Research Article

Effectiveness of *Tephrosia vogelii* and *Tephrosia candida* Extracts against Common Bean Aphid (*Aphis fabae*) in Malawi

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Common beans (*Phaseolus vulgaris*) remain an important dietary protein source in Malawi. However, its production is highly hindered by insect pest and disease attack. The study aimed at evaluating the effectiveness of *Tephrosia vogelii* and *Tephrosia candida* extracts against bean aphid (*Aphis fabae*). The evaluation involved two botanical extracts at three different concentrations (0.5%, 2%, and 5% w/v) against bean aphid. Plant extracts (leaves) were air-dried and milled. Powders were then soaked in a 2-litre plastic bucket of cold water. Results indicated that there was significant difference (*P* < 0.05) among treatments. The effectiveness of the treatments was based on reduction in aphid population per plant, pod length, and bean yield. Pod length and bean yield were higher in *T. vogelii* and Karate as compared to untreated and *T. candida*. There was a high mortality rate of aphid on the plots treated with *T. vogelii* compared to plots treated with *T. candida* at the same concentration. Though these two plant extracts were not as effective as the synthetic insecticide in reducing aphid population, they were considerably and significantly found to be effective; hence, its use by poor-resource farmers is recommended in the protection of bean against aphid.

1. Introduction

Crop production is hindered by multiple factors that are impacting global food and nutrition security (Michalik et al., 2006; Nderitu et al., 2010; [1]). It is anticipated that by 2050, pressure on food and nutrition requirements is likely to increase due to projected population increase (Stevenson and Belmain, 2017). This entails that production of crops as food and nutrition source is paramount. Therefore, production of common bean (*Phaseolus vulgaris* L.) in Malawi has become an important dietary food and cash crop lately. Despite year round availability of beans to maintain food and local market demand, its production systems are so challenging ([2]; Nderitu et al., 2010). For instance, this crop is produced by smallholder growers whose farm size is ranging from 0.25 to one hectare; climatic variability and pest and disease attack remain some of the critical challenges. However, the highest damage and yield losses on common bean production emanate from pest and disease attack with average yield loss of 10 to 37 percent (Nderitu et al., 2010; [3, 4]). So far, the damage by bean aphid is critical at all development stages of the plant growth since it feeds on young leaves, flower buds, and young pods. The damage on leaves leads to retarded growth, while on blossoms it makes the flowers prematurely abort, hence causing low yield (Nderitu et al., 2010).

The yield losses encountered due to pest pressure make controlling aphid inevitable and the common practice of insect control in developing countries depends largely on the use of synthetic insecticides. However, in most African countries, farmers tend to neglect because of high costs of these synthetic pesticides [5]. Although synthetic pesticides approach to pest control has been proven to be effective, there are yet several constraints associated with it [6]. These chemicals disturb natural balance of organisms in an ecosystem, increase insect pest resistance and resurgence, escalate cost of production, and are harmful to farmers as end users [1].
These risk factors are shifting more farmers into use of either organic compounds or no use of any chemicals at all (Nderitu et al., 2010; Nyirenda et al., 2011). These factors, therefore, have negative contributions towards bean production in Malawi. The use of organic pesticides (botanicals) is currently promoted because of multiple benefits. Basically, these plant materials could be propagated locally and their extracts are biodegradable (Belmain and Stevenson, 2001; [6, 7]). They are also less harmful to beneficial and nontarget insects because of production of unique secondary metabolites which do protect other herbivores ([7–10]). Moreover, plant extracts are less expensive and easily available because of their natural occurrence (Singh and Saralchand, 2005; Sadek, 2003; and Egho and Emosarrue, 2010).

The commonly used botanical as pesticide by smallholder farmers in Malawi is *Tephrosia vogelii* (Nyirenda et al., 2011). *Tephrosia* species belongs to leguminosea family. They can grow as high as 2-3 metres in approximately 210 days. These species have been extensively cultivated across Africa for multiple uses [11, 12]. Local communities worldwide have been using *Tephrosia* to catch fish through poisoning [13], serve as animal feed supplement [14], and improve soil fertility [15]. It is reported that these shrubs have greater biomass though *Tephrosia candida* is said to produce higher biomass than *Tephrosia vogelii* [11]. However, both species were introduced in Africa and later in Malawi particularly for soil fertility improvement program as green manure and cover crop [15]. Interestingly, these species are extensively promoted and cultivated for both soil fertility improvement and pest control [11, 16].

*Tephrosia vogelii* and *Tephrosia candida* have been reported to have pesticidal properties though the challenge has been their efficacies. Studies have revealed that both are rich sources of flavonoids, rotenoids, terpenoids, and sterols as secondary metabolites (Stephen and Wayne, 2003). Active ingredients like tephrosirolactone, tephrosirokesterolsassecondarymetabolites (StephenandWayne,2003).arerichsourcesofflavonoids, rotenoids, terpenoids, and has been their efficacies. Studies have revealed that both reported to have pesticidal properties though the challenge quantities of these products are reported to be very low or important compounds which have insecticidal properties are also less harmful to beneficial and nontarget insects because of production of unique secondary metabolites which do protect other herbivores ([7–10]). Moreover, plant extracts are less expensive and easily available because of their natural occurrence (Singh and Saralchand, 2005; Sadek, 2003; and Egho and Emosarrue, 2010).

2. Materials and Methods

2.1. Experimental Site. On-farm trials were conducted at Ntchenachen Extension Planning Area (EPA) in Rumphi district from October to August 2017 to 2018 bean growing seasons. Ntchenachen site lies in the latitude 10° 41.788’ N and longitude 34° 03.013’ S with an altitude of 1304 m above sea level. Rumphi district is one of the six districts in the northern part of Malawi. It is located within the highlands of Viphya and Nyika plateau latitudes between 1300 m and 1700 m above sea level, respectively. It has a population of 169,112, mostly Tumbuka tribe of which 85 percent of the population are bean farmers [17].

2.2. Experimental Design. A Randomized Complete Block Design with eleven treatments and four replications was used to conduct this study. The treatments consisted of 6 doses as follow: 0.5%, 2%, and 5% weight per volume (w/v) extracted using soap and 5% extraction without soap (wts), 0.01% and 0.001% volume per volume (v/v) of soap (dish washing liquid), and Karate-Lambda cyhalothrin Emulsified concentrate (EC), respectively. The experimental plots were measuring 5 m x 5 ridges. Ridges were spaced at 0.75m and bean var. Kholophete was planted singly at 0.15m. A space of 0.5m was separated by a pathway. Each experimental plot had four ridges gross with two middle ridges as net plot.

2.3. Choice and Collection of Plant Materials. The choice of plant materials used in the study was based on previously reported insecticidal properties of the plants against many insect pests (Nyirenda et al., 2011). The chemical composition of *Tephrosia* species was reported to vary depending on locality [18]. The plant materials (leaves) were collected from Ntchenachen EPA. The plant parts were plucked by hand and put in either sacks or bucket to the drying shed in readiness for extraction.

2.4. Plant Material: Collection and Preextraction Procedure. Samples of *Tephrosia vogelii* and *Tephrosia candida* leaves were collected locally at Ntchenachen in Northern part of Malawi. These plant leaves were collected in the dry season (September and October) because of seasonal variation in plant chemistry [15]. The part of the plant collected was specifically leaves which were neither very old nor very fresh. Leaves of the plant materials were collected because of high concentration of active ingredients [1]. Collected leaves were air-dried under well-ventilated shade at an ambient temperature around 24-28°C Celsius for 1-2 weeks. Locally, farmers at Ntchenachen use tobacco curing sheds as an ideal drying area. Dried leaves were pulverised and sieved into fine powder using local grinder (mortars) and a 0.2 mm wire mesh was used for sieving. The product was then weighed, packed, and sealed in plastic papers and kept under room temperature ready for use.

2.5. Preparation of Aqueous Extract. Extracts of the botanicals were prepared following Rezaul Karim et al’s [19] protocol of weight by volume (w/v). Each product was prepared at a concentration of 5%, 2%, and 0.5% w/v of the powder, respectively [20]. It was then soaked in a plastic bucket containing 2 litres of cold water at room temperature (24°C–30°C). In general, cold water was used as opposed to hot water to avoid readsorption during cooling water and that may affect the active compounds [21]. The resulting solution was stirred continuously for 5 minutes and left to stand for 12 hours and later filtered shortly before application in the field. Finally, each of filtrates was diluted with 4 litres of cold water. The incorporation of 0.01% soap early in the
### Table 1: Rating scale for aphid infestation and severity.

| Rating | Incidence | Infestation/severity |
|--------|-----------|----------------------|
| 1      | 0         | No infestation       |
| 2      | ≤ 100     | Slightly infested    |
| 3      | ≥ 200 but ≤ 300 | Moderate     |
| 4      | ≥ 300 but ≤ 400 | High infestation |
| 5      | ≥ 400     | Severe infestation   |

*Source: adopted from Litsinger et al. [22].*

### Table 2: Mean aphid infestation and abundance of two botanicals extracts at different concentrations.

| Treatment          | 1st Spray (initial) | 2nd Spray | 3rd Spray |
|--------------------|---------------------|-----------|-----------|
| Unsprayed          | 2.400<sup>de</sup>  | 3.475<sup>g</sup> | 1.775<sup>g</sup> |
| Soap               | 1.550<sup>b</sup>   | 2.300<sup>d</sup> | 3.375<sup>g</sup> |
| T. vogelii 0.5%    | 2.700<sup>ed</sup>  | 1.500<sup>c</sup> | 3.300<sup>de</sup> |
| T. vogelii 2%      | 1.775<sup>bc</sup>  | 1.625<sup>c</sup> | 2.000<sup>f</sup> |
| T. vogelii 5%      | 2.975<sup>f</sup>   | 0.800<sup>b</sup> | 1.275<sup>b</sup> |
| T. vogelii 5% wts  | 2.175<sup>de</sup>  | 1.450<sup>c</sup> | 1.200<sup>b</sup> |
| Karate             | 2.325<sup>de</sup>  | 0.075<sup>a</sup> | 0.175<sup>a</sup> |
| T. candida 0.5     | 3.075<sup>f</sup>   | 2.375<sup>d</sup> | 3.300<sup>de</sup> |
| T. candida 2%      | 1.425<sup>ab</sup>  | 1.400<sup>c</sup> | 3.250<sup>de</sup> |
| T. candida 5%      | 2.325<sup>de</sup>  | 2.475<sup>d</sup> | 3.800<sup>d</sup> |
| T. candida 5% wts  | 0.95<sup>a</sup>    | 2.225<sup>d</sup> | 3.000<sup>d</sup> |
| LSD                | 0.51                | 0.56      | 0.37      |
| CV %               | 43.0                | 17.6      | 6.1       |

*Means followed by the same letter are not significantly different according to Fisher's least significant difference test.*

### 2.6. Data Collection and Statistical Analysis.

Stand count at germination data (net plot) was collected 3 weeks after planting. Counting of aphid was visually done five weeks after planting (WAP). Aphid incidence and severity were assessed every fortnight from the two central ridges as net plot. Ten plants per treatment in each replicate were sampled and scored for the presence and abundance of aphid were recorded. The two middle ridges (net plots), ten plants, were randomly selected and tagged. Each of the ten plants was observed for aphid infestation. The colony size was visually scored based on a scale of 1-5 points as indicated in Table 1 [20, 22]. The number of plants infested and severity of infestation was recorded per plant in each plot. At maturity, pods were harvested from the net plots together with the 10 tagged plants which where separately assessed for the number of pods harvested. The assessment was based on effectiveness of the treatments on aphid reduction in population per plant.

Data were subjected to one-way analysis (ANOVA), while multiple comparison tests were made using the least significant difference (LSD) to separate treatment means at 95 percent level of significance. All statistical analyses were done by GenStat 14.1 version for Windows fourteenth edition. Graphs and tables were generated by using Microsoft Excel computer package.

### 3. Results

Infestation levels of aphid at each cycle of spray were observed and there was significant variation ($P<0.05$) in the severity of aphid in all treatments. Initial aphid count at 1st spray indicates slight to high infestations of aphid across treatments (Table 2). There was moderate aphid infestation on plots treated with *T. vogelii* extracts at a concentration of 5% w/v. Lower concentration of *T. vogelii* (0.5%, 2% w/v) extracts and *T. candida* (0.5%, 2%, 5% w/v) did not reduce the population of aphid during 1st spray and 3rd spray count. The severity of aphid on unsprayed escalated during 2nd spray and reduced at 3rd spray count. Plots treated with Karate showed lower infestation of aphid during 2nd and 3rd spray count (Table 2). The initial stand count of bean plants at germination was not significantly different between treatments ($P<0.05$, Figure 1(a)). At harvesting, the number of pods, its length, and yield of marketable shelled bean grains were significantly different between the control and treated
plots at different extraction concentrations. The average yield of pod number in all treatments ranged from 55 to 90. Plots sprayed with *T. vogelii* and *T. candida* had the highest pod number at higher extraction concentration of 5% w/v with and without soap (Figure 1(b)). The length of pods ranged from 10.4 cm to 11.4 cm across treatments. The length of bean pods treated with *T. vogelii* at the rate of 5% w/v and Karate had the longest pod length (Figure 1(c)). Figure 1(d) indicates considerably higher shelled bean weight on plots treated with *T. vogelii* at 5% w/v as compared with *T. candida* at the same concentration. Unsprayed and soap treatments had the least shelled bean yield.

4. Discussion

*Tephrosia vogelii* at 5% w/v reduced aphid infestation and consequently population. Significant reduction in infestation and population of aphid in treated plots with *Tephrosia vogelii* at a higher concentration would be a result of direct chemical contact and repellent. Hence, bean aphid must have been in direct contact with the active toxic substances. Bean aphids are less mobile and can rarely fly [23]. Therefore, botanical pesticidal sprays were directly in contact with aphid making them sluggish and later died.

This study results agree with observations by Stevenson and Belmain, 2017 that the strong toxic effects present in rotenoid had an effect on aphid population reduction. The presence of isoflavonoids which are toxic substances in *T. vogelii* might have reduced the presence and population of aphid ([15]; Stevenson and Belmain, 2017). According to Boek et al., 2004 and Gaskins, 1972 [24], the active components in leaves of *T. vogelii* are reported to have antifeedant, insecticidal, acaricidal, ovicidal, ichthyotoxic and be a cause of stomach poison to insects.

The highest level of infestation on unsprayed at second spray which dropped at third spray could have been attributed to availability of some plants that survived the pressure on aphid population. Similarly, the population of aphid considerably reduced on unsprayed because field observations showed that most of the plants were wiped out by third
scores. Regarding the survivability of insect, where increased competition in feeding is quite high, the population reduces [25]. Therefore, the major determinant on reduction in the presence of aphid population at third spray was due to high aphid mortality and high competition on food where the population size is affected by impinging effects on available plants as source of food.

The possibility of Tephrosia candida having the highest aphid infestation suggests the absence of or very little rotenoids present despite the presence of tephrosin and deguelin (Allan et al., 2009, [15, 26]). Tephrosia vogelii at 5% extraction with soap showed to be more effective compared to T. candida at the same concentration. Previous studies by Matovu and Olila [27] indicated that if botanicals are to be effective in controlling insect pest under field conditions, the ideal concentrations should be between 12.5 and 25% w/v. This entails quite enormous amount of botanical extracts to be collected and that may not be cost effective and environmentally friendly. This study, however, indicates that as low as 5% w/v extracts were able to reduce aphid infestation below economic threshold. However, extraction process at a higher concentration without using soap was not as effective because soap helped to dissolve and disperse active ingredients (Stevenson and Belmain, 2017).

The effectiveness of botanicals was also evaluated based on bean yield. Results showed an increase in shelled bean yield in plots where Tephrosia vogelii was sprayed. However, the number of pods harvested greatly varied impacting on bean yield levels. It was observed that plants highly infested with aphid had the pods either empty or aborted. Thus, the number of pods did not translate to increased harvests in terms of bean grains. Field observations showed that severe attack of aphid was during critical growth stages (vegetating, flowering, and podding) and that probably contributed to yield variations (Nyirenda et al., 2011). Unsprayed plots (control) had the lowest yield due to severe aphid attack. Our observations also showed that bean crop at early growth stages were greatly attacked by bean aphids. Severely attacked bean plants lead to loss of leaves. Generally common bean crop (Phaseolus vulgaris) is very sensitive to defoliation at the primary leaf stage, during flowering, and early pod formation [28]. It was observed that where aphid population was high, leaf defoliation was critical. This therefore might have contributed to reduction in bean yield.

5. Conclusion and Recommendations

The study has demonstrated the possibility of using extracts from T. vogelii and T. candida on bean aphids since farm products for protection is believed to reduce infestation levels of various pests below economic threshold level and can substantially increase yield. The present study has demonstrated that T. vogelii at 5% w/v concentration reduced common bean aphid which also led to higher yields than T. candida. It is, therefore, recommended that T. vogelii can be integrated in pest management options. It has the ability and potential to increase common bean production through aphid population reduction. Aphid population was apparent in plots treated with T. candida and untreated treatments.

However, aphid population reduction was evident on plots treated with T. vogelii than that treated with T. candida. This conclusion was reached since pods without bean seeds lead to equally lower yield in the T. candida and untreated control than where T. vogelii or Karate was applied. Considering the eco-friendly and nontoxic nature of pesticidal plants, T. vogelii may, therefore, be recommended for the suppression of bean aphids in the field. In general, T. vogelii treatments produced significantly lower damaged bean yield than unsprayed control treatment that may result into higher incomes. Furthermore, many poor-resource farmers do not have the financial capacity to purchase synthetic pesticides but have ability to freely collect and prepare plant materials for use in pest control. Therefore, farmers are encouraged to incorporate the use of Tephrosia vogelii on aphid control. However, the study has been unable to reveal the correlation between aphid presence and pod formation as a crucial yield component as well as application intensity. Nevertheless, differences in the efficacy of T. vogelii and T. candida have been found. In view of this study, it seems appropriate to conclude that some knowledge on the use of pesticidal plants has been validated and may contribute to bean aphid control amongst poor-resource farmers in developing countries.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Disclosure

The authors take full responsibility for any error. The content of this document is the sole responsibility of the authors and can under no circumstances be regarded as reflecting the position of the SADC Secretariat or the European Union.

Conflicts of Interest

The authors declare that there are no conflicts of interest in relation to publication of this research paper.

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