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Field Control of Maize Borers Using Aqueous Seed Extracts of *Thevetia Peruviana* (Pers.) K. Schum

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SBM, MZMB and PNZ designed the research. Authors SBM, ANKN and AH conducted the experiments. Authors SBM and AH analysed the data and conducted statistical analyses. Author SBM wrote the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: In order to find an alternative to chemical control, the insecticidal potential of aqueous extracts of *Thevetia peruviana* seeds formulated at 16.66 g/l were tested in the field on the maize stalk borer species.
Study Design: The factorial design in subdivided plots or "split-plot" with four replicates and two factors studies was used on an area of 250 m^2.
Place and Duration of Study: The experiment was carried out in a field located in the city of Yaounde, Cameroon 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 at 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

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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.
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 *Busseola fusca* and *Sesamia calamistis* 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 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 the environment and human health.

Keywords: Maize; Thevetia peruviana; stem borers; pesticides; biological control; Busseola fusca; Sesamia calamistis.

1. INTRODUCTION

Maize (Zea mays L.) is a very important cereal crop for human food livestockfodder and feed. It is the basis for the functioning of several industries; food processing, brewing, soap and oil production [1]. Maize (*Zea mays* L.), a member of the family Poaceae, is the most nutitious cereal [2], because of its peculiar nutritional contents (high starch content, presence of proteins, minerals). Moreover, it's cultivation, harvesting and shelling is 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 (*Triticum aestivum* 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 the 2016/2017 with 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 was 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 crop. 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 [11-14].

Several studies have been carried out with the aim of minimisie the use of chemical pesticides and promoting the use of plant-based biocides [15]. Indeed, a good number of plants such as *Thevetia peruriana* have natural substances with pesticidal properties [16-18]. 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 [19-21]. However, in Cameroon no work has been undertaken on the use of aqueous extracts from *T. peruviana* seeds for the control of maize stalk borers in the field. Thus, for the conservation of ecosystem and the safety of consumers' health, the ideal would be the adoption of natural pesticides of the plant origin [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 of the Testing Site

The experiment was carried out in a field where cassava was previously grown. 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. 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% (Fig. 1). The experiment was spread over a period of 3 months and one week, from sowing to harvesting on a plot of 250 m².

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 (Yaounde) 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.

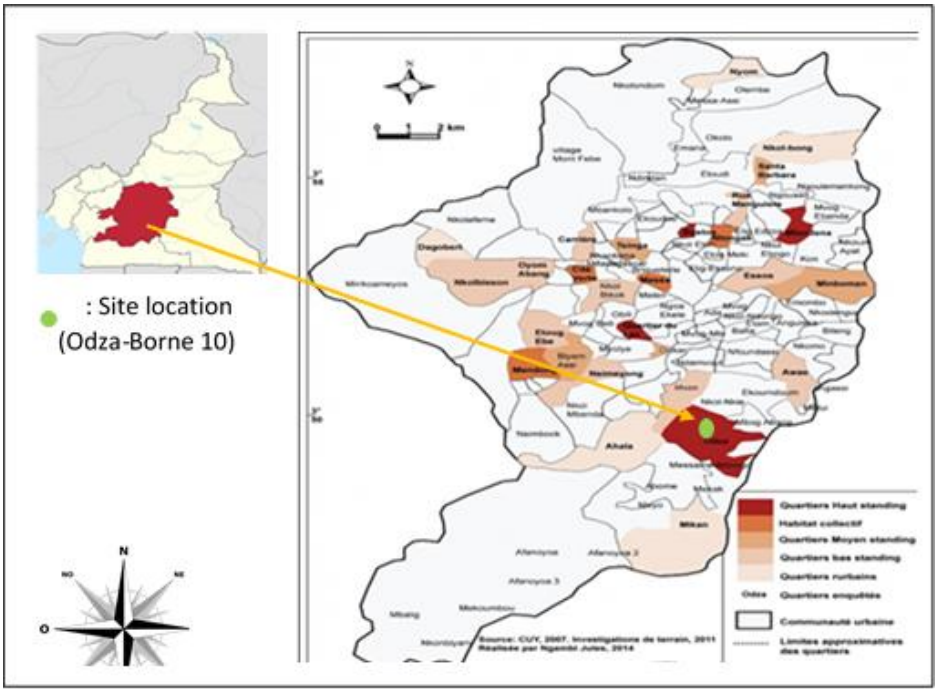

Fig. 1. Geographical position of the study site

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 is a systemic insecticide with the trade name Cypercal 12 EC (Fig. 4), 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 pot were left after demarriage. Each experimental unit measured 2.55 m² having 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 weeks after sowing (SAS) and the second at 7 SAS using a hoe.

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 the main factor at two levels (V1: CMS 8704 and V2: local variety). The sub-plots wer comprised of 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 were tested. The main 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 m^2.

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

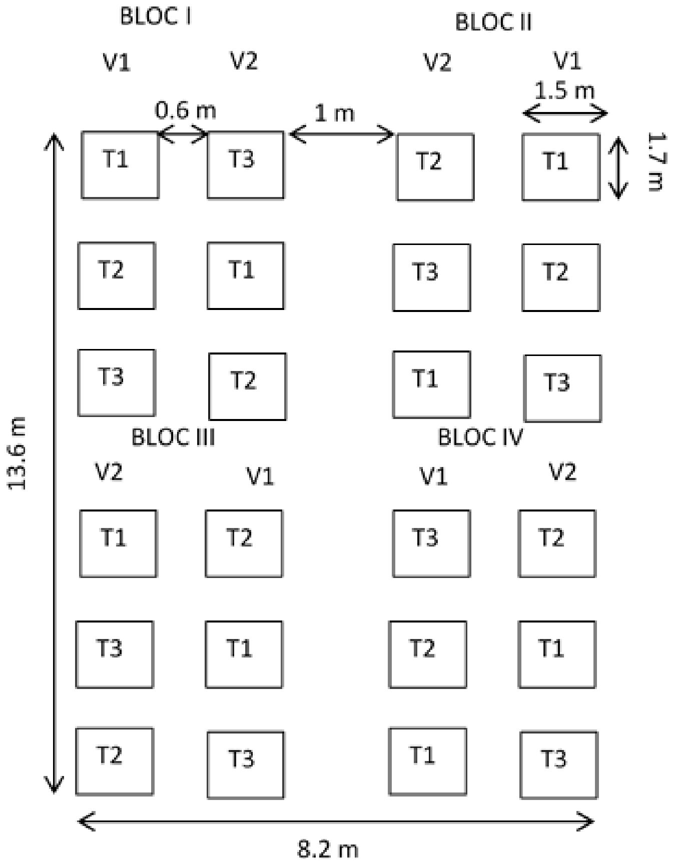

Fig. 6. Testing plan

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. peruviana* and applications

Aqueous extracts of *T. peruviana* were prepared according to Ondoa [23]. The fallen fruit was collected at the foot of the tree and the pulp was removed; then the stones were carefully dried (in the shade) to prevent the development of fungi. Three days before application, the seeds were extracted from the pits by hand crushing with a stone and finely ground. The powder obtained (250 g) was 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 poured into a knapsack sprayer, to which 10 g of powdered soap was added as a wetting agent. The solution was then filled up to 15 l and applied (i.e. at a concentration of 16.66 g/l). For the synthetic insecticide, the solution was prepared by taking 37.5 ml of Cypercal 12 EC from the 1-litre bottle 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 insecticide also once a week until the end of the experiment. Applications started 5 SAS (week after sowing) and ended 13 SAS. The different solutions were applied to stems, leaves and in leaf cones using a knapsack sprayer.

2.4.5 Evaluation of growth parameters

2.4.5.1 Exercise rate

The rate of emergence was obtained from the 6 th to the 8th day after sowing (DAS) by calculating the ratio between the number of stems emerged 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 measured with a ruler and then one meter from the collar to the level of the insertion of the young (last) leaf. This parameter was measured on a weekly basis from the 3 rd SAS to the 7 th SAS, on 8 randomly labelled plants in each treatment.

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 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 on 8 specifics plants in each experimental unit from the 7 th SAS until the harvest.

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. The grains obtained after threshing the ears were dried and weighed. The dry grain yield per hectare was determined using the following formula: [25]:

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

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 Teat at 5%

probability level 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 raise rate of the two maize varieties is shown in Fig. 7. Non significant differences were recorded between the varieties at 6, 7 and 8 days after sowing (JAS). The data show 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.

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 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 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, non 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 height 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).

3.1.2 Identification, inventory and damage to maize stalk borers

During the experiment, two stem boring insects attacking maize were identified. These were *Busseola fusca* Fuller and *Sesamia calamistis* Hampson, both belonging to the noctuidae family (Fig. 8).

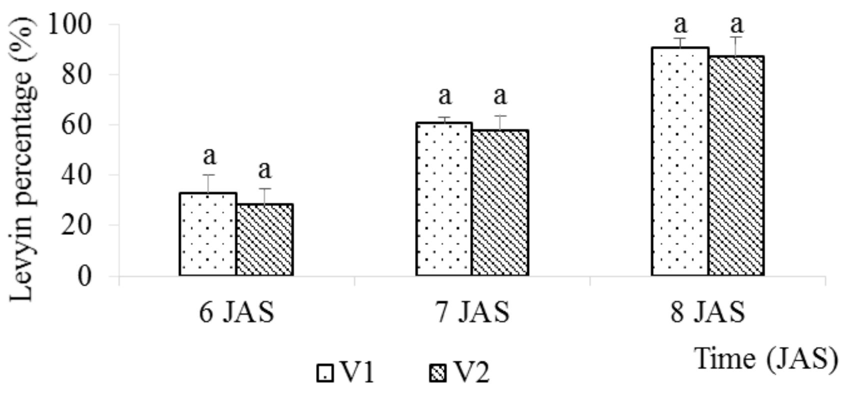

Fig. 7. Raise rate of the two maize varieties as a function of time. JAS: day after sowing; V1: improved variety CMS 8704; V2: local variety

*** *Values followed by the same letter are not significantly different when p<0.05*

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		*	***	**	ns
Interaction		***	***	***	**

*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% level of probality*

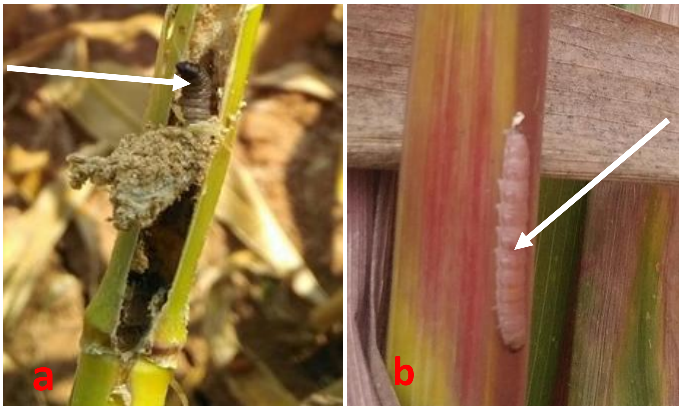

Fig. 8. Borers observed on maize plants (a): *Busseola fusca*; (b): *Sesamia calamistis*

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

Fig. 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).

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, 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 non significant difference among the different treatments and varieties (P > 0.05).

With regard to dry grain yield, a highly significant effect (p < 0.001) is observed among the different treatments as well as interactions between treatments x varieties. The insecticidal 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, non significant difference was observed between varieties for this parameter. Values of 1.84 ± 0.83 t/ha and 1.46 ± 0.17 t/ha were recorded for variety V1 (improved variety CMS 8704) and variety V2 (local variety) respectively.

3.2 Discussion

The results show that the varieties did not influence the emergence rate. It is evident 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, [26] showed in his findings 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

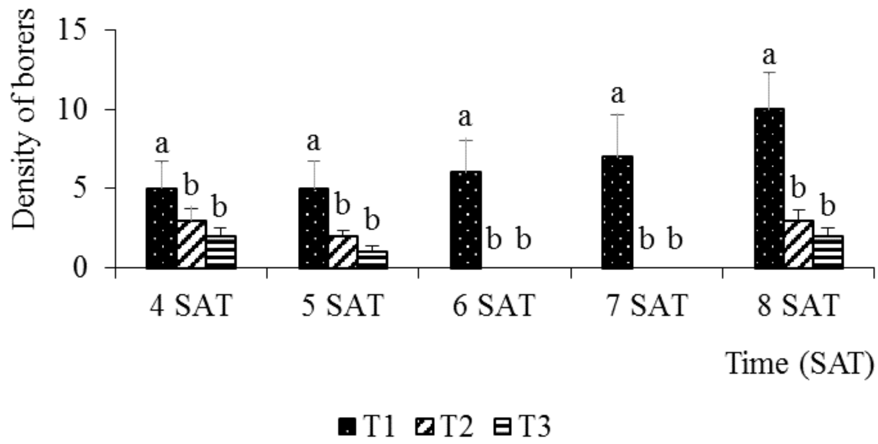

Fig. 10. Effect of treatments on stem borer density as a function of time
WAT: weeks after treatment; T1: untreated control, T2: aqueous extract of T. peruviana, T3: cypercal insecticide
**Histograms followed by the same letters are not statistically different (p>0.05)*

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. 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
Varieties		ns	ns	ns
Treatments		ns	ns	***
Interaction		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*

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 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].

Busseola fusca and *Sesamia calamistis*, were the species of maize stalk borers encountered during our study and which can secondarily attack the ear. 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 [36] in work on the effect of *T. peruviana* kernels and *Mucuna pruriens* 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 (*Sahlbergella singularis*) in the field. Similar results were also observed by [38] who demonstrated the insecticidal effect of *Hyptis suaveolens* against maize pests; notably *Mussidia nigrivenella* 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. peruviana* seeds. 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. peruviana* seeds 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.

4. CONCLUSION

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 insecticidal 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 *Busseola fusca* and *Sesamia calamistis*.The results obtained on stem borer density showed that the insecticidal 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 borers). Both maize varieties showed almost the same levels of sensitivity to stem borers.

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. These can therefore be used as a control product against maize stalk borers in the field.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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