

Original Research Article

Field control of maize borers using aqueous seed extracts of *Thevetiaperuviana* (Pers.) K. Schum.

Formatted: Title, Justified

ABSTRACT

Formatted Table

Aims: In order to find an alternative to chemical control, the insecticidal potential of aqueous extracts of *Thevetiaperuviana* seeds formulated at 16.66 g/l ~~were~~ tested in the field on the maize stalk borer species.

Study design: ~~The~~ A factorial design in subdivided plots or "split-plot" with four replicates and two factors ~~studied~~ was used on an area of 250 m².

Place and Duration of Study: The experiment was carried out in a field located in the city of Yaounde, ~~country??~~ where cassava was grown beforehand, between July and October 2021.

Methodology: The extracts at 250 g per 15 l of water were tested against a synthetic ~~insecticide~~ Cypercal@ 37.5 ml per 5 l of water and an absolute control (untreated) in a four replicate split-plot device. Two maize varieties (V1: CMS 8704; V2: local) and three treatments (T1: control; T2: *T. peruviana* seed extract; T3: Cypercal 12 EC) were used. The aqueous extract of *T. peruviana* was applied by spraying on stems, leaves and leaf cones from 5th to 9th weeks after sowing (SAS). ~~Data were recorded on~~ growth parameters, stem borer density, and maize grain yield ~~were evaluated~~.

Results: The results show that the application of the treatments resulted in a good development of the growth parameters in the two maize varieties used. Two species of borer *Busseolafusca* and *Sesamiacalamistis* belonging to the order Lepidoptera were identified. The density of maize stalk borers was significantly reduced (T2: 3 borers) in the subplots treated with aqueous extracts compared to the control (T1: 10 borers). Treatment T2 (2.05 t/ha) gave higher grain yield ~~(how much?)~~ than the control (1.41 t/ha).

Conclusion: The aqueous extracts of *T. peruviana* seeds having thus shown a strong insect repellent potential in the field can therefore be integrated into the framework of biological control that ~~protects respects~~ the environment and human health.

Keywords: Maize, *Thevetiaperuviana*, stem borers, pesticides, biological control, *Busseolafusca*, *Sesamiacalamistis*.

1. INTRODUCTION

Maize (*Zea mays* L.) is a very important cereal ~~plantcrop~~ for human ~~foodand~~livestock~~fodder andfeedfoed~~. It is the basis for the functioning of several industries; food processing, brewing, soap and oil production [1]. ~~TheMmaizeof its scientific name(Zea mays L.);a member of the family pPoaceae~~family, is the most ~~energetic~~nutritious cereal [2], because of its ~~peculiar~~ nutritional~~contents-asset~~s (high starch content, presence of proteins, minerals).~~Moreover, it s cultivation, harvesting and shelling is and themost~~ economical from a production point of view (simple crop to produce, harvest, ~~thresh~~ and store) [3]. Maize is an important cereal crop and ranks third in the world after wheat (*Triticumaestivum* L. Subsp. *aestivum*) and rice (*Oryza sativa* L.) [4]. World maize production for the 2017/2018 season is estimated at 1053.8 million tonnes, ~~lesser than down from~~ the 2016/~~2017with a~~ production of 1100.2 million tonnes[5]. The main maize producers are the US and China, which account for nearly 60 per cent of production ~~of the world~~. In Africa, maize production ~~iswas~~ estimated at around 70,076,591 tonnes in 2012 for a total area of 34,075,972 hectares [6]. In Cameroon maize remains the most important cereal consumed, far ahead of sorghum, rice or wheat, with an estimated production of 2.2 million tonnes in 2018 [7]. Maize is grown in all five agro-ecological zones of Cameroon. Long considered a simple subsistence product, maize is now the subject of agricultural speculation, which is intensifying in Cameroon because of the socio-economic stakes of this crop, which has become increasingly important [8].

Despite its strategic role in food security and its importance in agro-industry, maize production is still far from satisfying the growing population, due to the decline in yield caused by pests responsible for field attacks estimated at more than 50 percent [9].Indeed, their damage is present at all stages of the ~~croplant's development~~. Among the pests, the larvae of several species of stem-boring lepidoptera are prominent. Among the most commonly used means against these pests are synthetic pesticides, whose importance in modern agriculture is justified by their impact on increasing the yield of protected plants by an average of 30 to 40%, and reducing the damage caused by pests, which can reach 30 to 50% loss in the field [10]. Despite the spectacular success of synthetic chemical pesticides in controlling plant pests, they pose risks to humans, animals, other non-target organisms and the environment and are not always within the reach of farmers ([11]; [12]; [13]; [14]).

Several studies have been carried out with the aim of minimising~~eng~~ the use of chemical pesticides and promoting the use of plant-based biocides [15]. Indeed, a good number of plants such as *Thevetiaperuriana* have natural substances with pesticidal properties ([16]; [17]; [18]). Like most products with a biodegradable pesticidal effect, the antiparasitic activity of *T.*

peruviana seed extracts has already been the subject of numerous studies, after which insecticidal properties were also identified ([19]; [20] and [21]). However, in Cameroon no work has been done/undertaken on the use of aqueous extracts from *T. peruviana* seeds infor the control of maize stalk borers in the field. Thus, for the conservation of ecosystem in this world concerned about and the safety of consumers' consumer health and the preservation of ecosystem balance, the ideal would be for the adpoption of natural pesticides of the the plant origin future to be natural products that are biodegradable and capable of interfering directly or indirectly with the metabolism of crop pests[22]. As part of this concept, the main objective of this work is to test the insecticidal potential of aqueous extracts of *T. peruviana* seeds against maize stalk borers in the field.

2. MATERIALS AND METHODS

2.1 Details Presentation of the testing site

The experiment was carried out in a field where cassava was previously grown beforehand. It is located in the city of Yaoundé, more precisely in the Odza district, bounded by the 10 marker Odza, with the following geographical coordinates: latitude 3°52'00" North and longitude 11°31'00" East, in the Central region, Mfoundi department ??Name the country?? It belongs to agro-ecological zone V, known as the forest zone with bimodal rainfall. The soil is lateritic red. This zone is subject to an equatorial climate, characterised by two dry seasons December-March and June-August, alternating with the two rainy seasons March-June and September-November. The average rainfall varies between 1500 and 2000 mm/year. The average annual temperature is 23.7 °C. The relative humidity is over 80% (ffig.1). The experiment was spread over a period of 3 months and one week, from sowing to harvesting on a plot of 250 m².

Comment [G1]: Explain?

Comment [G2]: Briefly explain

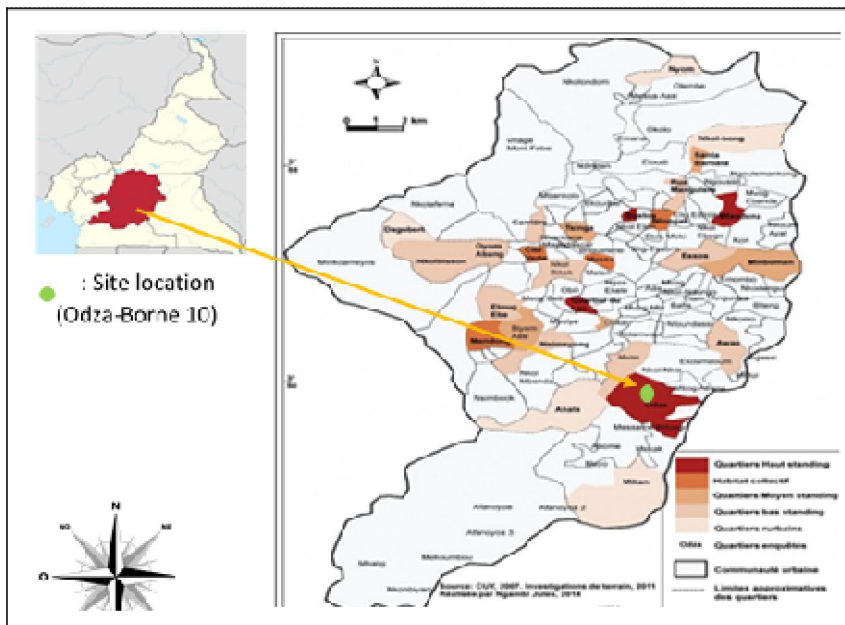


Fig.1. Geographical position of the study site.

2.2 Plant material

The trial involved two varieties of maize, one improved (V1: CMS 8704) supplied by the Agricultural Research Institute for the Development (ARID) in Nkolbisson (Yaoundé) and a local variety (V2) grown by most farmers in the area and obtained from the Odza market in Yaoundé (Fig.2). The characteristics of the two varieties are shown in Table 1 below.



Fig. 2. Maize varieties: (a) : V1: improved variety CMS 8704 ; (b) : V2 : local Variety.

Table 1. Characteristics of varieties of maize used (IRAD, 2010).

Varieties	Cycle duration (in d)	Texture	Color	Yield (t/ha)
V1 : CMS 8704.	100 (middle)	Floury	White	4 - 6
V2 : local Variety.	115 (late)	Glassy	Yellow	1 - 2

The *T. peruviana* seeds used in the experiment came from the crushed stones of the fruits harvested in the city of Yaoundé.



Fig. 3: Seeds of *T. peruviana* (a): Kernels; (b): Almonds

2.3 Chemical material

The [insecticide tested in this experiment](#) ~~chemical product used~~ is a systemic [insecticide](#) with the trade name Cypercal 12 EC (Fig. 4), ~~of liquid appearance;~~ and its active ingredient is cypermethrin 12 g/l.



Fig. 4. Systemic insecticide: Cypercal 12 EC

2.4 Methods

2.4.1 Site preparation

Site preparation began before the short rainy season at the end of July by clearing the site. Tree trunks and grass were piled up and burned in places. Ploughing is carried out with hoes after the study plot has been delimited by stirring the soil to a depth of 15 to 20 cm, following the installation of the experimental device.

2.4.2 Seed sowing and crop maintenance

Sowing took place in August 2019. The spacing of the seedlings in the experimental units is 40 cm x 50 cm at a rate of 3 seeds per 5 cm deep pots.

Two seedlings per pots ~~were~~ left after ~~demarriage~~???. Each experimental unit measuring 2.55 m² ~~having~~ contains three rows of 3 pots each, i.e. 12 pots in total. Two sessions of sarclo-weeding were carried out in order to control weeds. The first at 3 ~~ww~~ weeks after sowing (SAS) and the second at 7 SAS using a hoe.

Formatted: Font: Not Bold, Font color: Red

Comment [G3]: What is sarclo weeding?



Fig.5. Growth stages of maize cultivation: a. sowing; b. seed emergence; c. 3SAS sarclo hoeing; d. mature plants

2.4.3 Experimental device

The trial ~~was~~ conducted according to ~~the~~ factorial design in subdivided plots or "split-plot" with four replicates and two factors studied. Varieties ~~were~~ ~~are~~ the main factor at two levels (V1: CMS 8704 and V2: local variety). ~~The sub-plots were comprised of~~ ~~Treatments are the secondary factor at~~ three levels (T0: Control; T1: Aqueous extracts of *T. peruviana* seeds; T2:

Cypercal 12 EC insecticide) as a check. Six treatments resulting from the combination of the levels of two factors are were tested. The main elementary plots measuring approximately 1.7 m x 1.5 m are separated from each other by 0.6 m walkways and will each contain three rows and 12 pots. The blocks are 1 m apart from each other. The experimental set-up is spread over an area of 250 m².

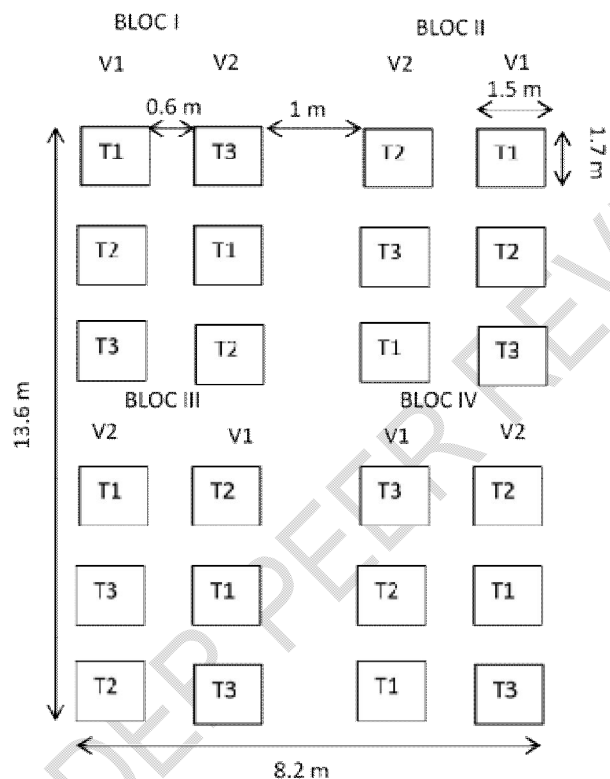


Fig.6. Testing plan

Vi: Maize varieties; V1: Variety CMS 8704; V2: Local variety.

Ti: Treatments; T1: Control; T2: Aqueous extracts of *T. peruviana* seeds; T3: Cypercal chemical insecticide.

2.4.4 Preparation of aqueous extracts of *T. hevetia*peruviana and applications.

Aqueous extracts of *T. peruviana* ~~were have been produced prepared~~ according to Ondoa(2009; 23) to the method described by [23]. The fallen fruit was is collected at the foot of the tree and the pulp was is removed; then the stones were are carefully dried (in the shade) to prevent the development of fungi. Three days before application, the seeds were are extracted from the pits by hand crushing with a stone and finely ground. The powder obtained

(250 g) ~~was is~~ placed in a muslin cloth tied with a thread and soaked for at least 12 hours in 5 litres of water. After soaking, the contents obtained ~~were are~~ poured into a knapsack sprayer, to which 10 g of powdered soap ~~was is~~ added as a wetting agent. The solution ~~was is~~ then ~~filled made~~ up to 15 l and applied (i.e. at a concentration of 16.66 g/l). For the synthetic insecticide, the solution ~~was is~~ prepared by taking 37.5 ml of Cypercal 12 EC from the 1-litre bottles ~~using the measuring cap on the product bottle, pouring it into the spray tank containing 15 litres of water and then applying~~ to different treatments. The aqueous extracts of *T. peruviana* seeds were applied once a week and the synthetic ~~also~~ insecticide ~~once a week until the end of the experiment. Applications started 5 SAS (week after sowing) and ended 13 SAS. The different solutions~~ ~~were are~~ applied to stems, leaves and ~~in leaf cones??~~ using a knapsack sprayer.

Comment [G4]: Insecticides are generally not used with such a frequency

2.4.5 Evaluation of growth parameters

2.4.5.1 Emergence rate

The rate of emergence ~~was is~~ obtained from the 6th to the 8th day after sowing (DAS) by calculating the ratio between the number of stems ~~emerged raised~~ and the total number of seeds sown using the following formula:

$$T (\%) = (n / N) \times 100$$

With T (%) = rate of seed emergence expressed as a percentage; n = number of stems raised; N = total number of seeds sown.

2.4.5.2 Stem height

The height of the maize plants ~~was is~~ measured with a ruler and then one meter from the collar to the level of the insertion of the ~~young~~ leaf. This parameter ~~was is~~ measured on a weekly basis from the 3rd SAS to the 7th SAS, on 8 randomly labelled plants in each treatment.

Comment [G5]: Is it last leaf? Mention it in the text.

2.4.6 Identification and inventory of maize stalk borers

Confirmation of the presence of stem boring insects in the field was made by visual diagnosis through precise observations of the symptoms and distinguishing characters of the pests [24]. In all cases, the parameter taken into account was the number of stem borer larvae. To do so, all stems showing signs of infestation (presence of galleries on the stems, holes on the leaves, drying of the leaf cone and panicle or dead heart) were dissected using a knife to look for borer larvae. The borer larvae were then ~~collected harvested~~ in the morning and stored in 70° alcohol and sent to the entomology laboratory for identification and characterisation. As far as the inventory of borer larvae is concerned, field sheets were prepared on which the date of the survey, the different varieties and treatments were

recorded. The data were taken weekly from the 7th SAS until the harvest and this on the 8 labelled plants in each experimental unit.

Comment [G6]: Re-write

2.4.7 Evaluation of the effect of treatments on the density of drillers

The effect of the treatments on the density of the drillers was evaluated on a weekly basis by simply counting the living individuals observed during our visits. It was carried out on 8 plants labelled on each subplot. It began 4 weeks after treatment (SAT) and ended 8 weeks after treatment (SAT) for both varieties.

2.4.8 Evaluation of performance parameters

2.4.8.1. Yield per hectare

The ears were dried for a week and then ~~threshed~~~~deseeded~~. The grains obtained after ~~threshing~~ ~~deseeding~~ the ears were dried and weighed. The dry grain yield per hectare was determined using the following formula: [25]:

$$\text{Rdt in kg/ha} = \frac{\text{weight/parcel (g)}}{\text{parcel/surface (m}^2\text{)}} \times \frac{10000 \text{ m}^2}{1 \text{ ha}} \times \frac{1 \text{ kg}}{1000 \text{ g}}$$

2.5 Data analysis

Collected data were entered into the Microsoft Excel 2013 spreadsheet for graphing and then subjected to an analysis of variance technique (ANOVA) using R version 3.4.3 software. The multiple comparisons of means were performed using Duncan's Multiple Range Test at 5% probability level, test when significant differences were detected by the F Test.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Effect of treatments and variety on maize plant growth parameters

3.1.1.1 Variation of rising rate as a function of time

The exercise rate of the two maize varieties is shown in Figure 7. Non significant differences ~~were~~~~is~~ recorded between the varieties at 6, 7 and 8 days after sowing (JAS). ~~The~~~~is~~~~data~~ ~~figure~~ shows that emergence for the two varieties behaved almost identically and started at 6 JAS with rates of 33.10% and 28.24% for V1 and V2 respectively. At 7 JAS, variety V1 had an emergence rate of 60.64% against 57.87% for variety V2. At 8 JAS, both varieties show a maximum emergence rate of 90.50% and 87.26% respectively for varieties V1 and V2, respectively.

Comment [G7]: Is ???

Comment [G8]: Why no DAS. It is suggested correct through the text accordingly.s

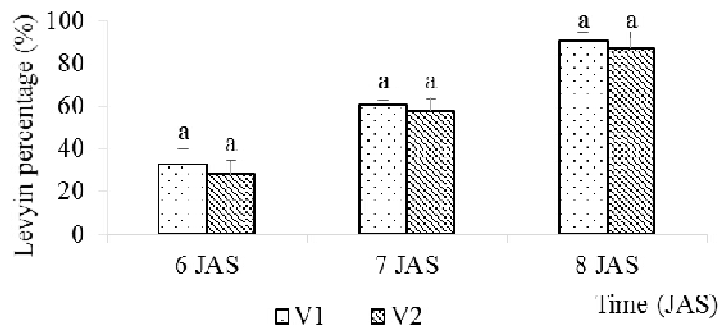


Fig. 7. Grain yield percentage of the two maize varieties as a function of time. JAS: day after sowing; V1: improved variety CMS 8704; V2: local variety.

* Values followed by the same letter are not significantly different when $p > 0.05$.

Comment [G9]: ??

3.1.1.2. Effect of treatments and variety on stem height

Stem height changes with time, treatments and varieties (Table 2). At 24 JAS, the analysis of variance reveals a significant difference between treatments. Comparison of the means shows that the control treatment T1 (9.88 ± 3.42 cm) recorded the greatest height compared to the treatment with water extract T2 (9.12 ± 2.45 cm) and insecticide T3 (8.51 ± 2.18 cm), respectively. Similarly, during this period a significant difference is observed between the two varieties tested. Variety V1 is respectively 9.76 ± 3.00 cm as compared to 8.59 ± 2.41 cm for variety V2. A significant interaction is recorded at 24 JAS where the CMS 8704 variety in the untreated plots V1T1 (11.48 ± 3.55 cm) exhibited a higher height than the local variety of the untreated plots V2T1 (8.29 ± 2.44 cm). From 38 to 52 JAS, there are significant differences between treatments. Indeed, at 38 and 52 JAS, respectively, the T1 control treatments (25.95 ± 10.71 cm and 70.98 ± 21.38 cm) recorded the highest stems compared to treatments with aqueous extracts of *T. peruviana* T2 (23.44 ± 7.02 cm and 62.96 ± 20.32 cm) and T3 insecticide treatments (20.81 ± 5.52 cm and 56.67 ± 17.15 cm). As far as the varietal effect is concerned, at 38 JAS there was a significant difference between the two varieties. The improved variety V1 has the greater height of 25.32 ± 9.58 cm than the local variety V2: 21.48 ± 6.22 cm. On the other hand, at 52 JAS, no significant difference between the two varieties was detected. A significant variety x treatment interaction was observed for plant height at 38 and 52 JAS. The heights of the CMS 8704 variety in the untreated plots V1T1 (31.42 ± 11.56 cm and 83.56 ± 29.09 cm)

are higher than those of the local variety in the untreated plots V2T1 (20.48 ± 6.15 cm and 58.40 ± 14.95 cm).

Table 2: Effect of treatments and variety on stem height as a function of time. JAS: days after sowing, V1: improved variety CMS 8704, V2: local variety, T1: untreated control, T2: aqueous extract of *T. peruviana*, T3: insecticide Cypercal 12 EC.

Varieties	Treatments	Time			
		24 JAS	38 JAS	52 JAS	66 JAS
V1	T1	11.48±3.55a	31.42±11.56a	83.56±29.09a	168.66±64.16a
	T2	9.59±2.40b	23.86±6.82b	59.23±23.58b	129.26±46.99b
	T3	8.20±1.93b	20.67±6.17b	58.01±20.68b	128.79±48.97b
Average V1		9.76±3.00a	25.32±9.58a	66.93±25.57a	142.24±56.56a
V2	T1	8.29±2.44b	20.48±6.15b	58.40±14.95b	118.56±62.75b
	T2	8.66±2.45b	23.02±7.29b	66.70±15.94b	142.97±58.55ab
	T3	8.83±2.40b	20.95±4.89b	55.32±12.91b	119.18±39.47b
Average V2		8.59±2.41b	21.48±6.22b	60.14±15.28a	126.91±55.16a
Average of treatments	T1	9.88±3.42a	25.95±10.71a	70.98±21.38a	143.61±67.82a
	T2	9.12±2.45ab	23.44±7.02ab	62.96±20.32ab	136.12±53.11a
	T3	8.51±2.18b	20.81±5.52b	56.67±17.15b	123.99±44.38a
Varieties		**	***	ns	ns
Treatments					
Interaction		*	***	**	ns
		***	***	***	**

P: 0**** 0.001 ***0.01 ** 0.05; ns: not significant. Values followed by the same letter are not significantly different according to Duncan's [multiple range test](#) at the 5% [threshold level of probability](#).

3.1.2. Identification, inventory and damage to maize stalkborers

During the experiment, two stem boring insects attacking maize were identified. These were *Busseolafusca* Fuller and *Sesamiacalamistis* Hampson, ~~both of~~ belonging to the noctuidae family (Fig. 8)



Fig.8. Borers observed on maize plants. (a): *Busseolafusca*; (b): *Sesamiacalamistis*.

As damages, these drillers drill holes in the stems and consequently cause a general weakening of the plant increasing the risk of stem breakage or a high rate of lodging in the event of heavy rainfall thus reducing the yield.



Fig.9. Some damages caused by borers on maize plants. (a) : stem bored ; (b) : sawdust on stem ; (c) : borers caused breaking stem ; (d) : stem nibbled.

3.1.3. Effect of treatments and variety on maize stalk borers density

Figure 10 illustrates the influence of treatments on the density of stem borers in the field. The analysis of variance shows that there is a significant difference between the control treatment and the two other treatments (T2 and T3), which are not statistically different at the 5% threshold. Generally speaking, it can be observed that the *T. peruviana* extracts behaved as well as the insecticide, even reaching a zero density of borer at 6 and 7 SAT, respectively. At 8 SAT, a density of 10 drills was recorded in the control

treatment T1 against respectively 3 and 2 drills in treatments T2 (aqueous extracts) and T3 (Cypercal).

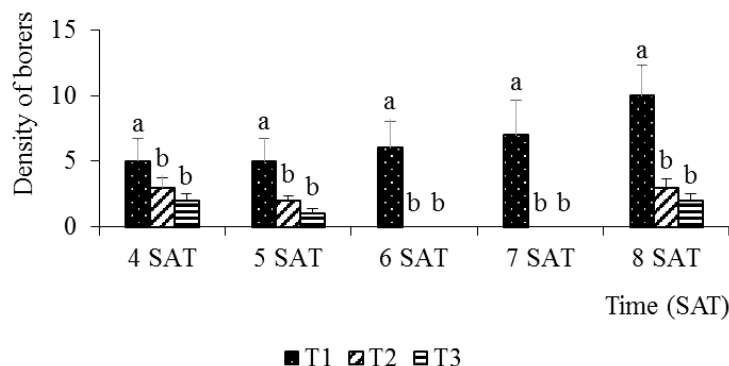


Fig. 10. Effect of treatments on stem borer density as a function of time WAT: weeks after treatment; T1: untreated control, T2: aqueous extract of *T. peruviana*, T3: cypercal insecticide.

*Histograms followed by the same letters are not statistically different ($p > 0.05$). when $p < 0.05$.

3.1.4. Effects of treatments and variety on maize yield parameters

Data related to the analysis of variance [on yield and its components data](#) on the number of ears; ear weight and dry grain yield are presented in Table 3. From this [data table](#), it can be seen that, for the number of ears, non significant differences existed between treatments, varieties and their interactions ($P > 0.05$). Nevertheless, the CMS 8704 variety (11.25 ± 3.50) and the local variety (10 ± 3.46) of the plots treated with Cypercal insecticide had the highest number of ears. Data on the weight of ears also show that there is no significant difference among between the different treatments and varieties ($P > 0.05$).

With regard to dry grain yield, a highly significant effect ($p < 0.001$) is observed among between the different treatments as well as interactions between treatments x varieties. The insecticide treatment (T3) recorded the highest yield (2.20 ± 0.81 t/ha) followed by the aqueous extract treatment (T2) (2.05 ± 0.66 t/ha) and finally the control treatment (T1) which recorded the lowest value (1.34 ± 0.22 t/ha). However, no significant difference was observed between varieties for this same parameter. Values of 1.84 ± 0.83 t/ha and 1.46 ± 0.17 t/ha were recorded for variety V1 and variety V2 respectively.

Table 3. Effect of treatments and variety on number of ears, weight of ears and dry grain yield. T1: untreated control, T2: aqueous extract of *T.*

Comment [G10]: Name the varieties (spell out)

Comment [G11]:

peruviana, T3: Cypercal insecticide. V1: improved variety CMS 8704, V2: local variety.

Varieties	Treatments	Parameters		
		Nbr of cob	weight of cob	yield (t/ha)
V1	T1	9.50 ± 2.51a	3.00 ± 0.5b	1.22 ± 0.11b
	T2	9.25 ± 4.03a	4.00 ± 1.73ab	1.37 ± 0.16b
	T3	11.25 ± 3.50a	5.65 ± 1.12a	2.94 ± 0.19a
Average V1		10.00 ± 3.21a	4.21 ± 1.57a	1.84 ± 0.83a
V2	T1	8.00 ± 2.94a	3.73 ± 1.10ab	1.46 ± 0.27b
	T2	9.50 ± 4.43a	3.00 ± 1.00b	1.46 ± 0.21b
	T3	10.00 ± 3.46a	3.90 ± 1.55ab	1.46 ± 0.08b
Average V2		9.16 ± 3.43a	3.54 ± 1.15a	1.46 ± 0.17a
Average of treatments	T1	8.75 ± 2.65a	3.36 ± 0.86a	1.34 ± 0.22b
	T2	9.37 ± 3.92a	3.50 ± 1.37a	2.05 ± 0.66a
	T3	10.62 ± 3.29a	4.77 ± 1.54a	2.20 ± 0.81a
<i>Varieties</i>		ns	Ns	ns
<i>Treatments</i>		ns	ns	***
<i>Interaction</i>		ns	*	***

P : 0 **** 0.001 *** 0.01 * 0.05. The values of each column with the same letters are not significantly different when $p < 0.05$ in the Duncan test.

3.2 Discussion

The results show that the varieties did not influence the emergence rate. It is evident in can be seen from the above results that the non-significant difference between the varieties on the emergence rate was obtained during the experiment is not related to maize genotypic factors, but influenced by environmental factors and crop conditions. Bonhomme indeed, [26] also showed in his findings work that environmental factors and crop conditions influence emergence and plant numbers per unit area.

The analysis referring to the plant growth parameters, in particular the height of the stems, reveals significant differences between treatments. The control treatment recorded a higher stem height compared to the aqueous extract and Cypercal treatments. This can be explained on the one hand by the heterogeneity of the site, and on the other hand by the fact that, during randomization, the control sub-plots were found on the parts where leaf debris and tree trunks had been burnt. The ashes would have been a fertiliser that would have been favourable to the good performance of the control on this growth parameter. This positive effect of ash has already been observed on many cultivated plants [27]. However, the aqueous extract treatment recorded higher stem height than the Cypercal insecticide treatment. This may be explained by the fact that the aqueous extracts contain metabolites such as tannins, sterols, sugars and alkaloids, which induce improved plant growth [28]. The evolution of growth parameters were also influenced by the two varieties. The improved variety V1 has better growth parameters than the local variety V2. This could be due to the genetic modifications of the improved variety V1 [29]. According to [29], the genetic improvement of plants aims at creating new plant material with the best agronomic and phytosanitary characteristics.

Busseolafusca and *Sesamiacalamistis*, were the species of maize stalk borers encountered during our study and which can secondarily attack the ears. The presence of these two maize stalk borers has already been reported in Cameroon [30]. The inventory of these borers was carried out from the angle of their attacks (dead hearts, damaged leaves, inlet/outlet openings, presence of debris), thus confirming their presence in maize stalks during dissection [31].

The various insecticide formulations effectively reduced the population of maize stalk borers in field conditions. The synthetic product (Cypercal) was significantly more effective in reducing the stem borer population density on maize plants, followed by the aqueous extract of *T. peruviana* seeds. This is thought to be due to the different insecticidal power and mode of action of the different formulations [32]. In general, synthetic products have a higher insecticidal power compared to organic products [33]. Several authors ([34]; [35] and [33]), have reported the efficacy of cypermethrin on cowpea insect pests. However, the reduction in stem borers density in subplots treated with the aqueous extract of *T. peruviana* seeds at a concentration of 16.66 g/l, shows the depressant effect of these extracts on maize stem borers as reported by [36] in work on the effect of *T. peruviana* kernels and *Mucunapruriens* plants on cassava root scales in the field. Thus, referring to this depressive effect, it could be a repellent or insecticidal effect against stem borers such as the one observed on the mealy bug of cassava shoots treated with aqueous neem extracts [37] confirming the low density of stem attack observed in the field. As a result, [20] in the same approach showed the repellent effect of *T. peruviana* seeds on the control of cocoa mirids?? in

the field. Similar results were also observed by [38] who demonstrated the insecticidal effect of *Hyptissuaveolens* against maize pests; notably *Mussidianigrivenella*Ragonot (Lepidoptera: Pyralidae). This repellent effect of yellow bay laurel could be attributed on the one hand to the glycosides present in the aqueous extracts of *T. peruvianaseeds*. This is in line with the work of [39] who showed that the root of *T. peruviana* contains toxic and insect-repellent glycosides and on the other hand to the presence in the extracts of secondary metabolites such as tannins, sterols, sugars and alkaloids with insecticidal, insect repellent, growth regulating and anti-appetant effects [28].

The crop protection products tested significantly increased the grain yield of maize compared to the control. These high yields in the different treatments are certainly linked to the effectiveness of the applied phytosanitary products, which would have induced a reduction in the density of stem borers. In addition, the analysis showed a significant difference between the aqueous extract treatment of *T. peruvianaseeds* and the control. This suggests that the aqueous extracts of *T. peruviana* seeds through the secondary metabolites they contain would stimulate maize grain yield, as claimed in the work of [40] where extracts of *Capsicum* sp. and *Anarcadium* sp. stimulated the yield of okra and aubergine. However, the V1 (improved) variety showed a higher yield than the local variety (V2). This would be justified by the genetic programme of the V1 variety, which aimed to increase yields through varietal improvement techniques.

CONCLUSIONS

The overall objective of this work, which is part of biological control, was to test the insecticidal potential of aqueous extracts of *T. peruviana* seeds in the control of maize stalk borers in the field. Varying results were obtained.

Despite the heterogeneity of the site and the presence of ash on the untreated control sub-plots following randomisation, which resulted in good growth compared to the other treatments, the application of the Cypercal aqueous extract and insecticide treatments also resulted in a good development of the growth parameters, in particular the height of the stems and the foliar surface area produced in the two maize varieties used. Both maize varieties were attacked by two species of stem borers, namely *Busseolafusca* and *Sesamiacalamistis*. The results obtained on stem borer density showed that the insecticide treatment and the aqueous extracts had a repellent action against attacks caused by stem borer insects in the field. This was characterised by a significant decrease in density (T2: 3 borers and T3: 2 borers) compared to the untreated control (10 borer). Both maize varieties showed almost the same levels of sensitivity to stem borers.

Formatted: Font: Italic

Formatted: Font: Italic

The sub-plots treated with aqueous extracts and the synthetic insecticide Cypercal recorded statistically similar grain yields. These treatments recorded a higher grain yield compared to the control treatment (T1: 1.34 t/ha; T2: 2.05 t/ha and T3: 2.20 t/ha). Aqueous extracts of *T. peruviana* seeds generally behaved as well as the synthetic insecticide, producing good effects on both borers density and yield. They can therefore be used as a control product against maize stalk borers in the field.

REFERENCES

- 1 Boone P. S., Charles J. D., Wanzie L. R. Sub-regional assessment of the maize value chain, ATP Technical Report No. 1. Bethesda, MD: ATP Project, Abt Associates Inc., 2008.
- 2 Charcosset A. and Gallais A. Emergence and development of the concept of hybrid varieties in maize. *The French coach*, 2009: 60, 21-30.
- 3 Nuss E.T., Tanumihardjo S.A. Quality protein maize for Africa: closing the protein inadequacy gap in vulnerable populations. *Adv. Nutr.*, 2011: (2): 217-224.
- 4 Mahmoodi S. and Rahimi A. The critical period of weed control in corn in Birjand region, Iran. *International Journal of Plant Production*, 2009: 3(2): 91-96.
- 5 Anonymous, 2016. Food and Agriculture Organization of the United Nations (FAO), Rome, FAOSTAT database; International Monetary Fund (IMF); Washington, D.C., International Financial Statistics, database; United Nations Statistics Division.
- 6 Anonymous, 2015. FAOSTAT (2012). <http://faostat.fao.org> (Accessed on October 6, 2015).
- 7 Anonymous, 2019. EcoMat editorial staff. <http://ecomatin.net/> Accessed on 05/20/2020, at 8 p.m.
- 8 Guibert H., Kenne Kueteyim P., Olin Bassala J.P., M'Biandoun M. Intensifying maize cultivation to improve food security: is it in the interest of producers in Northern Cameroon? *Cache. Agri.* 2016: (25): 65006.
- 9 Aroga R. Maize borers in Cameroon. Effects of different sowing dates on population dynamics. *Rev. Science and Tech. Ser. Science. Agron.*, 1997: 3(4): 7-12.

Formatted: Font: 18 pt

- 10 Anonymous, 2014. Maize Pest Management Guide for Cooperators. PIDMA. Douala, 36 pp.
- 11 Iwaro A.D., Screenivasan T.N., Butler DR. and Umaharan P. *Phytophthora* resistance in cacao (*Theobroma cacao* L.): influence of pod morphological characteristics. *Plant Disease*, 1997;81(6):615-624.
- 12 Saiyed H., Dewan A., Bhatnagar V., Shenoy R., Rajmohan H., Patel K., Kashyap R., Kulkarni P. and Rajong B. Effect of endosulfan on male reproductive development. *Health Perspective*, 2003: (111): 1958-1962. 51
- 13 Ambang Z., Ndongo B., Bime, Ngoh D., Maho Y. and Ntsomboh G. Effect of mycorrhizal inoculum and urea fertilizer on diseases development and yield of groundnut crops (*Arachis hypogaea*) using methanolic extracts of yellow oleander (*Thevetia peruviana*) seeds. *AJCS*, 2008: 5(3): 227-232.
- 14 Tano D.K., Seri-Kouassi B. and Aboua L. The effects of three plants aqueous extracts on feed intake and reproduction parameters of *Coelaenomenoderalameensis* Bert and Mariau (Coleoptera: Chrysomelidae) the pest of oil palm (*Elaeis guineensis* Jacq.) *Journal of Animal and Plant Sciences*, 2013;12(2):2527-2539.
- 15 Ngassoum B.M., Ngamo L.S. and Goudoum A. Post-harvest protection of maize with low residual insecticides: essential oils. In: Kapseu C., Nganhou J., Boudrant J. and Cruzet J. (eds.). *Drying and post-harvest technology*. Cameroon, 2002: pp. 240-246.
- 17 Abdoul H., Adam T. H. E. and Verheggen J. F. *Jatropha curcas* L. (Euphorbiaceae): Insect pests and biocontrol properties. *B.A.S.E.*, 2013;17(4), 604-612.
- 18 Sane B., Badiane D., Gueye M.T. and Ousmane F. Evaluation of the biological efficacy of neem extract (*Azadirachta indica* Juss.) as an alternative to pyrethroids for the control of the main cotton pests (*Gossypium hirsutum* L.) in Senegal. *Int. J. Biol. Chem. Sci*, 2018: 12(1): 157-167.
- 19 Deb P.R., Debashis D., Srivastava S., Kuma B. and Supradip S. Insect growth regulatory activity of *Thevetia nerifolia* Juss. against *Spodoptera litura* (Fab.). *Journal of Applied Botany and Food Quality*, 2012: 85: 212-215.
- 20 Mboussi S., Ambang Z., Ndogho P., Ngoh Dooh J. and Manga Essouma F. In vitro antifungal potential of aqueous seed extracts of

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

- Azadirachtaindica* and *Thevetiaperuviana* against *Phytophthora megakarya* in Cameroon. J.Appl. Life Sci. Int., 2016: 4 (4): 1-12.
- 21 Dida L.S.L., Ambang Z., Djieto C.L., Chedjou B.C, Heu A., Ndogho A. Effect of aqueousextracts of *Thevetiaperuviana* K. seeds on the control of lateblight and pestinsects of *Solanumtuberosum* L. in Cameroon. Greener J. journal of Agr.icultural Sci. ences, 2019: 9 (1): 14-22.
- 22 Djeugap J.F., Fontem D.A. and Tapondjou A.L. In vitro efficacy of plant extracts against downy mildew (*Phytophthora infestans*) of black nightshade. Int. J. Biol. Chem. Sci, 2011:5(6):2205-2213. 47.
- 23 Ondo F. Effect of aqueousextracts of oleander seeds and chemical pesticides on cassava leaf diseases. Masters Thesis, University of Yaoundé I, 39 p., 2009.
- 24 Renard F. and Foucart G. Leaf diseases at the end of vegetation in maize cultivation. CIPF-Pilot center in maize cultivation. Laboratory of Ecophysiology and Plant Breeding. UCL-Louvain-La-Neuve. 6 p., 2008.
- 25 Zakari A.H. Effect of seed quality on groundnut production in Senegal, National School of Agriculture (ENSA), Final studywork, Unpublished, 59 p. 2003.
- 26 Bonhomme R. Action of climatic factors on development ent of the corn. Senior Cycle of Agronomy, INA-PG, 1981.
- 27 Demeyer A., Voundi J.C. and Verlo o M. G. Characteristics of wood ash and influence on soil properties and nutrient uptake: an over view. Bioresource T. echnol. ogy. 2001: 77, 287-295.
- 28 N'Guessan K. F. Kouassi A. F. and Atindehou K. Study on the effect of the neem, *Azadirachtaindica* J. uss (meliaceae) on *Sahlbergellasingularis* (Hemiptera: Miridae), an important pest of cocoa. Proc. 15th Int. Cocoa Res. Conf. October 9-10, San Jose, Costa Rica pp. 1287-1296; 2006.
- 29 Gallais A. Evolution of plant breeding tools: from genealogical selection to trans-genesis. C.R. Acad. Agric. Fr., 2000: (86): 13-2
- 30 Cardwell K.F, Schulhess F., Ndemah R and Ngoko Z. A system approach to accessing crop health and maize yield losses due to pests and diseases in Cameroon. Agr. icultural Ecosyst. em — and Environ. ment 1997: (65) : 33-47

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

31 [PubMed] Schulthess F., N.A. Forest-Perez and S. Gounou. Sampling lepidopterous pests on maize in West Africa. Bull. Ent. Res. 1991: (81):297-3

32 Tahiri A., Assi M. and Amissa A. Toxicity and mode of action of *Caricapapaya* L. (Caricaceae) extracts on *Macrotermshellicosus* Rambur (Isoptera : Macrotermitinae). Cah. Agric. 2010: (19): 267-2

Formatted: Font: Italic

Formatted: Font: Italic

33 Tounou A.K., God G., Amadou S., Agboka K., Gumedzoe Y.M.D. and Sanda K. Bio-insecticidal effects of plant extracts and oil emulsions of *Ricinus communis* L.

Formatted: Font: Italic

(Malpighiales: Euphorbiaceae) on the diamondback, *Plutella xylostella* L. (Lepidoptera: Plutellidae) under laboratory and semi-field conditions. Journal of Applied Biosciences, 2011:(4):2899-2914.

Comment [G12]: Move these 3 lines up

Formatted: Font: Italic

34 Ajeigbe HA, Saidou AK, Singh BB, Hide O, Satoshi T. Potentials of cowpea (*Vigna unguiculata*) for dry season grain and fodder production in the Sudan and Sahel zones of West Africa. International Institute of Tropical Agriculture (IITA), 189-202; 2012.

Formatted: Font: Italic

35 Egho EO and Enujike EC Effect of native soap on insect pests and grain yield of cowpea (*Vigna unguiculata* (L) Walp) in Asaba and Abrakaduru during the late cropping season in Delta state, Nigeria. Sustainable Agriculture Research, 2012: Vol. 2.

Comment [G13]: Report the Issue No. of the journal??

36 Nguimbous LB. Effects of aqueous extracts of almonds of *Thevetia peruviana* (Pers.) K. Schum and plants of *Mucuna pruriens* (L.) DC. on the root cochineal of cassava (*Strictococcus vayssierei*) in the field. Maste THESIS II, University of Yaoundé I, 41p. 2012.

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

37 Mourier M. Effects of neem (*Azadirachta indica*) kernel water extracts on cassava mealy bug, (*Phenacoccus manihoti* (Homoptera, Pseudococcidae). Journal of Applied Entomology, 1997:121(4): 231-236.

Formatted: Font: Italic

Formatted: Font: Italic

38 Agboka K. Development and testing of plant health management options against the maize cob borer *Mussidia gravenella* Ragonot (Lepidoptera: Pyralidae) in West Africa PhD thesis, Georg-August University of Göttingen; 2009.

Formatted: Font: Italic

39 Burkill H.M. The useful plants of West tropical Africa, Ed. 2 vol (1) Families A.D. Royal Botanic Gardens, Kew, Richmond, United Kingdom. 960p. 46 ; 1985.

- 40 Kambou G. and Guissou I.P. Pytochemical composition and insecticidaleffects of aqueousspiceextracts on insectpectsfound on green beans(*Phaseolusvulgaris*) in Burkina Faso. Tropiculture, 2011: 29(4): 212-217.

Formatted: Font: Italic

UNDER PEER REVIEW