled ticks and the repellence

activity was associated with presence of sesquiterpenoids [18]. Also bark extracts induced mortality in nymphs and adults of *Rhipicephalus appendiculatus* ticks [32]. Insecticidal activity in the genus *Commiphora* is not unique to *C. swynnertonii*. There are other species with strong acaricidal activities including *C. erythraea* [33] and *C. myrrh* [34].

The effectiveness of the insecticidal activity of *C. swynnertonii* exudates on *T. absoluta* was a function of their concentration as well as the duration of exposure to the exudates. At 8% concentration, more than 90 of adults died by day 2. A lower concentration of 2% did not cause high mortality on day 1 and day 2, but progressively the adults' mortality increased on day 3 and by day 5 more than 90% of adults had died. At a higher concentration (4% and 8%) 100% mortality was realized on day 3. At a higher concentration the effect was immediate while at a lower concentration there was immediate action but the residual amounts on the adults continue to elicit the effect.

The present study shows that effect of plant extract decreased with time after treatment. So, the insect populations increased again as a result of the decrease of residual effects. Ghanim and Abdel [25] studied the effects of basil, geranium, chinaberry, onion and garlic aqueous extracts against *T. absoluta* (Meyrick) and the cotton aphid, *Aphis gossypii* (Glover). The authors reported the highest effect of the plant extracts after 4 d which also decreased with time. Decreased efficacy of plant extracts over time was previously attributed to activity of insects' secretion system [35]. Moreira *et al.* [36] associate differences in plant extracts toxicity with differential susceptibility of the insect.

In this study garlic had moderate effectiveness on the pest. However, Hussein *et al.* [37] showed a high reduction of *T. absoluta* population after tomato plants were treated with garlic extract. The moderate reduction of *T. absoluta* during this study was due to the extraction method that affects the presence of some volatile oil that confers to garlic its biological

properties. Results of this study were however in agreement with those reported by Ghanim and Abdel [25], who showed effects of garlic on *T. absoluta* 2nd, instars larvae under laboratory conditions, but with moderate effects under greenhouse conditions. Also, garlic leaf lectin (ASAL) had detrimental effect on growth and survival of two important homopteran insect pests, *Lypaphis erysimi*, commonly known as aphids and *Dysdercus cingulatus* (red cotton bug) [38]. Neem, garlic and ginger extracts contain insecticidal properties that are lethal to a wide range of insects [39].

Garlic is a major source of sulphur containing compounds (alkyl sulfides) with different numbers of sulfur atom (i.e., mono-, di- and tri-sulfide). Volatile compounds such as allicin, diallyl disulphide, diallyl trisulphide (a major constituent of garlic oil), dithiins, and ajoene originate from different metabolic pathways by tissue damage through cutting, crushing or chewing. These compounds provide garlic with its characteristic odour and flavour as well as its biological and antifeeding properties [40]. Similar results with other pests were obtained by Panhwar [41] who reported that good aqueous solution of garlic would effectively control worms, beetles and thrips in cowpea.

Results obtained in this study are similar to those reported by Ahmed *et al.* [42] on cowpea and by Panhwar [41]. These authors showed that, plant extracts increased the yield of vegetables by protecting them from insect pests. According to Gaby [43], plant extracts application at flowering and pod formation stages reduced the level of infestation of insect pests and increased yield of pea plants.

T. absoluta reduced yield and fruit quality grown under green house and open field conditions. Severely attacked tomato fruits lose their commercial value. Losses ranging from 50%-100% have been reported on tomato [44]. Damage is directly related to the reduction of plants' photosynthetic capacity and of production levels in both protected and open field.

Indirect damage to the tomato crop can also be caused by secondary infection by pathogens developing on the infested plants and fruits tissues [45]. As larvae are internal feeders it is difficult to achieve an effective control through application of chemical insecticides. Moreover, *T. absoluta* can rapidly evolve into strains with reduced susceptibility to insecticides that have been previously effective.

Results obtained by Hussein *et al.* [37] indicated that controlling *T. absoluta* by essential oil significantly affected fresh weight, shape index, total soluble solids, thickness of pericarp, pH and ascorbic acid. Interestingly, the tested plant extracts and essential oils affected the percentage of dry weight of fruits and vegetative growth of tomato plants significantly. Also, the lemon grass and garlic plant extracts and most of the essential aromatic oils (eucalyptus, rue, anise, basil) increased the total yield of tomato.

Results reported by Tyagi *et al.* [46] revealed that plant growth improved and plant weights also increased with increasing concentration of leaf lemon grass extract and with longer dip duration.

6. Conclusions

Based on the findings of this study, it is concluded that all plant extracts were effective and controlled adult *T. absoluta*. *Commiphora* extracts were highly effective and controlled *T. absoluta* in screen house. Foliar application reduced *T. absoluta* population, improved quality and yield of tomato. This bio-insecticide can be integrated in pest management program and organic farming.

7. Recommendations

Based on the finding of the present study, the followings are recommended:

Isolation and the screening of the bioactive compound against different strain of *T. absoluta*.

Since *Commiphora* exhibited a good activity *in vitro* and in the screen house, it should be subjected in

open field application to see its effectiveness. Since only one part of the each plant was used further studies should be carried out in order to study different parts of the same plant and extracted by different solvents to compare their effectiveness. It is recommended to do further studies on molecular characterization of *T. absoluta* insect for understanding different strains circulating in Tanzania. Therefore, further studies should be carried out to integrate *Commiphora* with other integrated or biological control methods in order to reduce the use of chemicals and, consequently, improve food safety and environment quality.

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**Controlling *Tuta absoluta* (Meyrick) by Selected Crude Plants Extracts
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