Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 20, No. 6, p. 1-13, 2022
http://www.innspub.net

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RESEARCH PAPER | OPEN ACCESS

Effect of *Tephrosia vogelii* formulation with rabbit urine on insect pests and yield of sesame in Singida, Tanzania

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Article published on June 15, 2022

Key words: Insect pests, Yield, Sesame, Percentage damage, *Tephrosia vogelii*

Abstract

A field experiment was conducted to assess the efficacy of *Tephrosia vogelii* formulated with rabbit urine on insect pests and yield of sesame. The experiment was done with five treatments namely 10% *T. vogelii* (w/v), 50% rabbit urine (v/v), 10% *T. vogelii* + 50% rabbit urine, Water and synthetic pesticide [Duduba 450 EC (Cypermethrin 100g/l + chlorpyrifos 350g/l)]. Results show that, sesame plants sprayed with the formulation of 10% *T. vogelii* + 50% rabbit urine significantly ($p \leq 0.001$) decreased the number of identified insect pests and encouraged high numbers of natural enemies compared with sesame plants sprayed with other treatments. For instances, Sesame plants sprayed with 10% *T. vogelii* + 50% rabbit urine had lower numbers of *Antigastra Catalaunalis* and *Alocypha bimaculata* that decreased as from week 1 to 5 compared with other treatments. Also, sesame plants sprayed with 10% *T. vogelii* + 50% rabbit urine possessed significantly ($p \leq 0.001$) lower percentage damage of sesame compared with other treatments from weeks 1 up to 5 respectively. The results also indicated that, the formulation of 10% *T. vogelii* + 50% rabbit urine was significantly ($p \leq 0.001$) increased sesame yield compared with other treatments. The highest yield was (740.59kg/ha) followed by that of a positive control (721.78kg/ha) and the lowest yield was (672.78kg/ha) that from negative control. Therefore, this study suggests that, treatment 10% *T. vogelii* + 50% rabbit urine can be used by the smallholder farmers to combat insect pests on sesame fields in Africa.

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Introduction

Sesame, *Sesamum indicium L.*, is a paramount oil yielding crop cultivated in tropical regions, where temperature of about 27°C and rainfall of about 625 to 1100 mm are available worldwide (Prasad *et al.,* 2012; Raikwar & Srivastva, 2013; Baraki & Berhe, 2019; Mujtaba *et al.*, 2020; Myint *et al.*, 2020). However, sesame seeds contain 50 to 60% of oil and 19 to 25% of protein with antioxidants lignans such as sesamin and sesamolin which have cholesterol lowering effect in humans and deter high blood pressure (Anilakumar *et al.*, 2010). As an oil seed, sesame is one of the most predominant crop in Africa for international market, produced by the smallholder farmers as a cash crop (Gebregergis *et al.*, 2018). Sesame oil contains high amount of linoleate in triglyceride that inhibit malignant melanoma growth due to the presence of docosahexaenoic acid (DHA) which has anti-inflammatory, anti-metastatic and anti-proliferative properties (Prasad *et al.*, 2012; Rani & Yadav, 2018). As sesame oil contains antioxidant, it can be used as cosmetics, medical and pharmaceutical being used as laxative, demulcent and emollient (Anilakumar *et al.*, 2010).

Despite the nutritional, cosmetics, medical, pharmaceutical and economic value of sesame, insect pests, weeds and diseases are major impediments (Raikwar & Srivastva, 2013) and insect pests being the most constraint that affect sesames production in African smallholder farmers (Dossa *et al.*, 2017; Hanna, 2017). Insect pests such as *A. catalaunalis* and *A. bimaculata* are among the major damaging insect pests of *S. indicum* (Gebregergis *et al.*, 2018; Langham, 2018a). *A catalaunalis* is a serious pest infesting sesame in all stages from seedling feeding on tender leaves by webbing, to capsule stage, boring the pods to reach and feed on the seeds inside the pods (Myint *et al.*, 2020). *A. catalaunalis* attacks sesame seed capsules and cause yield loss up to 100% (Geremedhin & Azerefegne, 2020). *A. bimaculata* is the prominent insect pest impede sesame production whereby both larvae and adults are the pests (Patole, 2017). The *A. bimaculata* larvae feed on roots of sesame seedlings whereby the *A. bimaculata* adults feed on sesame leaves and stems of the seedlings or on the tender leaves and branches (Zeit, 2021). During feeding *A. bimaculata* adults on sesame leaves, they pose the creation of irregular holes in the leaves (Langham, 2018b). The infestation of *A. bimaculata* pest cause yield loss of 75% (Zeit, 2021).

Sesame smallholder farmers in African focus on the heavy use of synthetic pesticides controlling insect pests since they kill insects indiscriminately (Chandler, 2008; Hakeem *et al.*, 2016). Nevertheless, the use of the synthetic pesticides is not currently encouraged globally to control insect pests in *S. indicum*, due to their detrimental effects to the environments and to the non-target organisms such as pollinators and natural enemies (Nguyen *et al.*, 2020). For instance, profenofos, DDT, cypermethrin and deltamethrin are considered WHO Class II moderately hazardous and abamectin is WHO Class Ib highly hazardous (Jayaraj *et al.*, 2016). Therefore, there is a need of searching environmentally friendly bio pesticides as replacements of synthetic pesticides (Glare *et al.*, 2012). Biopesticides are very effective, in control of insect pests in crops without posing ruin to ecological chain or exacerbate environmental pollution (Leng *et al.*, 2011).

Bio pesticides are natural products that are obtained from living organisms including plants, animals and microorganisms (Kumar *et al.*, 2021) such as entomopathogenic bacteria, fungi, viruses, and nematodes have been effective in controlling a wide range of insect pests, fungi and weeds (Thangavel & Sridevi, 2015; Kumar *et al.*, 2021). For example entomopathogenic *Bacillus thuringiensis, Metarhizium anisophae, Beauveria bassiana and baculoviruses* are often used to control fall armyworms pests in maize (Assefa *et al.*, 2019). *B. thuringiensis,* is acting as pathogen to most destructive lepidopterans larvae pests by releasing toxin which destroy the mid gut of the larvae pest once they ingest it (Kumar *et al.*, 2021; Samada & Tambunan, 2020). Moreover, botanical pesticides like *Allium sativum, Aristolochia ringens, Ficus exasperate* and *Garcinia kola* have been used in controlling *Sitophilus zeamais* (Arannilewa *et al*., 2006). Also extracts from plants such as *T. vogelii* and *Tephrosia candida* have been used to control aphids infestations on bean plants in Malawi and proved to be effective in mitigating their number (Kayange *et al*., 2019). In addition plant extracts and essential oils (EOs) extracted from plants, evince a broad ambit of action against insect pests for they can act as attractants, repellents and antifeedants inhibiting respiration, hamper the ability of insects to identify host plants, impede oviposition and subside adult emanation by ovicidal and larvicidal ramifications (Kumar *et al*., 2021). Most bio pesticides are important components for controlling pests for they are affordable in terms of costs, accessible in the natural environments and easy to be produced and utilized (Amoabeng *et al*., 2014; Seffrin *et al*., 2010). Also they are environmentally friendly not inimical to human beings as well as non-target organisms (Samada & Tambunan, 2020). Hitherto, there is midget information on the use of biopesticides which can be used to control the sesame insect pests. Therefore, a concoction of *T. vogelii*, with rabbit urine can be used as an alternative method to control the sesame insect pests. The present study was carried out to assess the effect of *Tephrosia vogelii* formulation with rabbit urine on insect pests and yield of *S. indicum* in the field.

Materials and methods

Study site

The study was conducted in Mwamisye in Singida located at latitude 4° 47′ 35.3″ S, longitude 34° 42′ 53.5″ E, at an elevation of 1513 m above sea level. The field experiment was conducted between January and July and the mean annual rainfall was between 500 and 800 mm. The mean minimum and maximum ambient temperature during experiment ranged from 15 and 30°C and the relative humidity was 58% and 36% Rh during the wet and the driest months seasons (Province *et al*., 2007).

Land preparation and source of materials

Source of materials

Sesame seeds was obtained from the authorized shop at Ilonga Morogoro, *T. vogelii* leaves were obtained from Mondul coffee estate (MCE) located in Kisongo, Arusha, Tanzania and confirmed by the botanist at Tanzania Plant Health and Pesticide Authority (TPHPA) and rabbit urine was collected from rabbit keeping farmers, in Sekei street in Arusha region, Tanzania.

Land preparation

The land was prepared by ploughing and harrowing two weeks before sesame seeds planting to offer enough time for weeds wilting (Riccardo Bubbolini, 2016). Laying out was done on the ploughed and harrowed land prior to sesame seeds planting. Sesame seeds were planted from late January and harvested early June 2021. The sesame plant spacing was 60 cm between rows and 30 cm between column (Yousif *et al*., 2020) in the plots size that were measured 3 m by 3 m at both sides and each plot had five plant rows and ten plants columns. Fifty (50) holes per plot were made where two seeds were sown per hole. Two to four sesame seeds were sown per hole then, two weeks (14 days) after germination, seedlings were thinned to achieve one plant per hole (Abdalla *et al*., 2015). Weeding was done manually using hand hoe and it was done once a month.

Experimental design and treatment preparation

The experiment was done in a Randomized Complete Block Design (RCBD) with five treatments namely 10% *T. vogelii* (w/v) only, 50**%** rabbit urine (v/v) alone, a mixture of 10% *T. vogelii* + 50% rabbit urine, Water and Synthetic pesticide (Duduba 450 EC). Each treatment was replicated three times. Water was applied as a negative control whilst synthetic pesticide was applied as a positive control. In this case there were five treatments with three plot replicates of each treatment randomly across the field making total of 15 plots.

Extraction and preparation of treatments

Tephrosia vogelii

The leaves of *T. vogelii* were washed thoroughly and dried under shade at room temperature. Then the dried leaves of *T. vogelii* were pulverized into powder. The pulverized dry powdered leaves of *T. vogelii* in a measured of 100g were dissolved in one liter of water contain containing 1% equivalent to 10 mL of liquid soap for 24 hours, to attain 10% concentration (Mwaura, Stevenson, Ofori, Anjarwalla, 2012). The soaked material was filtered by using muslin cloth to obtain the filtrate and stored in a shade area to avoid the decomposition of phytochemicals found in *T. vogelii* by sunlight rays (Kang *et al*., 2016)

Rabbit urine

Rabbit urine were collected also from the rabbit grazing farmer at Sekei to get at least thirty liters (30 L). One liter of rabbit urine was diluted in two liters of water in a ratio of 1:2 to get 50% rabbit urine solution for treatment application. The collected rabbit urine was stored for three weeks in a closed container to alleviate the risk of disseminating diseases which might arise as a result of the microbes that may be present in the urine (Farmers *et al*., 2012). The stored rabbit urine was put under shade area to elude the degradation of bioactive compounds in the urine by the sunlight rays (Gong *et al*., 2015).

Tephrosia vogelii with rabbit urine formulation

Formulation of *T. vogelii* with rabbit urine was prepared by mixing 10% *T. vogelii* with 50% rabbit urine. The 10% concentration of *T. vogelii* was obtained by dissolving 100g of pulverized dry powdered leaves in one liter of water contain containing 1% of liquid soap. On the other hand, the 50% concentration of rabbit urine was obtained by diluting urine in a ratio of 1:2 (urine: water). Then the two solutions were mixed to get the formulation of 10% *T. vogelii* with 50% rabbit urine.

Synthetic pesticide

Synthetic pesticide (Duduba 450 EC) was obtained from the retailer shops (businesses that sell pesticides to the public) and it was prepared as per manufacturer's recommendation.

Treatments applications

The treatments were applied into the *S. indicum* in the field at the interval of 7 days all over the growing season of sesame *S. indicum*. The concentration of synthetic pesticide was applied as per recommendations from the manufacturer. The formulations were applied on top and under the leaves of sesame plants by wielding a 2 L sprayer pump in the evening throughout growing period of sesame plants. The spraying was carried out during evening hours to elude direct sunlight which may pose the decomposition of bioactive compound of botanical in *T. vogelii*. Each plot required about 250 ml to 500 ml per spray depending on the growth level tantamount with tantamount with 278 L/ha and 556 L/ha respectively. The sprayer pump was thoroughly washed with water and soap prior to re-filling it again with another formulation.

Collection of Yield Parameters Data

Yield parameters were collected during flowering period of the sesame and the seed yield collected after harvesting. Yield parameters which were collected include number of seed per pod, number of pod per plant, weight of seeds per plot and 1000 seeds per plot. Number of seed per pod and number of pod per plant were counted while the weight of seeds per plot and 1000 seeds per plot treatment were measured by using an electronic balance. Yield ha^{-1} calculated by the following formula as it is expressed in equation 1

$$\text{Seed yield/ha (kg)} = \frac{\text{Seed yield/plot (kg)}}{\text{Plot size (m2)}} \times 10000 \quad \textit{Equation } 1$$

Insect pests' identification and sesame S. indicum plants damage assessment

Insect pests were counted one day before spraying of the pesticides by selecting randomly five sesame plants from the middle of each plot each week. Assessment of damage severity of sesame crops was done by counting the number of damaged leaves and pods of sesame plants. Damaged parts of the plants were differentiated into scale; 0% damage, 25% damage, 50% damage, 75% damage and 100% damage depending on the number of leaves and pods damaged (Mkenda *et al*., 2015).

Data Analysis

The data collected were analyzed using one-way analysis of variance (ANOVA) by STATISTICA software program version 8. The Fisher's Least Significance Difference (LSD) was used to compare treatment means at $p = 0.05$ level of significance. Results with $p < 0.05$ were considered to be significant statistically. The graphs were drawn using excel software program.

Results and discussion

Results

Effect of T. vogelii formulation with rabbit urine on Antigastra catalaunalis pest

In the field experiment, *A. catalaunalis* pest (plate 1) was identified on the *S. indicum* crop on the fourth week after planting. After application of formulations and the synthetic pesticides (Duduba 450 EC), the results showed that, there was significant difference ($p \leq 0.001$) among the treatments in the population abundance of *A. catalaunalis* at the field (Table 1). It was found that, sesame plants sprayed with the formulation of 10% *T. vogelii* + 50% rabbit urine possessed significantly lower number of *A. catalaunalis,* followed by the formulation of 10% *T. vogelii* extract only and synthetic pesticide treatments in week 1,2, 3 and 4 respectively while sesame plants sprayed with a formulation of 50% rabbit urine alone treatment possessed lower number of *A. catalaunalis* compared with sesame plants in negative control in week 1, 2, 3 and 4 respectively (Table 1). In week 5 sesame plants sprayed with the formulation 10% *T. vogelii* + 50% rabbit urine had lower number of *A. catalaunalis* followed by sesame plants sprayed with the formulation of 10% *T. vogelii* extract, ensued by those in synthetic pesticide and 50% rabbit urine only (Table 1). However, sesame plants in negative control treatment possessed higher number of *A catalaunalis* persisted from week one before spraying of the treatment up to the 5th week of the treatments (Table 1).

Table 1. Mean number of *A. catalaunalis* per plant in response to the treatments.

Treatments	Week 1 before	Weeks after treatments				
	Treatment	1	2	3	4	5
T. vogelii	1.74 ± 0.14a	1.74 ± 0.14bc	1.20 ± 0.00bc	1.06 ± 0.14bc	0.66 ± 0.14bc	0.40 ± 0.00b
Rabbit urine	1.60 ± 0.00ba	1.86 ± 0.14b	1.46 ± 0.14b	1.20 ± 0.00b	0.80 ± 0.00b	0.54 ± 0.14b
Tv+Ru	1.60 ± 0.00a	1.34 ± 0.14c	1.06 ± 0.14c	0.80 ± 0.00c	0.40 ± 0.00c	0.26 ± 0.14b
Sp	1.60 ± 0.00a	1.74 ± 0.14bc	1.20 ± 0.00bc	1.06 ± 0.14bc	0.66 ± 0.14bc	0.54 ± 0.14b
Water	1.86 ± 0.26a	2.94 ± 0.14a	3.46 ± 0.14a	3.74 ± 0.14a	4.26 ± 0.14a	4.56 ± 0.14a
1 - way ANOVA (F- Statistics)	0.80ns	20.30***	95.5***	138.67***	319.25***	207.5***
P-value	0.55	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001

Each value is a mean ± standard error of five replicates, *, **, and *** significant at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ respectively and ns means not significant. Means within the same column followed by the same letter (s) are not significantly differently at $p = 0.05$ from each other using Fishers Least Significant Difference (LSD) test; Tv means *T vogelii*, Ru means rabbit urine and Sp means synthetic pesticide (Duduba 450 EC).

Plate 1. A: Sesame webworm *A. catalaunalis* on sesame plant before flowering period, B: Sesame webworm *A. catalaunalis* on sesame plant during flowering period and C: Sesame plant damage caused by the *A. catalaunalis*. Photograph by Upendo Lekamoi, Nm-aist Arusha, Tanzania.

Effect of T. vogelii formulation with rabbit urine on Alocypha bimaculata pests

In the field experiment the insect pest *A. bimaculata* (Plate 2) was identified in the fourth week after the plantation of sesame crop and there was no significant difference ($p > 0.05$) among treatments. After application of treatments, sesame plants sprayed with the formulation of 10% *T. vogelii* + 50% rabbit urine had significantly ($p \leq 0.001$) lower number of *A bimaculata*, followed by those sprayed with the formulation of 10% *T. vogelii* extract only in week 1 (Table 2). Sesame plants sprayed with synthetic pesticide and the formulation of 50% rabbit urine alone treatments, had lower number of *A. bimaculata* compared with those in negative control in week 1 and 2. In week 3 sesame plants sprayed with the formulation of 10% *T. vogelii* + 50% rabbit urine possessed equal number of *A. bimaculata* with those sprayed with synthetic pesticide, followed by sesame plants sprayed with the formulation of 10% *T. vogelii* extract alone while those sprayed with the formulation 50% rabbit urine only had lower number of *A. bimaculata* compared with those in negative control (Table 2). Additionally, sesame plants sprayed with a formulation 10% *T. vogelii* + 50% rabbit urine possessed lower number of *A. bimaculata*, followed by those sprayed with synthetic pesticide and *T. vogelii* extract alone in week 4 and 5 respectively while sesame plants sprayed with rabbit urine only treatment, possessed lower number of *A. bimaculata* compared with those in negative control which had higher number of *A. bimaculata* among all treatments (Table 2)

Table 2. Mean number of *A. bimaculata* per plant in response to the treatments.

Treatments	Week 1 before	Weeks after treatments				
	Treatment	1	2	3	4	5
T. vogelii	1.46 ± 0.26a	1.20 ± 0.00b	1.06 ± 0.14b	0.94 ± 0.14bc	0.80 ± 0.00bc	0.66 ± 0.14b
Rabbit urine	1.46 ± 0.26ba	1.34 ± 0.14b	1.20 ± 0.14b	1.06 ± 0.14b	0.94 ± 0.14b	0.80 ± 0.00b
Tv+Ru	1.60 ± 0.24a	1.06 ± 0.14b	0.94 ± 0.00b	0.80 ± 0.00c	0.66 ± 0.14c	0.54 ± 0.14b
Sp	1.48 ± 0.26a	1.34 ± 0.14b	1.06 ± 0.00b	0.80 ± 0.00c	0.80 ± 0.00bc	0.66 ± 0.14b
Water	1.46 ± 0.26a	2.40 ± 0.00a	2.94 ± 0.00a	3.20 ± 0.00a	3.20 ± 0.00a	3.46 ± 0.14a
1 - way ANOVA (F- Statistics)	0.21ns	26.67***	49.63***	150.5***	163.25***	110.88***
P-value	0.93	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001

Each value is a mean ± standard error of five treatments, *, **, and *** significant at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ respectively and ns means not significant. Means within the same column followed by the same letter (s) are not significantly differently at p = 0.05 from each other using Fishers Least Significant Difference (LSD) test; Tv means *T vogelii*, Ru means rabbit urine and Sp means synthetic pesticide (Duduba 450 EC).

Plate 2. Sesame flea beetle, *A. bimaculata* foraging feeding on sesame leaves and stems in the field. Photograph by Upendo Lekamoi, Nm-aist Arusha, Tanzania.

The percentage damage of S. indicum crop caused by insect pests' infestations

The percentage damage of the *S. indicum* crops caused by insect pests' infestations was significantly ($p \leq 0.001$) lower in the treatments compared with the negative control. Before treatments, there was no significant difference ($p > 0.05$) in percentage damage of *S. indicum* caused by insect pests' infestations in all treatments in different plots (Table 3). After treatment application, sesame plants sprayed with a formulation 10% *T. vogelii* + 50% rabbit urine possessed significantly ($p \leq 0.001$) lower (28.33 ± 1.67, 23.33 ± 1.67, 20.00 ± 0.00, 16.67 ± 1.67 and 15.00 ± 2.89) percentage damage of *S. indicum* when compared with those sprayed with other formulations and synthetic pesticide from week 1 to 5 (Table 3). Also in week 1 and 2, sesame plants sprayed with a formulation 10% *T. vogelii* +50% rabbit urine had lower percentage damage level followed by those sprayed with synthetic pesticide and the formulation of 10% *T. vogelii* extract only (Table 3). Sesame plants sprayed with the formulation of 50% rabbit urine alone had lower damage level percentage compared to those in negative control (Table 3).

In week 3 the lower percentage level damage was recorded in sesame plants sprayed with a formulation 10% *T. vogelii* + 50% rabbit urine followed by those sprayed with synthetic pesticide (Table 3). Sesame plants sprayed with *T. vogelii* extract only had lower percentage damage compared with those sprayed with the formulation of 50% rabbit urine alone which had lower damage level percentage compared with those in negative control (Table 3). In week 4 the lower percentage damage level was recorded in sesame plants sprayed with the formulation of 10% *T. vogelii* + 50% rabbit urine followed by those sprayed with synthetic pesticide while the percentage damage level of sesame plants sprayed with the formulation of 10% *T. vogelii* extract and 50% rabbit urine (Table 3). In week 5, the lower percentage damage was recorded in sesame plants sprayed with the formulation of 10% *T. vogelii* + 50% rabbit urine followed by those sprayed with synthetic pesticide, the formulation of 10% *T. vogelii* extract and 50% rabbit urine alone equally which had possessed lower percentage damage level compared with those in negative control (Table 3). Sesame plants sprayed with negative control had higher (40.00 ± 0.00, 50.00 ± 2.89, 60.00 ± 0.00, 68.33 ± 1.67 and 75.00 ± 2.89) percentage damage level increased from week 1 up to week 5 respectively (Table 3).

Table 3. Mean percentage damage per *S. indicum* crop.

Treatments%	Week 1 before Treatment	Weeks after treatments 1	2	3	4	5
T. vogelii	35.00 ± 0.00a	33.33 ± 1.67b	26.67 ± 1.67b	25.00 ± 2.89bc	20.00 ± 0.00b	16.67 ± 1.67b
Rabbit urine	35.00 ± 0.00a	33.33 ± 1.67b	28.33 ± 1.67b	26.67 ± 1.67b	20.00 ± 0.00b	16.67 ± 1.67bc
Tv+Ru	35.00 ± 0.00a	25.00 ± 0.00c	23.33 ± 1.67b	20.00 ± 0.00c	16.67 ± 1.67b	15.00 ± 2.89b
Sp	36.67 ± 1.67a	33.33 ± 1.67b	26.67 ± 1.67b	23.33 ± 1.67bc	18.33 ± 1.67b	16.67 ± 1.67bc
Water	35.00 ± 0.00a	40.00 ± 0.00a	50.00 ± 2.89a	60.00 ± 0.00a	68.33 ± 1.67a	75.00 ± 2.89a
1 - way ANOVA (F- Statistics)	1.00ns	17.00***	29.86***	96.80***	296.17***	138.17***
P-value	0.45	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001

Each value is a mean ± standard error of five treatments, *, **, and *** significant at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ respectively and ns means not significant. Means within the same column followed by the same letter (s) are not significantly differently at $p = 0.05$ from each other using Fishers Least Significant Difference (LSD) test; Tv means *T vogelii*, Ru means rabbit urine and Sp means synthetic pesticide (Duduba 450 EC).

Effect of T. vogelii formulation with rabbit urine on natural enemy per S. indicum

The natural enemies observed during the study period were those which control *A. catalaunalis* which were *Cocinella undecimpunctata* and *Tapinoma sessile* (Plate 3). Fig. 1 describe the effect of treatments on population of *C. undecimpunctata* and *T. sessile*. Generally, the mean number of natural enemies were higher in the sesame plants sprayed with formulations treatments compared with those sprayed with the synthetic pesticide (Fig. 1). It was observed that, sesame plants sprayed with the formulations used to control the insect pests possessed higher population of *C. undecimpunctata* and *T. sessile* compared with those sprayed with synthetic pesticide in the field. Fig. 1 showing that, the formulations prepared had very less effect toward the natural enemies. The sesame plants sprayed with positive control (synthetic pesticide) treatment possessed very low population of natural enemies, while those sprayed with negative control (water) possessed as high number of natural enemies as in formulations (Fig. 1).

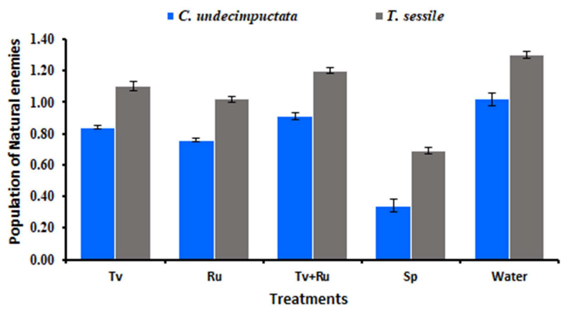

Fig. 1. Population of *C. undecimpunctata* and *T. sessile* per *S. indicum* in response to treatments. Tv means *T vogelii*, Ru means rabbit urine and Sp means synthetic pesticide.

It was also, noted that, the population of *C. undecimpuncta* was lower in number compared with *T. sessile* throughout the growing season of *S. indicum* (Fig. 1).

These natural enemies together enhanced the reduction of the population of the *A. catalaunalis* and finally reduced the damage of *S. indicum* in the field.

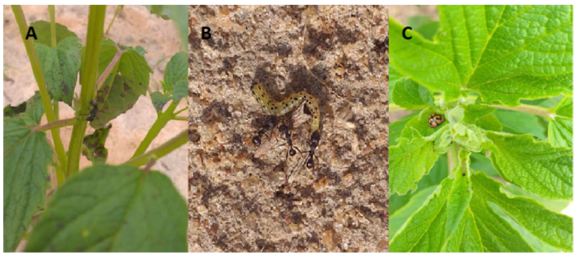

Plate 3. A: *T. sessile* foraging for prey *A. catalaunalis* larva on sesame plant crop and B: *T. sessile* feed on a fallen down *A. catalaunalis* larva. C: *C. undecimpunctata* foraging for prey *A. catalaunalis* larva on sesame plant. Photograph by Upendo Lekamoi, Nm-aist Arusha, Tanzania.

Effect of T. vogelii formulation with rabbit urine on S. indicum yield

The yield of *S. indicum* was measured by using number of pods per plant and seed yield per plot (Fig. 2). The higher number of pods per plants and higher weight of seed yield per plot, were significantly recorded in the formulation of 10% *T. vogelii* + 50% rabbit urine, followed by synthetic pesticide. However, negative control had lower number of pods per plant and lower seed yield per plot among all treatments (Fig. 2). Likewise, the highest yield was obtained in plots treated with the formulation of 10% *T. vogelii* + 50% rabbit urine (740.59kg/ha), followed by synthetic pesticide (721.78kg/ha) while the lowest yield was obtained in plots treated with negative control (672.78kg/ha) (Fig. 4).

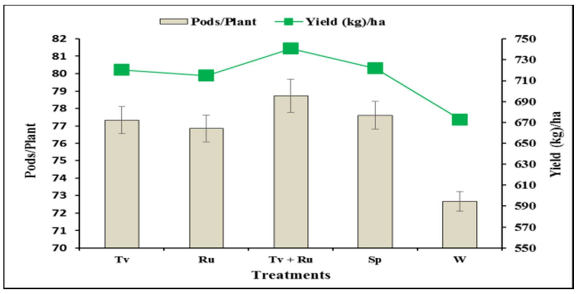

Fig. 2. Relationship of the mean yield and pods per *S. indicum* crop. Tv means *T vogelii*, Ru means rabbit urine, Sp means synthetic pesticide and W means water.

There was a relationship between number of pods per plant and the sesame seeds yield per plot. Fig. 2 shows the relationship present between the number of pods and the mean seed yield per plot. It was observed that, mean seed yield per plot were highest in the plots of sesame plants sprayed with the formulation of 10% *T. vogelii* + 50% rabbit urine as the number of pods per plant was also highest compared with the plots of other formulations and synthetic pesticide. Also it was revealed that, sesame plants, planted in the negative control treatment plots had low mean seed yield per plot, tantamount with the number of pods per plant which were also low among all treatments (Fig. 2). These results show the promising of the formulation in controlling yield loss without devaluing the quality of the products.

Discussion

This study has shown the significance of using biopesticides in combating insect pest rather than rely on heavy utilization and mixing of broad spectrum synthetic pesticides to control sesame insect pest which have health and environmental impacts. Treatments application were done weekly to ensure the effectiveness of the formulations used. The results revealed that formulations used in controlling sesame insect pests in the field were effective. It was found that, among the formulations used, the formulation of 10% *T vogelii* + 50% rabbit urine was the most effective for controlling sesame insect pests by significantly ($p \leq 0.001$) reducing the number of insect pests in week 1 up to 5 of spraying the formulations. For example, it was found that, sesame plants sprayed with the formulation of 10% *T. vogelii* + 50% rabbit urine had significantly ($p \leq 0.001$) lower number of *A. catalaunalis* and *A bimaculata* among all treatments in week 1 up to 5 respectively. The number of insect pests were decreasing from week 1 to 5.

The effectiveness of a formulation 10% *T vogelii* + 50% rabbit urine is attributed by the synergistic effects of the bioactive compounds found in the extract from *T. vogelii* and rabbit urine. The results of synergistic effects indicated that, the complex mixture of bioactive compounds in bio pesticides have synergistic effects (Tak & Isman, 2017). Synergistic effect occurs when the mixture of two or more chemical compounds interact and produce combine effects on biological system which is greater than the effects of those chemical compounds when act individually (Mpumi *et al.*, 2020).

Apart from that, the formulation of 10% *T. vogelii* extract used in this study was more effective in reduction of the number of insect pests and the damage of *S. indium* compared with the formulation of 50% Rabbit urine. The efficacy of formulations against insect pests is contributed by the presence of bioactive compounds. For example, *T. vogelii* contains a bio active compound called rotenone which has been revealed to have insecticidal traits (Said *et al.*, 2020). Rotenone ($C_{23}H_{22}O_6$) is a selective chemical which act as both a contact and stomach toxin to insects that it kills pest slowly by stupefying them (Ekanem *et al.*, 2004). Rotenone exerts its toxic action by impeding the cellular respiration through limiting electron transport chain in mitochondria by inhibition of the enzyme NADH ubiquinone reductase to a diverse range of insects including *A. catalaunalis* and *A. bimaculata* (Forest *et al.*, 2011). The higher toxicity of rotenone to insects and fish is due to the fact that the lipophilic rotenone is easily conveyed through trachea and gills but not easily conveyed through the skin and gastrointestinal tract (Ene *et al.*, 2010). Several studies have reported the effectiveness of *T. vogelii* in controlling insect pests on various crops and proved to be effective (Mkindi *et al.*, 2020; Mpumi *et al.*, 2021).

The effectiveness of rabbit urine in controlling insect pests may be attributed to the fact that it contains high amount of ammonia which is caused by high level of nitrogen (Wandita *et al.*, 2016). Ammonia is toxic and at certain concentrations may harm organisms depending on the species. For example, ammonia at a concentration higher than 5ppm (parts per million) affects invertebrates compared with vertebrates and even within invertebrates, it may varies from species to species (Dias *et al.*, 2019). Currently, ammonia has been reported being effective in controlling pests (Epa & Programs, 2004). Insects pests are controlled by direct contact with ammonia or by breathing in ammonia where it extirpates the respiratory surface of the insect pest to death. Since ammonia is corrosive in nature once it gets into direct contact with the insect pest bodies it may ruins the insect to a point of death (Dias *et al.*, 2019). The toxicity of ammonia to insects is higher due the fact that in a very low concentration, invertebrates including insects get harmed but that same concentration does not affect vertebrates including human being. This can be attributed by the body size (Mathew *et al.*, 2015).

In addition, this study also evaluated the percentage damage of the *S. indicum* by insect pests in the field. The results showed that, sesame plants sprayed with the formulation of 10% *T. vogelii* + 50% rabbit urine possessed significantly ($p \leq 0.001$) lower (28.33 ± 1.67, 23.33 ± 1.67, 20.00 ± 0.00, 16.67 ± 1.67 and 15.00 ± 2.89) percentage damage of *S. indicum* when compared with those sprayed with other formulations and synthetic pesticide from week 1 to 5 respectively. However, and the higher percentage damage of the *S. indicum* in the field was recorded in sesame plants sprayed with negative control treatment.

Also, the study assessed population abundance of natural enemies in the field after application of treatments. The results also showed that, sesame plants sprayed with the formulations used to control the insect pests possessed higher population of natural enemies compared with those sprayed with synthetic pesticide in the field while a formulation 10% *T. vogelii* + 50% rabbit was leading by having the higher number of natural enemies among other formulations used.

Moreover, the study reports the effectiveness of *T. vogelii* formulation with rabbit urine on yield of sesame. It was found that, high seed yield was recorded in plots treated with the formulation of 10% *T. vogelii* + 50% rabbit urine compared with those treated with other treatments followed by those treated with synthetic pesticide. However, the lowest yield was recorded in the negative control treatment plots. The low yield in negative control is due to the fact that heavy infestation of insect pests affected the yield by reducing the sesame seed weights at the field (Dossa *et al.*, 2017). This study suggests that the formulation of 10% *T vogelii* + 50% rabbit urine, can be used by the smallholder farmers to control insect pests in the *S. indicum* field in African countries to reduce the effects of using synthetic pesticides such soil and water contaminations, ecosystem and health disturbances. The dosage recommended per spray in hectare is 27.8kg of *T. vogelii* leaves and 139 liters of rabbit urine per spray. More studies on different concentrations of rabbit urine to get the best concentration required to effectively control the insect pests in different crops is highly needed.

Conclusion

In this study *T. vogelii* formulation with rabbit urine was very effective in controlling insect pests of sesame, reducing the percentage damage level of *S. indicum* and enhance yield compared synthetic pesticide. Its use avail to reduce the need for synthetic pesticide by sustainably reducing the number of insect pests, reducing the percentage damage level of the *S. indicum* crop hence increasing yield. Therefore, the individual formulations at higher concentrations and the mixture of formulations 10% *T. vogelii* + 50% Rabbit urine can be used to control insect pests in the field in place of synthetic pesticides. The results divulged the significant of mixing of the formulations which induced extension of insecticidal efficacies in mitigation of the damage of *S. indicum* by insect pests in the fields compared with the negative control. Therefore, the present study suggests the use of the formulations 10% *T. vogelii* + 50% Rabbit urine for the control of insect pests of *S. indicum*.

Author Contribution

All authors read and approved the final manuscript for publication.

Funding

This work was supported by Agro Ecology Hub Tanzania (AEHT) and Centre for Research, Agricultural advancement, Teaching Excellence and Sustainability (CREATES) through The Nelson Mandela African Institution of Science and Technology (NM-AIST), Arusha, Tanzania.

Acknowledgements

The authors are grateful to The Nelson Mandela African Institution of Science and Technology, Arusha (NM-AIST) Tanzania for providing institutional support for this study and Agro Ecology Hub Tanzania (AEHT) for proving fund of this study. The author thankfully recalls the cooperation of the Principle Agricultural Field Officer (PAFO 1) Ms. Florence Rashid Ntua, Singida region for providing permission to conduct the study. The author also profoundly appreciates the contribution of Mr. Nelson Mpumi for availing in finding a research site.

Conflict of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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