

## Original Research Article

Effectiveness of plants extracts and mycoinsecticide on management of cowpea flower thrips  
*Megalurothrips sjostedti* (Thysanoptera : Thripidea) under field conditions

### ABSTRACT

To promote the use of natural substances for better management of the cowpea thrips *Megalurothrips sjostedti*, the potential of aqueous extract of *Azadirachta indica*, *Boswellia dalzielii* and *Metarhizium anisopliae*, alone and their combinations in comparison with the synthetic chemical insecticide (Decis) were tested. The experiments were carried out in two cowpea varieties under field conditions within the Sudano-Sahelian agro-ecological zone of Cameroon. Trials were arranged in a completely randomized block design with nine treatments. The nine treatments consisted of a negative control, *A. indica*; *B. dalzielii*; *M. anisopliae*, *A. indica* + *B. dalzielii*; *M. anisopliae* + *B. dalzielii*; *M. anisopliae* + *A. indica*; *M. anisopliae* + *A. indica* + *B. dalzielii* and Decis. Each treatment replicated four times. *Vigna unguiculata* plants were sprayed from flowering stage thrice with insecticidal products at 5 day intervals. The density of adults and larvae thrips was assessed on 5 flowers per block during 5 days after the last spraying of treatments. Results showed that, there were more thrips on Bafia variety than B125 variety ( $p < 0.0001$ ). All the tested treatment significantly ( $p < 0.0001$ ) reduced the cowpea flower thrips of 30% for *A. indica*, *B. dalzielii* and *A. indica* + *B. dalzielii*, 75% for *M. anisopliae* and its various combinations, and of 90% for Decis. Plants extracts, mycoinsecticide and their combinations considerably reduced damage induced by thrips compared to the negative control. *A. indica*, *B. dalzielii*, *M. anisopliae* and their combinations showed ability as natural traitement for the management of thrips in *V. unguiculata*. These products do not only protect *V. unguiculata* crop from its major pest, but also preserve the environment from harmful effects induced by the use of synthetic commercial pesticides.

**Keywords:** *Azadirachta indica*; *Boswellia dalzielii*; *Metarhizium anisopliae*; *Vigna unguiculata*; Efficacy.

## 1. INTRODUCTION

Agriculture plays an important role in the development of many countries (Adeoti *et al.* 2002). Hence, the cultivation of legume crops such as cowpea is necessary to promote diversified incomes. In Cameroon, cowpea is the staple food in the entire country. It is used in several dishes (Nielsen *et al.* 1997) by all the ethnics in the country and it is called in some localities 'meat of poor', because it sometimes replaces animal protein in some dishes. Cowpea is cultivated in almost all the different agroecological zones of the country due to its economic value. It generates incomes for the farmers and provide them with food during hungry gap (Odion *et al.* 2017). In addition to its nutritional qualities (Ndiaye 1996), cowpea improves the soil fertility by its ability to naturally fix the atmospheric nitrogen (Okigbo *et al.* 1978). However, very useful, the yield of this crop is slow in Cameroon even though the demand in cowpea grain is still growing.

Unfortunately, cowpea cultivation is faced with several constraints, such as fungal, bacterial and viral diseases (Singh *et al.* 1997), and insect pests, all of which are responsible for serious damages yield and losses (Tamò *et al.* 1993). Among the insect pests, cowpea flower thrips (*Megalurothrips sjostedti*) has been reported as the most harmful, because more than 80% of yield loss is attributed to this pest (Omo-Ikerodah *et al.* 2009). This justifies the necessity to protect cowpea from this damaging insect pest.

Previous studies have shown that, management of cowpea thrips is attributed to the use of synthetic insecticides (Alghali 1992-; Karungi *et al.* 2000). Deplorably, the use of these synthetic pesticides has many harmful effects on other organisms and the environment (Bambara and Tiemtoré 2008). Commercial insecticides are expensive and also acidify the soil in case of misuse, while their residues are toxic to non-target organisms, in addition to resistance development by insect pests (Immaraju *et al.* 1992-; Margni *et al.* 2002). More so, they pollute surface and groundwater through leaching (Ouédraogo 2004). Therefore, the promotion of eco-friendly control strategies to manage the density of *M. sjostedti* in field is important.

Several plant extracts provide natural insecticides, and can be used as substitutes to synthetic chemical insecticides (Barry *et al.* 2017). Neem tree (*Azadirachta indica*) has been shown as a potential insecticidal plant (Mouffok *et al.* 2008). Its extract has been shown efficacy in controlling many harmful insect species (Harouna *et al.* 2019). Other plants such as *Boswellia dalzielii* has been used to protect stored food grains (Kémeuzé *et al.* 2012). These properties make these two plants potential alternatives to synthetic pesticides. The use of entomopathogenic fungus ~~M. Metarhizium~~ *Metarhizium anisopliae* against the flower thrips was discussed by Mfuti *et al.* (2021), and has shown insecticidal potential against cowpea flower thrips (Ngakou *et al.* 2008).

~~The~~ comparative effects of combination of *B. dalzielii* and *A. indica* extracts with *M. anisopliae* in the sudano-sahelian agroecological zone for the management of cowpea flower thrips under field conditions has ~~not yet~~ been investigated. ~~This justifies t~~The investigation of these products as potential alternative to ~~synthetic insecticides in the~~ management of cowpea flower thrips was carried out in this study.

## MATERIALS AND METHODS

### 1.1. Study area

Comment [R1]: Add author

Comment [R2]: Add author

Comment [R3]: Add author

Comment [R4]: Investigating the potential of *B. dalzielii*, *A. indica* and *M. anisopliae* to management of cowpea flower thrips is a better justification than the lack of study in the area.

Comment [R5]: Here is sub-item 2

The experiment was carried out in Béguélé-Maroua located in the subdivision of Maroua, Far-North region of Cameroon. The climate of the region is Sudano-Sahelian, characterized by a mean annual rainfall of about 757.2 mm and a mean annual temperature of about 28 °C. This region has two seasons, a dry season from November to May and a raining season from June to October. The vegetation in this area is characterized by shrub savannah locally arboreous with various grasses. Trials were conducted for two consecutive years (2014 and 2015), and the field GPS coordinates are latitude 10°35'58.3" N; longitude 14°11'28.4" E; altitude 450±2 m.

## 1.2. Plant materials

Plant materials consisted of two cowpea varieties: the local Bafia multiplied locally during subsequent work, and the B125 provided by the 'Institut de la Recherche Agricole pour le Développement (IRAD)' Maroua. The B125 variety was an early maturing variety (75 days), whereas the Bafia variety was an intermediate maturing variety (85 to 95 days). The leaves of *Azadirachta indica* (Meliaceae) and *Boswellia dalzielii* (Burseraceae) were collected in Maroua at the locations of geographical coordinates: latitude 10°35'27.1" N; longitude 14°17'32.34" E; altitude 409±2 m above sea level, and latitude 10°37'37.95" N; longitude 14°12'4.19" E; altitude 457±2 m above sea level respectively.

## 1.3. Cropping calendar

The sowing was carried out on August 23<sup>rd</sup> for the first season (2014), and August 24<sup>th</sup> for the second (2015). The cowpea crop reached their maturity after 75 and 95 days after sowing respectively for B15 and Bafia varieties concerning the first year of cropping (2014). While in the second year, the same varieties in the same period reached their maturity after 75 and 87 days of sowing respectively.

## 1.4. Formulation of Insecticides Products

The aqueous extract of *A. indica* leaves was obtained in accordance the method recommended by Sahel People Service. Five litres of solution was obtained by macerating 1 kg of *A. indica* fresh leaves in water. The resulting concentrated macerate was then diluted to 10% with water and filtered through a 0.4 mm mesh tissue, for a working concentration of 20 g/L. The same method was applied to obtain the aqueous extract of *B. dalzielii*. The *M. anisopliae* based solution was obtained using the method described by Ngakou *et al.* (2008), which requires the mixture of 50 g of *M. anisopliae*, 700 mL of kerosene and 300 mL of cotton oil (Diamor stamp). *Metarhizium anisopliae* was prepared at a concentration of 10 g/L. The myco-insecticide *M. anisopliae* originated from IITA Cotonou-Benin, while Deltamethrin-based synthetic insecticide (Decis) was purchased from a phytosanitary store and was prepared by diluting 3 mL of Decis in 15 L of water.

## 1.5. Experimental layout and Treatments

Plants were grown on flat surface measuring 57.75 × 25 m<sup>2</sup>. The experimental field was divided into two parts representing each a cowpea variety separated by 4 m path. The experimental plots representing the treatments were 4.5 × 1.5 m<sup>2</sup> for B125 variety, and 4.5 × 2.25 m<sup>2</sup> for Bafia variety. Seeds were planted at 50 cm distance from one plant to another, and the distance between rows of plants was also 50 cm for the early maturing variety. On the intermediate maturing variety, the distance between plants was 50cm but between rows its was 75 cm; giving a population of 40 plants per plot for each variety. Treatments were sprayed using four distinct manual gauge sprayers (AgroPro stamp) purchased from a phytosanitary store, each corresponding to a

specific insecticidal product. For multi-product treatments, each component was sprayed separately. Treatments were applied early in the morning between 6 and 8 a.m, 3 times at 5 days interval, as soon as the appearance of the first flower was noticed.

The experimental design applied for each variety was completely randomized which consisted of 9 treatments, each replicated 4 times. The treatments were: T1, negative control representing plots that did not receive any treatment; T2, plots treated with aqueous *A. indica* leaves extract; T3, plots treated with aqueous *B. dalzielii* leaves extract; T4, plots treated with *M. anisopliae* formulation; T5, plots treated with the combination of *M. anisopliae* + *A. indica*; T6, plots treated with the combination *M. anisopliae* + *B. dalzielii*; T7 plots treated with the combination *A. indica* + *B. dalzielii*; T8, plots treated with the combination of the three bioinsecticides *M. anisopliae* + *A. indica* + *B. dalzielii*; T9, plots treated with the synthetic insecticide Decis.

**Comment [R6]:** The 9 treatments can be presented in a table.

### 1.6. Assessed Parameters

The assessed parameters were thrips density and leaf damage. All these parameters were assessed compared to the control. The evaluation of adults and larvae of thrips were carried out on 5 flowers per block during 5 days after the three spraying (Nderitu *et al.* 2007; Ngakou *et al.* 2008) for all treatments. The leaf damages were determined by observing and counting the number of holes on perforated cowpea leaf for each treatment.

**Comment [R7]:** Several phytophagous insects cause holes in cowpea leaves. It better describes how the holes were counted and differentiated in cowpea leaves.

### 1.7. Statistical Analysis

The statistical analysis was carried out using the SAS software version 9.1. The number of adults and larvae, and cowpea leaf damage were subjected to the analysis of variance (ANOVA) to split the means between all the treatments. The Student-Newman-Keuls test at  $5\% p < 0.05$  was used to compare the different treatments and the T-test to compare two varieties in the same year and or the same variety the two years for cropping concerning the different assessed parameters (adults and larvae thrips populations, and leaf damage).

## 2. RESULTS

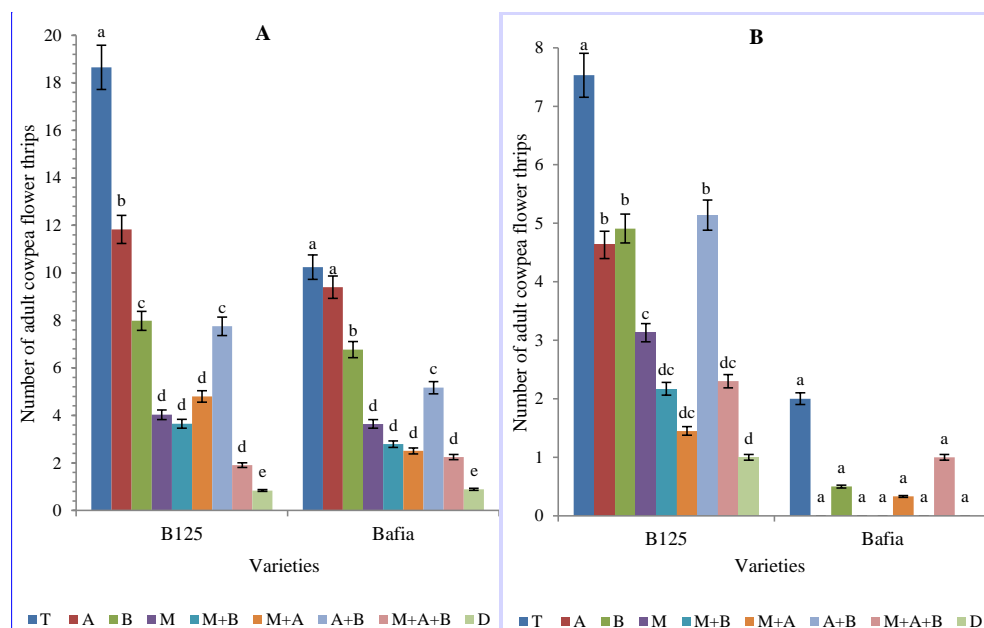
**Comment [R8]:** Here is sub-item 3

### 2.1. Impact botanicals application on the thrips population density

#### 2.1.1. Adults

There were more adult thrips on the cowpea flowers of B125 variety ( $6.82 \pm 0.23$ ) than Bafia variety ( $5.00 \pm 0.19$ ) in 2014 ( $Df=1302.5$ ;  $t=6.04$ ;  $p<0.0001$ ) and 2015 ( $B125=3.59 \pm 0.18$ ;  $Bafia=0.56 \pm 0.22$ ;  $Df=42.33$ ;  $t=10.43$ ;  $p<0.0001$ ). All treatments applied to cowpea variety B125 significantly ( $p<0.0001$ ) reduced the density of adult thrips population compared to the negative control during the 2014 cropping season (Figure 1A). Among the natural insecticidal treatments, *A. indica* extract with 30% adult thrips reduction was the least effective treatment. *Metarhizium*, *M. anisopliae* and its various combinations reduced the density of adult thrips by 75%, but the synthetic insecticide Decis was more effective in reducing the density of adult thrips by 90%. On Bafia variety, apart from treatment *A. indica* which had many adult thrips as in the negative control, the other treatments significantly ( $p<0.0001$ ) reduced the adult thrips population density compared to the negative control. *Boswellia*, *B. dalzielii* extract was only able to reduce 20% of adult thrips. Despite being more effective than plant insecticides, *M. anisopliae* and its various combinations (*M. anisopliae* + *A. indica*, *M. anisopliae* + *B. dalzielii*, and *M. anisopliae* + *A. indica* + *B. dalzielii*) were less effective than Decis.

In 2015 (Figure 1B.), treated cowpea plants with different insecticidal formulations significantly reduced the density of adult thrips compared to the negative control ( $p < 0.0001$ ) on variety B125. Treatments of *A. indica* and *B. dalzielii* reduced the density of adult thrips by 30%, and appeared less than the other insecticidal treatments. As in 2014, *M. anisopliae* combinations were the most effective natural insecticides but did not reach the efficacy of Decis. There was no significant difference between the different insecticidal treatments and the negative control on the Bafia variety in 2015 ( $p = 0.480$ ).



T: Negative control; A: *A. indica*; B: *B. dalzielii*; M: *M. anisopliae*; M+B: *M. anisopliae* + *B. dalzielii*; M+A: *M. anisopliae* + *A. indica*; A+B: *A. indica* + *B. dalzielii*; M+A+B: *M. anisopliae* + *A. indica* + *B. dalzielii*; D: Decis. For each cowpea variety bars denoted by the same upper-case letter are not significantly different between treatments at the indicated level of probability ( $p < 0.05$ ) (Student–Newman–Keuls test).

**Fig 1.** Variation of adult thrips population density between treatments of the cowpea B125/Bafia varieties in 2014 (A) and 2015 (B).

### 2.1.2. Larvae

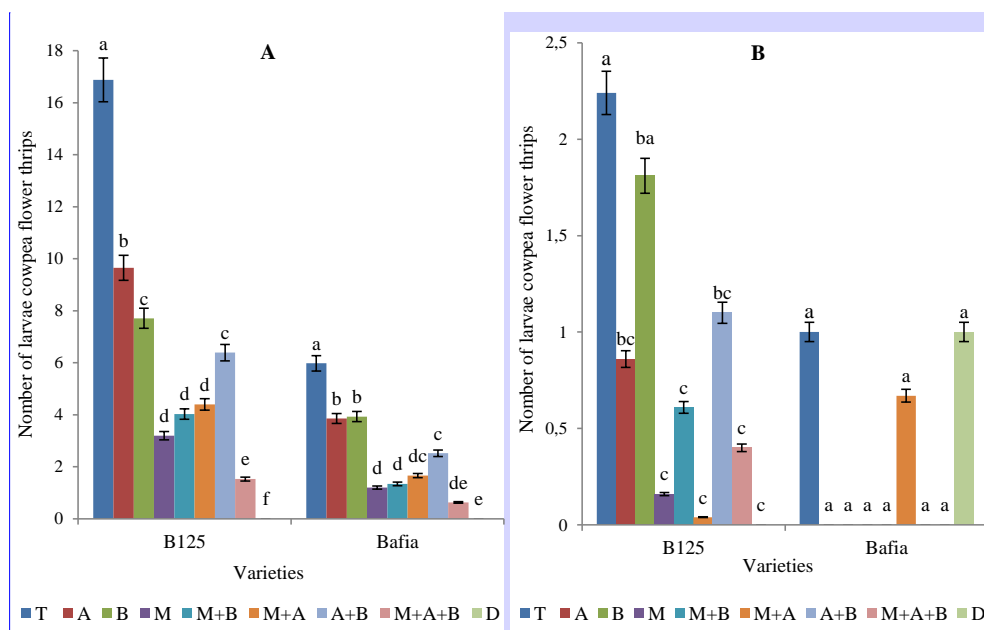
The effect of natural insecticide on the thrips larvae population was similar to that on adults. There were more thrips larvae on cowpea B125 variety ( $5.97 \pm 0.22$ ) than Bafia variety ( $2.43 \pm 0.12$ ) in 2014 ( $Df = 1125.6$ ;  $t = 13.65$ ;  $p < 0.0001$ ), and in 2015 ( $B125 = 0.80 \pm 0.10$ ;  $Bafia = 0.31 \pm 0.17$ ; ( $Df = 26.48$ ;  $t = 2.44$ ;  $p < 0.0215$ ). It was evident that all insecticidal formulations significantly ( $p < 0.0001$ ) reduced the larvae thrips population compared to the negative control of both cowpea B125 and Bafia varieties in 2014 (Figure 2A). The synthetic insecticide Decis eliminated all of the larvae thrips on flowers of the two varieties. On variety B125, despite a 50% reduction in larvae, *A. indica* extract was the least effective natural insecticide. The ternary combination, *M. anisopliae* + *A. indica* + *B. dalzielii* was the most effective natural insecticide with 90% reduction of larvae on both B125 and Bafia varieties. *Azadirachta indica* and *B. dalzielii* were the least effective natural insecticide treatments on Bafia variety with 30% reduction.

Formatted: Space After: 10 pt

**Comment [R9]:** In Figure B (2015), Bafia variety, the letters are confusing. The bars do not overlap. Please check.

**Comment [R10]:** Do the bars indicate standard error or standard deviation?

In 2015, all natural insecticide applied to variety B125 significantly reduced the larvae thrips population density compared to the negative control ( $p<0.0001$ ), that was not the case on variety Bafia ( $p=0.5395$ ), where the different formulations had the same performance (Figure 2B). On variety B125, *B. dalzielii* extract was the least effective insecticidal treatment with a 25% reduction in larvae. The effect of *M. anisopliae* treatment and synthetic insecticide Decis was similar in term of larvae reduction.



T : Negative control ; A : *A. indica* ; B : *B. dalzielii* ; M : *M. anisopliae* ; M+B : *M. anisopliae* + *B. dalzielii* ; M+A : *M. anisopliae* + *A. indica* ; A+B : *A. indica* + *B. dalzielii* ; M+A+B : *M. anisopliae* + *A. indica* + *B. dalzielii* ; D : Decis. For each cowpea variety bars denoted by the same upper-case letter are not significantly different between treatments at the indicated level of probability ( $p<0.05$ ) (Student–Newman–Keuls test).

**Fig 2.** Variation of larvae thrips population density between treatments of the cowpea B125/Bafia varieties in 2014 (A) and 2015 (B).

## 2.2. Influence of bioinsecticide treatments on leaf damage

The results obtained after the application of the treatments on the two cowpea varieties in the 2014 and 2015 cropping seasons are shown in tables 1 and 2. In general, there was more damage on B125 variety ( $3.86\pm0.20$ ) leaves' than those on Bafia variety ( $3.34\pm0.14$ ) in 2014 ( $t=2.11$ ;  $p=0.0357$ ). The contrary tendency was observed in 2015 (B125= $3.49\pm0.13$ ; Bafia= $12.06\pm0.69$ ;  $t=12.07$ ;  $p<0.0001$ ). It appears that all the insecticidal treatments significantly reduced the damage on cowpea leaves compared to the negative control in 2014 and 2015 on both varieties and reduction significantly varied according to insecticidal preparations (B125-;  $p<0.0001$  in 2014 and 2015-; Bafia-;  $p<0.0001$  in 2014 and 2015).

In 2014, the natural insecticides applied to variety B125 equally protected cowpea leaves as Decis (Table 1), except *A. indica* and *B. dalzielii* extracts, which were least effective than the Decis. On the Bafia variety, *A. indica* treatment was the least effective natural insecticides. *Metarhizium*, *M. anisopliae* and the

Formatted: Space After: 10 pt

Comment [R11]: Idem.

Comment [R12]: Idem.

Formatted: Space After: 10 pt

combined treatments protected the leaves better than *B. dalzielii* extract alone, which was more effective than *A. indica* extract. Overall, Decis was the most effective treatment.

**Table 1.** Differences in the mean holes number on cowpea leaves as affected by treatments in 2014.

Treatments	Cowpea varieties in 2014		
	B125	Bafia	t values
Control	9.75 ± 0.77 <sup>a</sup>	8.40 ± 0.48 <sup>a</sup>	3.64**
<i>A. indica</i>	6.15 ± 0.68 <sup>b</sup>	4.65 ± 0.32 <sup>b</sup>	4.88**
<i>B. dalzielii</i>	4.95 ± 0.53 <sup>b</sup>	3.75 ± 0.23 <sup>c</sup>	5.08**
<i>M. anisopliae</i>	2.60 ± 0.25 <sup>c</sup>	2.44 ± 0.26 <sup>d</sup>	1.08
M+B	2.50 ± 0.21 <sup>c</sup>	2.25 ± 0.21 <sup>d</sup>	2.06
M+A	1.73 ± 0.20 <sup>c</sup>	2.70 ± 0.22 <sup>d</sup>	7.99***
A+B	2.95 ± 0.29 <sup>c</sup>	2.80 ± 0.25 <sup>d</sup>	0.95
M+A+B	2.00 ± 0.21 <sup>c</sup>	2.10 ± 0.14 <sup>d</sup>	0.97
Decis	1.30 ± 0.11 <sup>c</sup>	0.90 ± 0.15 <sup>e</sup>	5.26***
F	39.04***	65.97***	
Means (Df=605.82)	3.86±0.20	3.34±0.14	2.11*

C-: Negative control-; A-: *A. indica*-; B-: *B. dalzielii*-; M-: *M. anisopliae*-; M+B-: *M. anisopliae* + *B. dalzielii*-; M+A-: *M. anisopliae* + *A. indica*-; A+B-: *A. indica* + *B. dalzielii*-; M+A+B-: *M. anisopliae* + *A. indica* + *B. dalzielii*-; D-: Decis; ns: p>0.05; \*, p<0.05; \*\*, p<0.001; \*\*\*, p<0.0001. For each cowpea variety values of the same column denoted by the same upper-case letter are not significantly different between treatments at the indicated level of probability (Student–Newman–Keuls test).

In 2015, natural insecticides protected cowpea leaves of the B125 variety as Decis did (Table 2). *Azadirachta indica* treatment was even least effective, while the ternary combination *M. anisopliae* + *A. indica* + *B. dalzielii*, and the binary combination *M. anisopliae* + *A. indica* were more effective than Decis (synthetic insecticide). On Bafia variety, all *M. anisopliae* treatments recorded the same performance as Decis in cowpea leaf protection, whereas treatments of *A. indica*, *B. dalzielii* and their combinations were the least effective natural insecticides. However, they significantly suppressed damage induced on leaves of both cowpea varieties in the two experimental years compared to the control.

**Table 2.** Differences in the mean holes number on cowpea leaves as affected by treatments in 2015.

Treatments	Cowpea varieties in 2015		
	B125	Bafia	t values
Control	7.68 ± 0.60 <sup>a</sup>	28.08 ± 3.53 <sup>a</sup>	13.95***
<i>A. indica</i>	4.43 ± 0.36 <sup>b</sup>	18.28 ± 2.13 <sup>b</sup>	15.70***
<i>B. dalzielii</i>	3.28 ± 0.30 <sup>cd</sup>	20.58 ± 1.75 <sup>b</sup>	23.86***
<i>M. anisopliae</i>	2.48 ± 0.23 <sup>cd</sup>	6.48 ± 0.61 <sup>c</sup>	15.02***
M+B	2.55 ± 0.25 <sup>cd</sup>	6.60 ± 0.66 <sup>c</sup>	14.05***
M+A	2.35 ± 0.18 <sup>d</sup>	5.08 ± 0.62 <sup>c</sup>	10.35***
A+B	3.75 ± 0.36 <sup>cb</sup>	16.38 ± 1.35 <sup>b</sup>	22.14***
M+A+B	2.35 ± 0.17 <sup>d</sup>	5.35 ± 0.72 <sup>c</sup>	9.93***
Decis	2.58 ± 0.33 <sup>cd</sup>	1.83 ± 0.23 <sup>c</sup>	4.56**
F	26.87***	30.66***	
Means (Df=387.67)	3.49±0.13	12.06±0.69	12.07***

C-: Negative control-; A-: *A. indica*-; B-: *B. dalzielii*-; M-: *M. anisopliae*-; M+B-: *M. anisopliae* + *B. dalzielii*-; M+A-: *M. anisopliae* + *A. indica*-; A+B-: *A. indica* + *B. dalzielii*-; M+A+B-: *M. anisopliae* + *A. indica* + *B. dalzielii*-; D-: Decis; ns: p>0.05; \*, p<0.05; \*\*, p<0.001; \*\*\*, p<0.0001. For each cowpea variety values of the same column denoted by the same upper-case letter are not significantly different between treatments at the indicated level of probability (Student–Newman–Keuls test).

Formatted: French (France)

Formatted: French (France)

Formatted: French (France)

Formatted: French (France)

Formatted: French (France)

Formatted: Space After: 10 pt

Formatted: French (France)

Formatted: French (France)

Formatted: French (France)

### 3. DISCUSSION

Comment [R13]: Here is sub-item 4

The higher thrips population density was observed on the B125 cowpea variety probably due to its short growing cycle which has promoted early flowering. In the Sudano-Sahelian agro-ecological zone, the rainy season is short duration (up to 3 months). Under these conditions, the dry season came too early and did not allow the Bafia variety to produce enough flowers with its intermediate cycle longer than that of B125. It has been reported that the agroecological parameters can influence the blooming phase of cowpea varieties (Dugie *et al.* 2009). Regarding the action of natural insecticides, the reduced efficacy of *A. indica* extract is similar to the observations of Barry *et al.* 2017, confirming the argument that neem-based products could be more effective in storage than in the field (Bambara and Tiemtore 2008). The higher efficacy of *B. dalzielii* extract is due to the adhesive factors such as a gum found in *B. dalzielii*, which makes it viscous (Younoussa 2016), to improve its efficiency. According to Mfuti *et al.* (2021), adhesion is an important factor of the effectiveness of a treatment. The efficiency of *M. anisopliae* treatment may have been boosted by kerosene, which has insecticidal properties too (Djouaka *et al.* 2007). Kerosene and cotton seed oil have shown good adhesion to promote adequate application (Mfuti *et al.* (2021) for direct contact and efficacy on thrips as pointed out by Seye *et al.* (2012), who indicated that *M. anisopliae* was more effective than neem. The fact that combination of *A. indica* and *B. dalzielii* treatments were more effective in the thrips population density reduction than single treatments could be explained by the increased synergetic effects of both treatments. For other combinations with *M. anisopliae*, the bioactivity was attributed to the presence of adhesive factors which is in agreement with other studies (Barry *et al.* 2019; Seye *et al.* 2012), which showed a better efficacy of *M. anisopliae* combined with neem rather than individual applications. ~~*Metarhizium*~~ *M. anisopliae* and other plant extracts used in this work have potential to act synergistically in reducing the thrips population. Decis, with its large spectrum and systemic action, was more effective than all natural insecticides. Several authors (Barry *et al.* 2019; Bambara and Tiemtore 2008; Ngakou 2007) have demonstrated the greater effectiveness of Decis than other treatments. The efficacy of different insecticidal treatments was more pronounced on larvae than on adult thrips; this could be explained by the fact that cuticle of larvae are still very weak, not hard to protect larvae as that of adult since being the primary protective barrier for insects (Bensarradj 2014).

Concerning the reduction of damage on the cowpea leaves, the different treatments had a similar effect on B125 and Bafia cowpea varieties in both years of experiment. Kerosene and cottonseed oil promoted the dissolution of *M. anisopliae* spores (Djouaka *et al.* 2007; Mfuti *et al.* (2021) and render the leaves stiff enough. This makes leaves less prone to be perforated by thrips. In addition to the leaf stiffness, the viscosity of *B. dalzielii* previously mentioned reinforces the protection of cowpea crop against thrips infestation. This is in turn considerably suppressed the leaf damage when using the combination of *M. anisopliae* + *B. dalzielii*. All this would therefore enable this treatment to protect cowpea leaves as much as the Decis on B125 and Bafia varieties in 2014 and 2015. Combination treatments, through the synergy of their different constituents (Barry *et al.* 2017; Seye *et al.* 2012; Ngakou 2007) equally protected cowpea leaves as the synthetic insecticide Decis, and have been more effective than that of synthetic insecticide.

### 4. CONCLUSION

Comment [R14]: Here is sub-item 5

~~In the present study,~~ The aqueous extracts of *A. indica* and *B. dalzielii* and the mycoinsecticide *M. anisopliae* alone or in combination were found effective to reduce pest population and crop damage. The

aqueous extracts of *A. indica* and *B. dalzielii*, the mycoinsecticide *M. anisopliae* and their combination, could be recommended as component of integrated management of the cowpea flower thrips [in the Sudano-sahelian zone of Cameroon](#). These natural insecticides could cope well when applied on the early mature B125 cowpea variety than intermediary Bafia variety. Considering the conservation of environment, the insecticidal formulations tested in this study could supersede the commercial pesticides used in crop protection. However, further studies on these natural products concerning their effect on beneficial insects and their persistence need to be carried out in order to optimize their use and potentialize their protective effect.

## REFERENCES

- Adeoti R., Coulibaly O., Tamò M. 2002. Factors affecting the adoption new cowpea (*Vigna unguiculata*) technologies in West Africa. *Bulletin of Agronomic Research of Benin*, (36): 1-18.
- Alghali A. M. 1992. Insecticide application schedules to reduce grain yield losses caused by insect pests of cowpea in Nigeria. *Insect Science Application*, 13: 725-730.
- Bambara D., Tiemtore J. 2008. Biopesticide efficacy of *Hyptis spicigera* Lam., *Azadirachta indica* A. Juss. and *Euphorbia balsamifera* Ait. on cowpea (*Vigna unguiculata*) L. Walp. *Tropicicultura*, 26: 53-55.
- Barry B. R., Ngakou A., Nukenine N. E. 2017. Pesticidal Activity of Plant Extracts and a Mycoinsecticide (*Metarhizium anisopliae*) on Cowpea flower Thrips and Leaves Damages in the Field. *Journal of Experimental Agriculture International*, 18 (2): 1-15
- Barry B. R., Ngakou A., Tamò M., Nukenine E. N. 2019. The incidence of aqueous neem leaves (*Azadirachta indica* A. Juss) extract and *Metarhizium anisopliae* Metch. on cowpea thrips (*Megolurothrips sjostedti* Trybom) and yield in Ngaoundere (Adamawa-Cameroon). *Journal of Entomology and Zoology Studies*, 7 (5): 333-338.
- [Benserradj O. 2014. Evaluation of \*Metarhizium anisopliae\* as biological control agent against de mostico larvae. Doctorate thesis LMD, University of Constantine 1, Algeria, 208p.](#)
- Djouaka R. F., Bakare A. A., Bankole H. S., Doannio J. M.C., Kossou H., Akogbeto M. C. 2007. Quantification of the efficiency of treatment of *Anopheles gambiae* breeding sites with petroleum products by local communities in areas of insecticide resistance in the Republic of Benin. *Malaria Journal*, 6 (56): 1-6.
- Dugje I. Y., Omoigui L. O., Ekeleme F., Kamara A. Y., Ajeigbe H. 2009. Production of cowpea in West Africa. Farmer guidelines, IITA, 26p.
- Harouna M.A., Baoua I., Lawali S., Tamò M., Amadou L., Mahamane S., Pittendrigh B. 2019. Essai comparatif de l'utilisation des extraits du Neem et du virus entomopathogène MaviNPV dans la gestion des insectes ravageurs du niébé en milieu paysan au Niger, *Int. J. Biol. Chem. Sci.* 13(2): 950-961
- [Hassan H. S., Musa A. M., Usman M. A., Abdulaziz M. 2009. Preliminary phytochemical and antispasmodic studies of the stem bark of \*Boswellia dalzielii\*. \*Nigerian Journal of Pharmaceutical Sciences\*, 8 \(1\): 1-6](#)
- Immaraju J. A., Paine T. D., Bethke J. A., Robb K. L., Newman J. P. 1992. Western thrips (Thysanoptera: Thripidae) resistance to insecticides in coastal California greenhouses. *Journal of Economic Entomology*, 85: 9-14.
- Karungi J., Adipala E., Kyamanywa S., Ogenga-Latigo M. W., Oyobo N., Jackai L. E. N. 2000. Pest management in cowpea. Integrating planting time, plant density and insecticide application for management of cowpea field insect pests in eastern Uganda. *Crop Protection*, 19: 237-245.

**Comment [R15]:** Please, check this citation. Benserradj 2014 or Benserradj 2014 in the text?

**Comment [R16]:** Please, check this citation in the text.

Kemeuze V. A., Mapongmetsem P. M., Tientcheu M. A., Nkongmeneck B. A., Jiofack R. B. 2012. *Boswellia dalzielii* Hutch: State of the population and traditional utilization within the Mbe region (Adamawa-Cameroon). *Secheresse*, 23: 278-83.

Comment [R17]: Idem

Margni M., Rossier D., Crettag P., Jolliet O. 2002. Life cycle impact assessment of pesticides on human health and ecosystem. *Agriculture, Ecosystem and Environment*, 93: 279-392.

Mfuti, D.K.; Tamiru, A.; Kirk, W.D.J.; Akinyemi, A.O.; Campbell, H.; O'Brien, M.; Drijfhout, F.P.; Pope, T.W.; Niassy, S.; Subramanian, S. Exploiting Thrips Aggregation Pheromones to Develop a Lure-and-Kill Strategy for the Management of the Bean Flower Thrips. *Agronomy* 2021, 11, 1269. <https://doi.org/10.3390/agronomy11071269>

Mouffok B., Raffy E., Urruty N., Zicola J. 2008. The neem, a biological efficient insecticide. Project S2, Biological Engineering, IUT, University of Paul Sabatier, France, 15p.

Nderitu J. H., Wambua E., Kasine J. O. F., Waturu C. 2007. Evaluation of pesticide/variety combination for thrips (Thysanoptera: Thripidae) management on French Beans (*P. Vulgaris* L.) in Kenya. *African Crop Science Conference Proceeding*, (8): 987-992.

Ndiaye M. 1996. Pre-vulgarization study of cowpea in farmer milieu of northern and centre northern zones of Senegal. ISRA, a work and study document, 27p.

Ngakou A. 2007. Potential of selected biofertilizers and a mycopesticide in managing *Megalurothrips sjostedti* and improving cowpea production in Cameroon. Department of Biochemistry and Microbiology, University of Buea, Cameroon. 197p.

Ngakou A., Tamò M., Parh I. A., Nwaga D., Ntonifor N. N., Korie S., Nebane C. L. N. 2008. Management of cowpea flower thrips, *Megalurothrips sjostedti* (Thysanoptera: Thripidae), in Cameroon. *Crop Protection*, 27: 481-488.

Nieslen S. S., Ohler T. A., Mitchell C. A. 1997. Cowpea leaves for human consumption: production, utilization, and nutrient composition. *Advances in Cowpea Research*. IITA, Ibadan, Nigeria, pp. 326-332.

Comment [R18]: Idem

Odion E. C., Asiribo O. E., Ogunlela V. B., Singh B. B., Tarawali S. A. 2007. Strategies to improve and sustain food production capacity in the savannah: The role of leguminous fodder crops in maintaining soil fertility and health. *Journal of Food, Agriculture and Environment*, 5 (2):338-344.

Comment [R19]: Idem. 2007 or 2017 ?

Okigbo B. N. 1978. Grain legumes in the Agriculture of the tropics. In: *Pest of grain legumes*. Ecology and control (ed.): Singh S.R. Van Emden H.F., Taylor T.A. Academic press London, New York, 454p.

Omo-Ikerodah, E.E., Fatokun, C.A., Fawole, I. 2009. Genetic analysis of resistance to flower bud thrips (*Megalurothrips sjostedti*) in cowpea (*Vigna unguiculata* [L.] Walp.). *Euphytica* 165:145–154.

Ouedraogo E. 2004. Utilization of natural insecticides in the protection of crops in Burkina Faso. Communication, CTR -INERA Di. Ouagadougou CEAS, Burkina Faso. 56 p.

Comment [R20]: Idem

Sahel People Service (SPS) Association. Technical Form n°2: Neem, the natural pesticide, 2.

Seye F., Ndiaye M., Faye O., Afoutou J. M. 2012. Evaluation of entomopathogenic fungus *Metarhizium anisopliae* formulated with suneem (Neem Oil) against *Anopheles gambiae*s.l. and *Culex quinquefasciatus* adults. *Malaria Chemotherapy, Control & Elimination*, 1: 1-6.

Singh B.B., Chambliss O.L., Sharma B. 1997. Recent advances in cowpea breeding. In: *Advances in Cowpea Research*, Singh BB, Mohan Raj DR, Dashiell KE and Jakai LEN (Eds.), IITA, Ibadan, Nigeria, pp. 30-49.

- Singh S.R., Allen D.J. 1980. Pests, diseases, resistance and protection of (*Vigna unguiculata* (L.) Walp. In: Summerfield RJ, Bunting AHK (Eds.), *Advances in Legume Science*, Royal Botanic Gardens, London, and Ministry of Agriculture, Fish and Food, MAFF, pp. 419-443.
- Tamò M., Baumgärtner J., Gutierrez A. P. 1993. Analysis of cowpea monocropping system in West Africa. II. Modelling the interaction between cowpea and the bean flower thrips *Megalurothrips sjostedti* (Trybom) Thysanoptera: Thripidae. *Ecological Modélisation*, 70: 89-113.
- Younoussa L. 2016. Mosquitocidal activity of *Annona senegalensis* Pers. (Annonaceae) and *Boswellia dalzielii* Hutch. (Bruceraceae) leaf extracts and essential oils against three major vector species: *Anopheles gambiae* Giles, *Aedes aegypti* Say and *Culex quinquefasciatus* Linnaeus (Diptera: Culicidae). Thèse de Doctorat, Université de Ngaoundéré, 194p.

Comment [R21]: Idem

UNDER PEER REVIEW