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Potential of botanicals to control cowpea flower thrips (*Megalurothrips sjostedti*) and production in the Guinea-savannah and Sudano-Sahelian zones of Cameroon

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Abstract
The effectiveness of aqueous leaves extracts of *Lippia rugosa*, *Annona senegalensis* and *Jatropha curcas* were used for the control of thrips (*Megalurothrips sjostedti*) on two cowpea varieties (Bafia and Lori) under field conditions in the Cameroonian agro-ecological zone I (Modélé) and II (Dang). Trials were arranged in a completely randomized block with eight treatments each of which was replicated four times. There were seven insecticide treatments in addition to a negative control. Cowpea (*V. unguiculata*) plants were sprayed at flowering thrice at five days interval. Data collection consisted of counting/evaluating the population density and dynamic of adults and larvae thrips as affected by treatments, and evaluating the seed yield at harvest. As the results, all the bio-insecticide treatments generally reduced the density of larvae and adult thrips population above 95%, as much as the Decis. Thrips population density was averagely the same at Dang (11.72 ± 1.54) and Modélé (10.71 ± 1.63) in 2017, but was instead higher at Dang (9.27 ± 1.44) in 2018 than at Modélé (5.37 ± 1.35). Insect density was more elevated on the Bafia variety (10.71 ± 1.63 in 2017; 4.77 ± 0.88 in 2018) than on the Lori variety (6.53 ± 0.98 in 2017; 1.22 ± 0.82 in 2018) at Modélé. Cowpea seeds yield (kg/ha) of Lori variety was significantly ($p < 0.0001$) improved by treatment *J. curcas* (1066.87 ± 43.66) in 2017, compared to treatment *A. senegalensis* + *J. curcas* (1457.27 ± 126.62) in 2108. Cowpea Bafia variety recorded the highest yield at Modélé (365.55 ± 29.21) than at Dang (316.08 ± 36.68) in 2017, with lower yields obtained in 2018. After Decis, *A. senegalensis* + *J. curcas* was the best of all bio-insecticides in reducing the cowpea thrips, thus improving cowpea seeds yield of the two studied cowpea varieties at Modélé and Dang during the two cropping seasons.

Keywords: *Annona senegalensis*, *Lippia rugosa*, *Jatropha curcas*, botanicals, cowpea, thrips, population density/dynamic, yield

1. Introduction

Agriculture is an important element in the economic development [1], which meets the food needs of the growing human population [2]. Thus, agricultural productivity was greatly improved by the green revolution from 1970 to 1980 [3]. Among food crop legumes, cowpea (*Vigna unguiculata* [L.] Walp) is important in tropical and subtropical regions, as it provides almost all of the world's production [1, 4]. It is the second legume consumed in the northern part of Cameroon [5]. Cowpea is adapted to all agro-ecological zones [6, 7], and is rich in protein (29 to 43%) [8], carbohydrates, fiber, vitamins, minerals and energy [9]. It also improves health [10], and enriches the soil with nitrogen [11]. Therefore, this crop legume would be a major meal, not only for food balance, but also for economic development.

Despite its wide adaptation and importance, cowpea productivity is generally very low because of many biotic and abiotic constraints that include: diseases, parasitic plants, drought or heat, agricultural practices [4] and insect pests [12-14]. Among these insects, the cowpea flower thrips *Megalurothrips sjostedti*, Trybom (Thysanoptera, Thripidae) cause yield losses ranging from 20 to 100% in the absence of treatments [15, 16]. It is therefore important to combat these pests by using alternative strategies to synthetic insecticides, which have been reported to pollute the environment [3, 17] and cause resistance to insect pests [18, 19].

Many bio-pesticides have shown approval use in organic farming [20-22]. In addition, essential oils of *Annona senegalensis* and *Lippia rugosa* have been used against storage insect Pests

[23, 24], while extracts of *Jatropha curcas* have shown their efficacy against mosquitoes [25]. In fact, the aqueous bio-insecticide extracts from these plants have not yet been tested against cowpea flower thrips (*M. sjostedti*) in the field. Therefore, the main objective of this study was to improve cowpea yields through utilization of natural substances like plant extracts, as substitutes of synthetic insecticides, against cowpea flower thrips. These aqueous extracts from the leaves of *A. senegalensis*, *L. rugosa* and *J. curcas* may have an insecticidal potential on cowpea thrips, thus could contribute to improved yield of this important crop legume in cultivated areas.

2. Materials and Methods

2.1. Study sites

The study was carried out in two agro-ecological zones of Cameroon over a two years period (2017 and 2018) on 2 sites. The first site was located at Modélé-Maroua in the Far-North region within the Sudano-Sahelian zone or zone I (latitude: 10°22,813'N; longitude: 013°40,459'E; altitude: 847± 3m). The second site was located at Dang-Ngaondere in the Adamawa region, within the Guinea-savannah zone or zone II (latitude: 07°25,357'N; longitude: 013 ° 32,402'E; altitude: 1087 ± 3 m).

The cowpea varieties (*Vigna unguiculata*) used were the Bafia variety, from Bafia town and propagated in the field, and the Lori variety, from Lori locality (Cameroon).

Fig 1: Cowpea varieties used: (A) Bafia variety; (B) Lori variety

2.2. Experimental field

Trials were carried out from July to November 2017 and 2018 in the Soudano-Sahelian zone, and from August to November 2017 and 2018 in the Guinea-savannah zone. The varieties Bafia (Fig. 1a) and Lori (Fig. 1a) of cowpea were used. The experimental fields were set up flat on (18.10 x 30.50) m^2 surface area for the Lori variety, and on (16 x 27)m^2 for the Bafia variety. The plots representing the treatments were (4 x 3) m^2 for the Lori variety and (3.75 x 3)m^2 for the Bafia variety. The two varieties were 4m apart.

The sowing respected a 80 cm spacing between and 50 cm within the lines for the Lori variety, instead of 75 cm between and 50 cm within the lines for the Bafia variety [27]. Insecticidal substances were sprayed using 4 calibrated manual sprayers, each sprayer corresponding to an insecticide product. For treatments combining several products, each component was sprayed separately. Treatments were applied in the morning between 6 a.m. and 8 a.m., 3 times at 5 days interval, as soon as the appearance of flower buds.

The experimental design was a completely randomized blocks, with 8 treatments each repeated 4 times. These treatment were: T1, treatment with aqueous leaves extract of *A. senegalensis*; T2, treatment with aqueous leaves extract of *L. rugosa*; T3, treatment with aqueous leaves extract of *J. curcas*; T4, treatment with synthetic insecticide, Decis®; T5, treatment combining aqueous leaves extracts of *A. senegalensis* + *L. rugosa*; T6, treatment combining aqueous leaves extracts of *A. senegalensise* + *J. curcas*; T7, treatment combined with aqueous the leaves extracts of *L. rugosa* + *J. curcas*; T8, negative control concerning plots that did not receive any insecticide treatment. The cowpea experimental fields were maintained following the prescriptions in Table 1 [12].

Table 1: Monitoring guidelines of the experimental fields

Monitoring periods	Year 2017 at Modélé	Year 2017 at Dang	Year 2018 at Modélé	Year 2018 atDang
Sowing (Bafia, Lori)	01/07/2017	01/08/2017	12/07/2018	07/08/2018
1st weeding (Bafia et Lori)	18/07/2017	17/08/2017	29/07/2018	25/08/2018
2nd weeding (Bafia, Lori)	10/082017	10/09/2017	21/08/2018	16/09/2018
Treatments (Bafia)	01, 07, 13/09/ 2017	01, 07, 13/10/ 2017	03, 09, 15/09/ 2018	26/09/2018, 01, 07/10/2018
Treatments (Lori)	05, 11, 17/10/ 2017	01, 07, 13/10/ 2017	02, 08, 14/10/ 2018	26/09/2018, 01, 07/10/2018
Thrips count (Bafia)	14, 15, 16, 17, 18/09/2017	14, 15, 16, 17, 18/10/2017	16, 17, 18, 19, 20/09/2018	08, 09, 10, 11, 12/10/2018
Thrips count (Lori)	18, 19, 20, 21, 22/10/2017	14, 15, 16, 17, 18/10/2017	15, 16, 17, 18, 19/10/2018	08, 09, 10, 11, 12/10/2018
Harvesting (Bafia)	25/10/2017	21/11/2018	05/12/2018	21/11/2018
Harvesting (Lori)	18/12/2017	21/11/2018	05/12/2018	21/11/2018

2.3. Formulation of insecticide products

Plant species were collected locally in each of the regions concerned. The aqueous leaves extracts of *L. rugosa*, *A. senegalensis* and *J. curcas* were prepared as recommended in the data sheet no. 2 in which 5L of solution is prepared from 1kg of fresh leaves. For this work, 200g of leaves from each plant were crushed, macerated in 1L of water for 12 hours. Macerates were then filtered through a 0.4 mm mesh screen before being diluted to 10% (1L of extract for 10L of water). The synthetic insecticide solution based on Deltamethrin (Decis®) was applied according to the instructions in the leaflet (3mL in 15L of water).

2.4. Data collection

The average number of adults and larvae thrips per flower, the variation of the thrips population (adults and larvae) over time were determined as described by Ngakou *et al.* [14]. The evaluation of the thrips population on cowpea flowers was carried out at the flowering stage after the last application of treatments, and their dynamics were evaluated daily. Thrips were counted in 5 days at the rate of ten (10) flowers per elementary plot, thus forty (40) flowers per treatment were harvested separately and kept in polyethylene tubes containing 5ml of ethanol (50%) per day [14, 23]. Treatments were applied between 8 am and 10 am, corresponding to the visiting time of flowers by insects. Flowers were collected from cowpea plants, then dissected, skinned and observed with a magnifying glass to identify adults and larvae thrips [28, 29]. The grains weight (mg) was evaluated per cowpea plant of each elementary plot [30] using a KERN brand electric scale at 0.01 g sensibility. Yield (kg/ha) was then deduced by extrapolation knowing the surface of the experimental unit, the density of plant the and the surface of an hectare.

2.5. Statistical data analysis

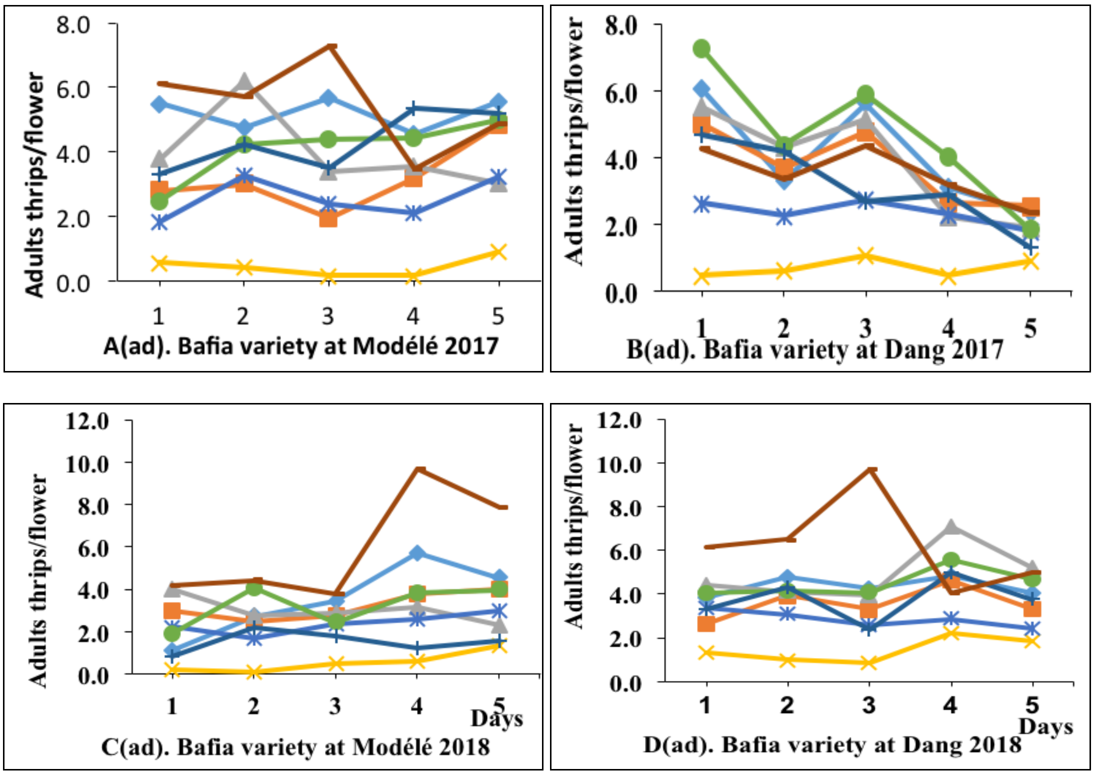
All data were analyzed using the Statistical Programm for Social Science (SPSS) 2.0 software. The density of thrips (larvae and adults) was subjected to Analysis of Variances (ANOVA) to compare the means, while the Tukey test was used to separate them. Diagrams were plotted using the Microsoft Excel 2013.

3. Results

3.1. Changes in the population density/dynamic of *Megalurothrips sjostedti* (adults and larvae) as affected by treatments on cowpea Bafia variety at Modélé and Dang (2017-2018)

3.1.1. Adults

The effect of different insecticides on the population density/dynamic of adult and larvae thrips is summarized in Fig. 2(ad, la). In 2017, insecticide treatments significantly reduced ($p < 0.0001$) the population of adult thrips at Modélé compared to the negative control. Treatments *A. senegalensis* + *L. rugosa* was as effective as Decis in reducing the density of adult thrips by almost 95%. A relative instability in the density of adult thrip population due to application of different insecticides was characterized by an increased population of adult thrips on the 2nd day after spraying (DAS) before stabilization on the 3rd to the 5th DAS. *A. senegalensis* + *L. rugosa* and *L. rugosa* alone are the treatments in which less fluctuation of adult thrips were recorded. Decis was the best insecticide in stabilizing the density of adult thrips over time (Fig. 2A(ad)).



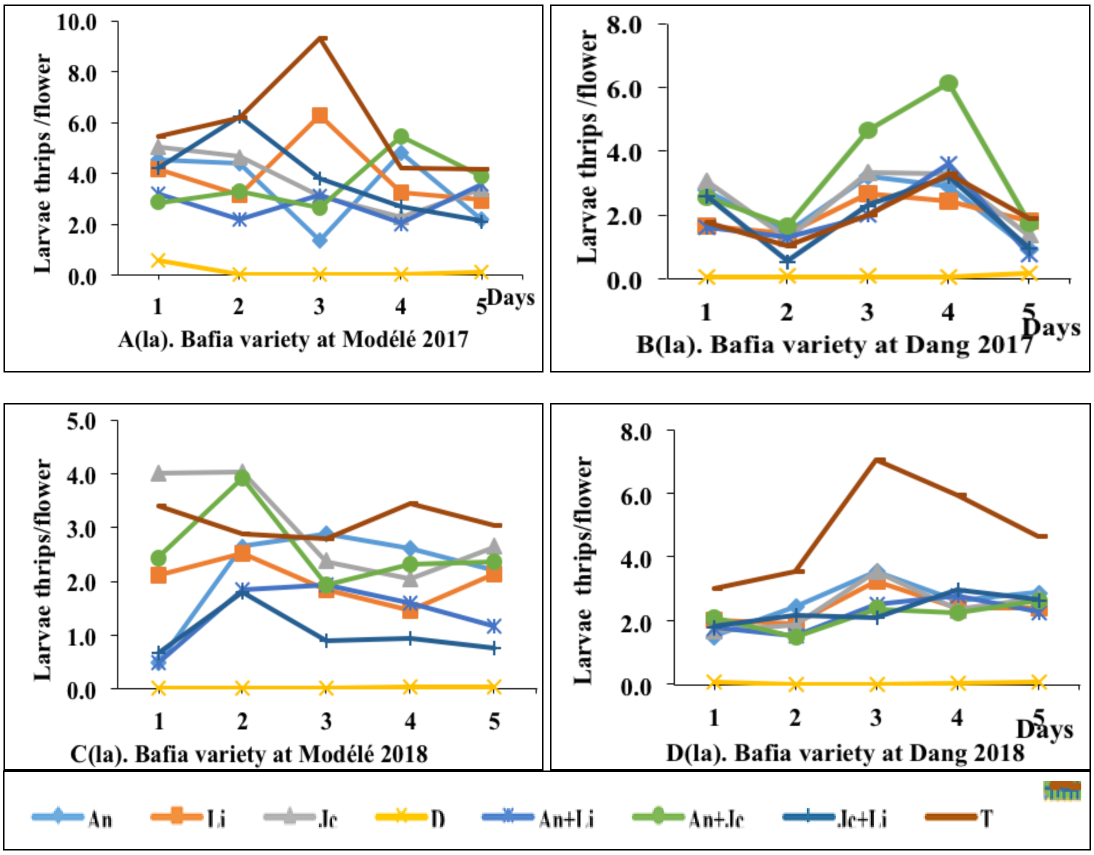


Fig 2: Variation in the population density/dynamic (adults, larvae) thrips as influenced by botanicals on cowpea Bafia variety at Modélé and Dang (2017-2018)

An: *A. senegalensis* ; Li : *L. rugosa* ; Jc : *J. curcas* ; D: Decis ; An+Li : *A. senegalensis* + *L. rugosa* ; An+Jc : *A. senegalensis* + *J. curcas* ; Jc+Li : *J. curcas* + *L. rugosa* ; T: negative control.

At Dang, only treatment Decis, *A. senegalensis* + *L. rugosa* and *J. curcas* + *L. rugosa* significantly reduced ($p < 0.0001$) the population of adult thrips compared to the negative control. The adult thrips population increased slightly on the 3rd day before gradually decreasing until the 5th DAS. *A. senegalensis* + *L. rugosa* was the bio-insecticide which had the less fluctuation in the population of adult thrips from the 1st to the 5th DAS (Fig. 2B(ad)).

In 2018, treatment *A. senegalensis* + *J. curcas* was the most effective on thrips (95% reduction) at Modélé, followed by treatment *A. senegalensis* + *L. rugosa* (95% reduction), but both were less effective than Decis (Fig. 2C(ad)). At Dang, all insecticides significantly decreased ($p<0.0001$) the population of adult thrips, although bio-insecticides remained less effective than Decis, with *A. senegalensis* + *L. rugosa* referring to as the best bio-insecticides (Fig. 2D(ad)). All insecticides influenced the population dynamics of adult thrips compared to the negative control at Modélé and Dang (Fig. 5C and 5D). Different insecticides kept the density of adult thrips relatively stable over time compared to the negative control. *L. rugosa* + *J. curcas* was the bio-insecticide to keep the density of adult thrips lower, although not lower than Decis.

3.1.2. Larvae

In 2017, all insecticides positively impacted on the larvae thrips population compared to the negative control at Modélé, although at a lower extent than that of Decis (Fig. 2A(la). Little fluctuations were observed on the larvae thrips population on the 4th DAS, before stabilizing from the 4th to the 5th DAS. *A. senegalensis* + *L. rugosa* was the most effective in keeping the population of thrip larvae lower, but remained less effective than the Decis. At the Dang, only treatment Decis significantly ($p < 0.0001$) reduced the larvae thrips population on cowpea flowers (Fig. 2B(la). The dynamic of larvae thrips was disturbed by different treatments as evidenced by a drop in the larval population on the 2nd and 5th DAS. The population of larvae thrips was reduced on all bio-insecticide treatments more than the negative control on the 5th DAS.

In 2018, *L. rugosa*+ *J. curcas* mostly decreased larvae thrips with 95% reduction, followed by *A. senegalensis* + *L. rugosa* (93% reduction), while no larvae thrips was found on flowers applied with Decis (Fig. 2C(la)). The density of the larvae population was disturbed by all the applied bio-insecticides at Modélé. *A. senegalensis* + *L. rugosa* and *L. rugosa* + *J. curcas* kept the larvae thrips population lower over the time, but were less effective than treatment Decis, for which the population of thrips larvae did not fluctuate. At Dang, bio-insecticide significantly ($p < 0.0001$) reduced the larvae thrip population, with both treatments *L. rugosa* + *J. curcas*, *A. senegalensis* + *L. rugosa* as the most efficient (Fig. 2D(la)). Compared to the negative control, the population of thrips larvae was stable over time under the effect of all insecticides, for which the effect ended up keeping the larvae thrips population lower than the control from the 1st to the 5th DAS.

3.2. Variation of the population dynamics of *Megalurothrips sjostedti* as affected by treatment on cowpea Lori variety at Modélé and Dang (2017-2018)

3.2.1. Adults

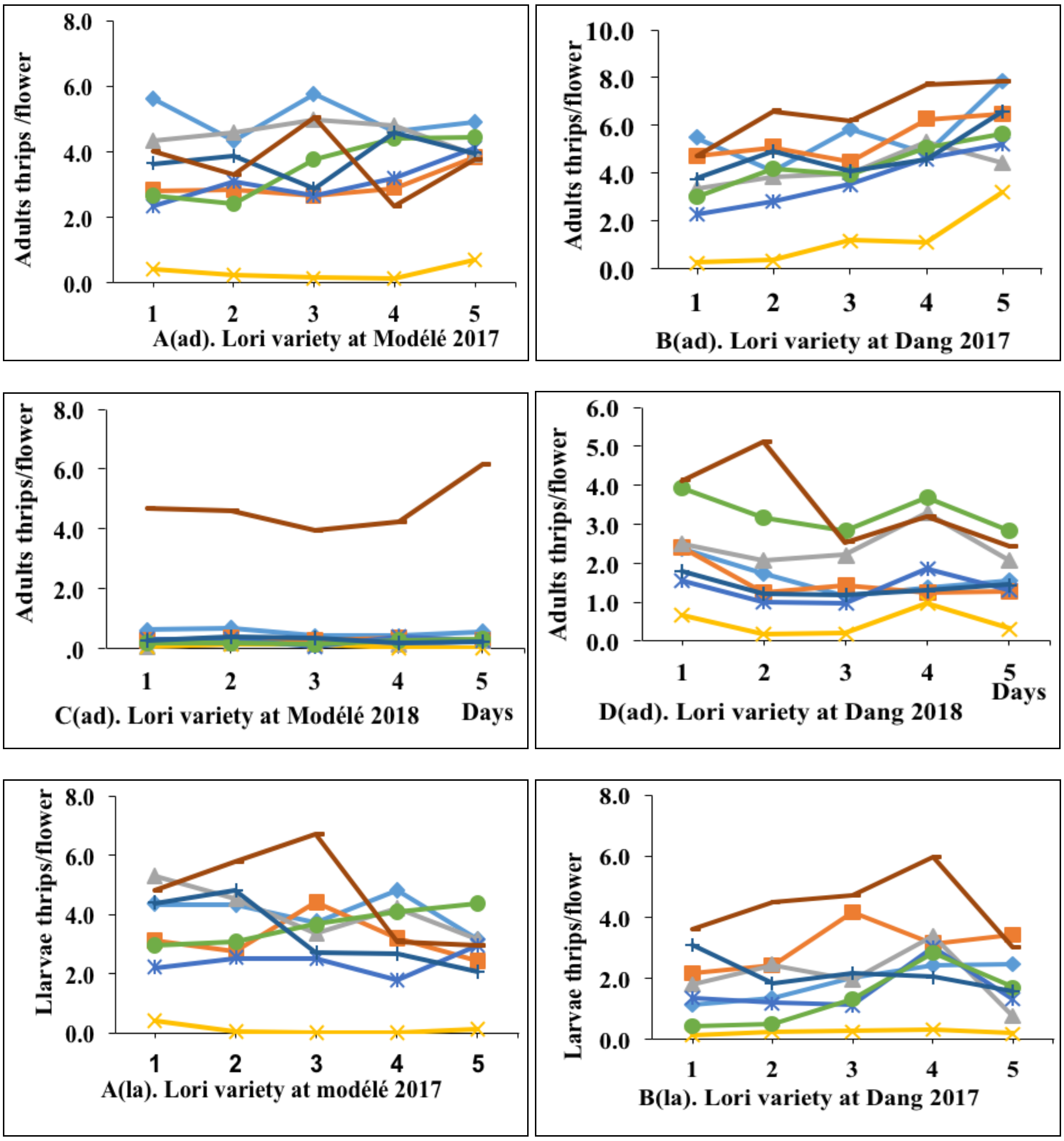
In 2017, leaves extracts from *L. rugosa* and *A. senegalensis* +

L. rugosa were the best treatments that reduced and stabilized the population dynamics of adult thrips over time at Modélé, although Decis even kept it more lower. Adult thrips population fluctuations varied over time from one treatment to another (Fig. 3A(ad)), and were pronounced after the 1st and 5th DAS. In 2018, all the bio-insecticide treatments completely reduced (100%) the density of adult thrips population, as much as the Decis, and kept the population density of adult thrips lower than the negative control.

At Dang, in 2017, different treatments significantly ($p < 0.0001$) reduced the population of adult thrips, with *A. senegalensis* + *L. rugosa* as the most effective bio-insecticides, but was less effective than the Decis. In 2018, apart from treatment *A. senegalensis* + *J curcas*, all bio-insecticides significantly ($p < 0.0001$) reduced the population of adult thrips, and maintained their population dynamics lower than that of the negative control from the 1st to the 5th DAS, but did not stabilize better than treatment Decis. The effect of *A. senegalensis* + L. rugosa and *L. rugosa* + *J. curcas* produced the most widespread effect on thrips and was comparable to that of Decis. In the two agro-ecological zones and during the two cropping years, treatment *A. senegalensis* +*L. rugosa* was the most effective bio-insecticide on adult thrips population.

3.2.2. Larvae

At the Modélé, in 2017, all treatments reduced on the larvae thrip population compared to the negative control, with treatment *A. senegalensis* + *L. rugosa* contributing to the better reduction of the larvae thrip density by almost 95%, although this was less than the efficacy of Decis. The relative fluctuation of larvae thrips population was the lowest after application of *A. senegalensis* + *L. rugosa* extract.



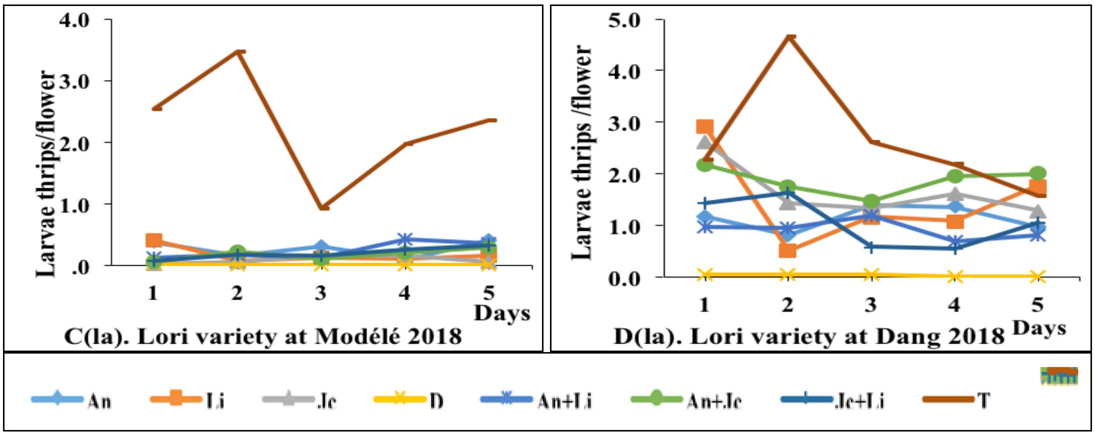


Fig 3: Variation in the population density/dynamic (adults, larvae) thrips thrips as influenced by insecticides on cowpea Lori variety at Modélé and Dang (2017-2018)

An: *A. senegalensis* ; Li : *L. rugosa* ; Jc : *J. curcas* ; D : Decis ; An+Li : *A. senegalensis* + *L. rugosa* ; An+Jc : *A. senegalensis* + *J. curcas* ; Jc+Li : *J. curcas* + *L. rugosa* ; T: negative control.

At Dang, bio-insecticide treatments had a significant (p <0.0001) effect in reducing the larvae thrip population by 96% compared to the negative control. *A. senegalensis* alone treatment was as effective as the *A. senegalensis* + *L. rugosa*.
In 2018 at Modélé, all bio-insecticide treatments completely reduced and stabilized the larvae thrips population density, as much as Decis. Treatments *A. senegalensis* + *L. rugosa*, *L. rugosa* + *J. curcas*, *A. senegalensis* alone kept the larvae population lower than the negative control from the 1st to the 5th DAS, with a more pronounced effect accounting for treatment *A. senegalensis* + *L. rugosa*. At Dang, bio-insecticides treatments remained significantly (p <0.0001) less effective than Decis, but the stabilization was as low as possible on the 2nd and 5th DAS, with a peak on the 4th DAS. Treatments *A. senegalensis* + *L. rugosa*, *J. curcas* + *L. rugosa* reduced the larvae thrip density up to close to 95% and 93% respectively. In general, thrips population density was averagely the same at Dang (11.72 ± 1.54) and Modélé (10.71 ± 1.63) in 2017, but was instead higher at Dang (9.27 ± 1.44) in 2018 than at Modélé (5.37 ± 1.35). However, the insect density was more elevated on the Bafia variety (10.71 ± 1.63 in 2017; 4.77 ± 0.88 in 2018) than on the Lori variety (6.53 ± 0.98 in 2017; 1.22 ± 0.82 in 2018) at Modélé.

3.3. Differences in responses to botanicals on cowpea seeds yield of the Bafia and Lori varieties (2017-2018)

Insecticide treatments significantly improved (p <0.0001) cowpea seeds yield (kg/ha) within the two study sites in 2017 and in 2018. Cowpea Bafia variety recorded the highest yield at Modélé (365.55 ± 29.21) than at Dang (316.08 ± 36.68) in 2017. However, the 2018 yield was rather high at Dang (310.08 ± 16.95) than at Modélé (173.39 ± 16.37). As for cowpea Lori variety, yield was higher in Modélé (789.21 ± 42.83) than in Dang (674.90 ± 32.00) in 2017, while in 2018, it is instead at Modélé (582.15 ± 42.87) that cowpea yield was higher than that of Dang (622.90 ± 99.00).
The influence of these treatments on cowpea seeds weight of the Bafia variety is summarized in Table 2. In 2017, all bio-insecticides significantly increased (p = 0.045) cowpea seeds yield at Modélé, as the positive control Decis taken. At Dang, the greatest seed weight was obtained when treatment *A. senegalensis* and *J. curcas* (542.35 ± 37.32). In 2018, insecticide treatments significantly (p <0.0001) improved the seed weight at Modélé and Dang, compared to the negative control.

Table 2: Variation cowpea seed yield (kg/ha) of the Bafia variety between treatments at Modélé and Dang

Treatments	Bafia 2017		Bafia 2018	
	Modélé	Dang	Modélé	Dang
An	403.74±63.94^{a}	349.40±38.66^{b}	199.24±20.88^{ab}	364.64±25.78^{a}
Li	282.75±39.10^{a}	218.13±20.79^{d}	149.00±18.58^{b}	258.25±20.97^{bc}
Jc	354.70±49.73^{a}	306.59±24.32^{bcd}	191.05±26.68^{ab}	324.33±22.07^{abc}
D	477.28±50.43^{a}	281.00±21.48^{bcd}	171.58±17.34^{ab}	285.50±21.57^{abc}
An+Li	433.56±58.59^{a}	347.25±22.84^{bc}	114.55±15.24^{b}	342.36±21.41^{ab}
An+Jc	350.75±58.90^{a}	542.35±37.32^{a}	262.67±33.76^{a}	302.09±21.51^{abc}
Jc+Li	400.47±66.34^{a}	251.64±26.13^{bcd}	128.93±15.95^{b}	366.50±23.22^{a}
T	221,29±32.69^{b}	232.00±17.55^{cd}	170.25±25.18^{ab}	236.91±13.64^{c}
F	2.079*	15.01***	4.230***	5.13***
Valeur de p	0.045	<0.001	<0.001	<0.001

An: *A. senegalensis* ; Li: *L. rugosa* ; Jc : *J. curcas*; D: Decis ; An+Li : *A. senegalensis* + *L. rugosa* ; An+Jc : *A. senegalensis* + *J. curcas* ; Jc+Li : *J. curcas* + *L. rugosa* ; T : negative control. For each location site and at a particular year, values on the same colum affected by the same letter are not significantly different at the indicated level of probability

A. senegalensis + *J. curcas* (262.67 ± 33.76) has proven to be the most effective bio-insecticide in improving the yield in term of seeds weight at Modélé, rather than treatments *J. curcas* + *L. rugosa* (366.50 ± 23.22) or *A. senegalensis* (364.64 ± 25.78) alone at Dang. Insecticide treatments also positively impacted the yield by weight of seeds of the Lori variety in the two agro-ecological zones during the two cropping seasons (Table 3).

Table 3: Variation cowpea seed yield (kg/ha) of the Lori variety between treatments at Modélé and Dang

Treatments	Lori 2017		Lori 2018	
	Modélé	Dang	Modélé	Dang
An	1033.95±73.09[ab]	878.56±51.11[abc]	817.07±53.45[ab]	926.56±116.29[bc]
Li	1066.50±92.03[ab]	805.78±39.08[bc]	656.63±39.14[bc]	570.56±38.07[bcd]
Jc	1058.67±97.87[ab]	1066.87±43.66[a]	777.78±52.90[abc]	1017,39±78.19[ab]
D	1281.42±89.11[a]	843.50±39.14[abc]	1001,34±64.79[a]	571.93±36.50[bcd]
An+Li	1035.83±78.26[ab]	770.18±41.52[bc]	610,37±57.05[bc]	366.96±29.36[d]
An+Jc	964.23±66.34[ab]	922.75±47.06[abc]	837.18±37.13[ab]	1457.27±126.62[a]
Jc+Li	903.65±83.66[ab]	936.27±47.07[ab]	764.35±41.82[abc]	506.81±38.80[cd]
T	737.32±59.54[b]	687.17±38.38[c]	496.32±59.745[c]	960.91±122.19[bc]
F	2.14*	4.28***	5.61****	11.14***
p-value	0.039	<0.001	<0.001	<0.001

An : *A. senegalensis* ; Li: *L. rugosa* ; Jc : *J. curcas*; D: Decis ; An+Li : *A. senegalensis* + *L. rugosa* ; An+Jc : *A. senegalensis* + *J. curcas* ; Jc+Li : *J. curcas* + *L. rugosa* ; T : negative control. For each location site and at a particular year, values on the same colum affected by the same letter are not significantly different at the indicated level of probability

In 2017, all bio-insecticides significantly (p = 0.039) increased the seeds weight at Modélé. At Dang, the same treatments significantly (p <0.0001) increased the seeds yield, the better effect accounting for treatment *J. curcas* (1066.87 ± 43.66). In 2108, the significant increase (p <0.0001) in cowpea seeds yield was much more observed after application of treatments *A. senegalensis* + *J. curcas* (837,18 ± 37.13), *A. senegalensis* alone (817.07 ± 53.45) at Modélé, and treatment *A. senegalensis* + *J. curcas* (1457.27 ± 126.62) at Dang. After Decis, *A. senegalensis* + *J. curcas* was the best of all bio-insecticides in improving cowpea seeds yield of the two studied cowpea varieties at Modélé and Dang during the two cropping seasons.

4. Discussion

In the process of protecting cowpea against flower thrips in the field, different bio-insecticides used in this work have shown to reduce the pest population, which was higher at Dang than at Modélé during the 2017 and 2018 cropping seasons. Differences observed between treatments were attributed either to low rainfall [31] at flowering at Dang, or the unfavorable environmental conditions to thrips [32] at Modélé. These results are opposite to those pointed out by Barry *et al.* [23], who found more thrips in a related experiment in Maroua than in Ngaoundéré during the 2014 and 2015 cropping seasons, as the result of leaching of thrips due to rainfall [33]. The density of thrips was highly noticed on cowpea Bafia variety than on Lori variety at Modélé, due to the delayed flowering of Lori under conditions that are unfavorable to devepolment of thrips [34]. Conversely, the density of thrips was higher in the Lori variety than in the variety Bafia at Dang in 2017. The preference of this variety by thrips has been reported to be related to their white color of flower that attracts the pest [35]. In 2018, the population density of thrips was almost similar on the two cowpea varieties, because flowers of the Lori variety preferred by thrips were not available.

Despite its effectiveness on insect pests in storage [24, 36], mosquitoes [37], *A. senegalensis* was the less effective bio-insecticide at Modélé, than at Dang, whereas treatment *A. senegalensis* + *J. curcas* was instead the less effective. *J. curcas* may have a slow mechanism of action that has negatively affected the combined treatment *A. senegalensis* + *J. curcas*. According to Abdoul *et al*. [38], the average mortality of thrips may vary according to extract doses, since there exist a linear relationship between the dose of *J. curcas* oil and the mortality of thrips. The efficacity of the treatments *A. senegalensis* + *L. rugosa* and *J. curcas* + *L. rugosa* on both cowpea varieties and at both sites could be attributed to the synergistic action of the various constituents of these combined extracts [23, 39]. The population dynamics of thrips (adults and larvae) were marked by their stability in 2018 at Modélé on Lori variety, and by their fluctuation on the two varieties in 2017 and 2018 at Dang, or in 2017 at Modélé. These fluctuations could be attributed to winds [40], climate conditions [41], the nature of the food source [35], or applied treatments [42, 43].

Regarding the different insecticides used in 2017 and 2018, Decis was more effective than any other one, on the two cowpea varieties and within the two agro-ecological zones, due to its broad spectrum, and its systemic action as insecticide. This finding lines with reported results on cowpea by Ngakou [30], Bambara and Tiemtore [44], who proved the effectiveness of Decis compared to other treatments. *A. senegalensis* + *L. rugosa* was the bio-insecticide that most impacted the population dynamics of thrips in 2017, whereas in 2018 it is instead treatments *L. rugosa* + *J. curcas* and *A. senegalensis* + *L. rugosa* that expressed a similar effect. Related results were reported by Barry *et al.* [23], on *Megalurothrips sjostedti* after application of *Azadirachta indica* extract and *Boswellia dalzielii* on cowpea at flowering. *J. curcas* was the less effective bio-insecticide on the population of these pests. According to Solsoloy *et al*. [43], *J. curcas* takes some time before being at its maximum of efficiency, since it acts on insect growth. The different modes of action of bio-insecticides on cowpea thrips have been reported to be anti-palatable, anti-reproductive or retarding the reproduction and longevity of insects [45-49].

Bio-insecticide treatments improved cowpea yield (kg/ha) at both study sites in 2017 and in 2018. Bafia variety had the highest yield at Modélé and Dang in 2017, but in 2018, it was rather high at Dang than Modélé. The low seed yield of the Bafia variety at Modélé could be attributed to low density of cowpea plants in the field as indicated by Taffouo *et al.* [50]. Concerning the Lori variety, the seed yield was higher at Modélé than at Dang in 2017, whereas in 2018, the reverse situation accurred. The low seed yield of the Lori variety at Dang in 2017 and at Modélé in 2018 can be justified by the increased ramification of cowpea plants [51-53]. These results do not agree with on those of Barry [54], who did not find a significant difference between the seed weights from different insecticide treatments in Maroua in 2014 and 2015, but are in line with the positive impact on seeds weights of B125 and Bafia varieties following insecticide treatments.

5. Conclusion
The outcome of this study is that bio-insecticides applied as plant extracts alone and in combinations positively affected the two cowpea varieties, both at Modélé and Dang. These bio-insecticides not only reduced the adults and larvae thrips population, but also stabilized it over time, resulting in increased the plant yield. The aqueous extracts of the leaves of *A. senegalensis, L. rugosa* and *J. curcas*, and their different combinations were sometimes as effective as the synthetic insecticide Decis. These bio-insecticides can therefore be used as a substitute for synthetic insecticides to control thrips (*Megalurothrips sjsotedti*) in order to improve cowpea yield in the growing areas.

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