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Effect of extracts from seeds of *Thevetia peruviana* (Pers.) K. Schum against cassava root scale *Stictococcus vayssierei* Richard (Hemiptera: Stictococcidae) in field

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Key words: Aqueous extract, Organic extracts, *Thevetia peruviana, Stictococcus vayssierei, Manihot esculenta*

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Abstract

The African Root and Tuber Scale (ARTS) *Stictococcus vayssierei* R. is a formidable enemy to cassava (*Manihot esculenta* Crantz) production, responsible for production losses ranging from 60 to 100% in plantations if strong measures are not taken to control its spread. To improve the production of this commodity, a study was carried out to reduce the number of root scale insects, and their effects on cassava production in the field. The present study test the insecticidal activity of aqueous and organic extracts of *Thevetia peruviana* seeds against *Stictococcus vayssierei*. The cassava varieties TMS 92/0057 (improved) and Miboutou (local) as well as five treatments (T0= control, T1= aqueous extract, T2= methanol extract, T3= acetone extract and T4= BASTION-SUPER chemical insecticide) were used in a split-plot design with four replicates. Growth parameters, number of live and dead root scale insects per plant and yield were evaluated. The results show that the highest number of live root scale insects per plant is observed on Miboutou variety (125 ARTS/P) in control plots than on the 92/0057 variety in plots treated with aqueous extract (84.13 ARTS/P). The lowest yield of fresh tubers is observed in control plots of the Miboutou variety (11.50 t ha^{-1}). Highest yields are observed in 92/0057 variety in plots treated with acetone extract (15.20 t ha^{-1}) and the Miboutou variety in plots treated with synthetic insecticide (15.05 t ha^{-1}). *Thevetia peruviana* seeds, through their repressive effect against cassava root scale, would indicate an insecticide potential.

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Introduction

Cassava production (*Manihot esculenta* Crantz) is compromised in tropical regions of the world by pressure of disease and pest (Hillocks *et al.*, 2002; Moses *et al.*, 2005; Nassar and Ortiz, 2007; Legg *et al.*, 2015). In Central Africa, as the most harmful pests of cassava, the African root and tuber scale (ARTS) *Stictococcus vayssierei* Richard is high on the list, causing yield losses of cassava ranging from 60 to 100% in plantations and could pose a major threat to production if strong measures are not taken to control its spread or effects (Ngeve, 2003; Hanna *et al.*, 2004; Lema *et al.*, 2004; Tata-Hangy *et al.*, 2006). *S. vayssierei* feeds on the cassava root system and causes leaf drop, wilting, tip dieback and growth retardation (Ngeve, 2003; Williams *et al.*, 2010).

Cassava is used as food to help relieve problems of hunger and carbohydrate deficiency, and therefore its importance in terms of food security in tropical and subtropical zone (IITA, 1990). Total annual world production is estimated at 278 million tons (Mt) in 2017. In Cameroon, cassava is the dominant root and tuber crop with an estimated annual production of 5.4 million tons (Mt) on average in 2017 (FAO, 2018). In Cameroon and the Democratic Republic of Congo, cassava root scale contributes in part to a tuberous root production deficit of nearly 31 million tons (FAO, 2014). This biting-sucking insect is one of the most important arthropod pests of the country's semi-humid forest agrosystems (CNRCIP, 1989; Ambe *et al.*, 1999). To control its damage in the field, several control strategies have been developed, including chemical control, which is very often used by the farmers against crop enemies (Adigoun, 2002). Synthetic insecticides used in pests control are very expensive for subsistence farmers and degrading for the environment (Ben-Dov, 1997; Keita *et al.*, 2000) due to the presence of their residues in groundwater (Ndongo, 1999). According to the World Health Organization (WHO), more than 25 million producers worldwide are poisoned each year, of which about 10 to 20 thousand die of pesticide poisoning (Rajiv *et al.*, 2016). Indeed, plants with pesticide effects have a real advantage in a pest control and are a suitable alternative to the phytosanitary methods proposed so far. Several plant species has been identified as having insecticidal properties (Benayad, 2008; Regnault-Roger, 2008). Thus, *Thevetia peruviana* has already been the subject of several studies showing the effectiveness of these extracts on insect pests (Ojo and Okafor, 2000; Ambang *et al.*, 2005). This work aims to study the effect of aqueous and organic solvent extracts of *Thevetia peruviana* seeds in controlling damage caused by *Stictococcus vayssierei* in the field.

Materials and methods

Study site description

This experiment was undertaken in March 2018 in a fallow farms (4 years old) in the locality of Akonolinga, Loum, (03° 48.136' N and 012° 15.518' E, altitude 663m), at the Centre Region of Cameroon. Crops like groundnut, macabo and cassava are routinely been cultivated in this area. This locality belongs to the agro-ecological zone 5 of Cameroon (humid forest zone with bimodal rainfall). The site is naturally infested with cassava root scale and is characterized by a Congo-Guinean sub-equatorial climate, with two dry seasons alternating with two rainy seasons. The average rainfall is 1633 mm/year distributed in a small rainy season (March-June) and a long rainy season (September-November). The average annual temperature is relatively constant (around 23 to 27°C). Relative and average humidity is above 80%. The soil is ferralitic and is characterized by outcrops of the indurated horizon in the form of slabs or gravel (Moudingo, 2007).

Plant material

The plant material used was cassava cuttings and almond stones from *Thevetia peruviana*. The cassava cuttings used in the framework of this study are of two varieties. Improved variety, namely TMS 92/0057 donated by the International Institute of Tropical Agriculture (IITA) is tested tolerant to Cassava mosaic disease whereas local varieties namely Miboutou which sensitive to Cassava mosaic disease based on field observations and locally grown by farmers. The mature stone of *Thevetia peruviana* collected near trees in the cities of Yaoundé and Bafoussam was used.

Chemical material

The chemical material was a product with a BASTION-SUPER commercial name, granular in appearance and purple in color, and the active ingredient is Oxamyl 5%.

Methods

Experimental design and culture conditions

The experimental was a "split-plot" design (Sehgal, 2003) with four replicates. The Varieties constituting the main plots randomly in a replication with two variants: V1 (improved variety TMS 92/0057) and V2 (local variety Miboutou). Five treatments represented sub-plots randomized the main plot (T0: control, T1: aqueous extract, T2: methanol extract, T3: acetone extract and T4: insecticide BASTION-SUPER). Each block with a total of 160 cuttings, consisted of ten sub-plots was made up of 16 cuttings planted at a spacing of 1 x 0.8m (12,500 plants ha^{-1}). The sub-plots measuring approximately 4m x 4m were ploughed and ridged using hand hoe, and separated by 1m paths and blocks were separated by 2m spaces. They each contain four rows of four plants. Cassava cuttings about 20cm long are planted obliquely position by pushing the stalk 2/3 of the length into the soil (IITA, 2000). No fertilizers were applied during the crop growth of cassava plants. Weeding was done at 2, 3, 5 and 8 months after planting (MAP) using hand hoe.

Preparation of seeds extracts of Thevetia peruviana

The mature fruits of *Thevetia peruviana* were collected at the foot of the trees in the cities of Yaoundé and Bafoussam. The stones of the harvested fruits were dried in the shade in the laboratory and then peeled and the kernels obtained were crushed using a manual "Victoria" mill. The organic extracts were prepared by macerating the powder obtained at a rate of 500g in 2L (concentration: 250g L^{-1}) of Acetone and Methanol. After 48 hours of maceration, the products obtained rich in extracted substances, were filtered by filter paper and concentrated in a rotary evaporator until the essential oil was obtained. The extracts obtained were placed in a desiccator to remove the remaining solvent and stored for further use (Gata-Gonçalves *et al.*, 2003). The aqueous extract of *T. peruviana* was obtained by macerating for 24 hours 1500 g of powder in 15L of water this corresponds to a 10% solution and 30g of soap powder was added as a wetting agent (Stoll, 1994). The resulting product was filtered with a cloth and poured into a sprayer. The chemical and phytochemical composition of *T. peruviana* extracts is well known (Hammuel *et al.*, 2011; Ngoh dooh *et al.*, 2014).

Spraying of treatments

The synthetic insecticide (BASTION-SUPER) was buried and covered with soil to a depth of about 5cm and within 14cm of the plant collar, at a rate of 30g per plant. The chemical treatment of the plants was carried out only once until the end of the experiment. From the essential oils obtained a volume of 60 mL (1200mL ha^{-1}) of extracts (methanol and acetone) was collected and diluted in a sprayer containing 15L of water to which 30g of soap powder was added as a wetting agent (Zakari, *et al.*, 2011). Aqueous, organic extracts and control (water + soap) were applied to the neck of cassava plants. Application of all treatments begins at two months after planting (2 MAP) and sprays of extracts of *T. peruviana* and control have been repeated at 3, 4, 5, 6 and 7 MAP.

Parameters measurement

Evaluation of plant growth, development and yield

The stem collar diameter (2-3cm above the soil surface) was measured using caliper on three randomly selected and labeled plants at 3, 6, 9 and 12 months after planting (MAP). Fresh shoots and tuber weights were measured and number of tubers per plants was enumerated on two plants randomly selected in each sub-plot at 3, 6, 9 and 12 MAP by uprooting plants. Tuber weights were extrapolated at each sampling per ton per hectare as proposed by Kamau *et al.* (2011).

$Y\,(t\,ha^{-1})$ = tuber weight (kg/m^2) x 10 000 m^2/ha x 1 t/1000 kg.

Where, Y= yield

Evaluation of cassava root scale number

The number of root scale insects was enumerated using hand meter on two randomly sampled plants per sub-plots by uprooting plants at 3 months intervals. Cassava root scale was counted per plants selected using a magnifying glass 10 at each assessment date. All life stages (larvae 1, larvae 2, adults and dead individuals) of the scale insect have been counted on cassava stem, strains, mother cuttings, tuberous roots and feeder roots (Ambe *et al.*, 1999; Ndengo *et al.*, 2016a). The living and dead individuals was separate in each treatments.

Statistical analysis of data

Data were subjected to one-way and two-ways ANOVA, using R software version 3.5.1. The Tukey's multiple comparison based test set at 5% threshold were performed to separate mean values when the analysis of variance was found significant.

Results

Effect of Thevetia peruviana seed extracts on stem diameter

Data on the stem diameter of cassava plants are recorded in Table 1. There is an increase in the stem diameter of cassava plants in the treatments of the two varieties over time. At 3 MAP, no significant differences ($P < 0.05$) are recorded between treatments, varieties and variety x treatment interaction. On the other hand, at 6 MAP a very highly significant effect is observed between treatments ($P < 0.001$), varieties ($P < 0.001$) and variety x treatment interaction ($P < 0.01$).

The largest diameter is produced by Miboutou variety in plots treated with synthetic insecticide (2.43 ± 0.12cm) and the smallest in plots treated with *Thevetia* aqueous extract (1.81 ± 0.12cm) of the same variety. No significant effects were observed between the varieties and the variety x treatment interaction at 9 and 12 MAP. Only the treatment effect is significant ($P < 0.05$). The treated plots gave the largest diameters. In plots treated with synthetic insecticide, 92/0057 variety (2.41 ± 0.19; 2.56 ± 0.17cm) and Miboutou variety (2.57 ± 0.27; 2.63 ± 0.20cm) have the largest diameters while the 92/0057 variety (2.12 ± 0.23; 2.27 ± 0.22cm) and the Miboutou variety (1.94 ± 0.18; 2.09 ± 0.25cm) in control plots had the smallest diameters at 9 and 12 MAP respectively.

Table 1. Effect of treatments and cassava variety on the stem diameter of cassava.

Varieties	Treatments	3 MAP	6 MAP	9 MAP	12 MAP
V1	T0	1.69 ± 0.13a	2.04 ± 0.10bcd	2.12 ± 0.23ab	2.27 ± 0.22a
	T1	1.45 ± 0.08a	1.90 ± 0.09cd	2.22 ± 0.27ab	2.42 ± 0.34a
	T2	1.51 ± 0.04a	1.99 ± 0.11cd	2.24 ± 0.12ab	2.29 ± 0.13a
	T3	1.49 ± 0.18a	1.97 ± 0.12cd	2.28 ± 0.19ab	2.37 ± 0.26a
	T4	1.57 ± 0.09a	2.04 ± 0.09bcd	2.41 ± 0.19ab	2.56 ± 0.17a
Means (V1)		1.54 ± 0.14a	1.99 ± 0.11b	2.25 ± 2.29a	2.38 ± 0.24a
V2	T0	1.56 ± 0.15a	2.01 ± 0.15bcd	1.94 ± 0.18b	2.09 ± 0.25a
	T1	1.45 ± 0.16a	1.81 ± 0.12d	2.08 ± 0.09ab	2.23 ± 0.19a
	T2	1.68 ± 0.06a	2.29 ± 0.19ab	2.43 ± 0.17ab	2.57 ± 0.18a
	T3	1.72 ± 0.11a	2.19 ± 0.06abc	2.25 ± 0.08ab	2.41 ± 0.22a
	T4	1.59 ± 0.16a	2.43 ± 0.12a	2.57 ± 0.27a	2.63 ± 0.20a
Means (V2)		1.60 ± 0.15a	2.15 ± 0.26a	2.27 ± 0.30a	2.40 ± 0.28a
Interaction		ns	**	ns	ns
Treatments		ns	***	**	*
Varieties		ns	***	ns	ns
Cv (%)		8.02	6.00	9.88	9.41

P: 0'***' 0.001'**' 0.01'*' 0.05, ns: not significant. MAP: months after planting, Cv: Coefficient of variation; T0: control; T1: aqueous extract; T2: methanol extract; T3: acetone extract; T4: insecticide BASTION-SUPER; V1: improved variety TMS 92/0057; V2: local variety Miboutou. The values followed by the same letter are not significantly different according to Tukey's test at ($P < 0.05$).

Effect of Thevetia peruviana seed extracts on the fresh shoots weight

Overall, the fresh weight of shoots increases with time in all treatments (Table 2). At 3 MAP, there is a very significant effect ($P < 0.001$) between the treatments of the two varieties. The highest fresh shoot weight is produced by TMS 92/0057 variety (0.98 ± 0.08kg) and Miboutou variety (0.92 ± 0.07kg) treated with acetone extract compared to the fresh shoot weight of 92/0057 variety (0.75 ± 0.02kg) and the Miboutou variety (0.80 ± 0.06kg) treated with aqueous extract. A very highly significant effect (*P < 0.001*) is recorded between varieties, treatments and variety x treatment interaction at 6 MAP. The highest fresh shoot weight is recorded in plots treated with synthetic insecticide (1.96 ± 0.12kg) followed by plots treated with acetone extract (1.91 ± 0.13kg) of 92/0057 variety. For Miboutou variety, the highest shoot fresh weight is observed in plots treated with synthetic insecticide (2.05 ± 0.06kg) followed by plots treated with acetone extract (1.97 ± 0.13kg) and plots treated with methanol extract (1.97 ± 0.12kg). Control plots have the lowest values (1.38 ± 0.05kg). At 12 MAP, there is a significant effect (*P < 0.001*) between treatments and varieties (*P < 0.01*).

The highest fresh shoot weight is recorded in the Miboutou variety treated with acetone extract (2.91 ± 0.06kg) and the lowest fresh shoot weight in the control of 92/0057 variety (2.06 ± 0.08kg).

Table 2. Effect of treatments and cassava variety on the fresh shoots weight.

Varieties	Treatments	3 MAP	6 MAP	9 MAP	12 MAP
V1	T0	0.82 ± 0.07abc	1.38 ± 0.05b	1.54 ± 0.43c	2.06 ± 0.08c
	T1	0.75 ± 0.02c	1.45 ± 0.14b	2.51 ± 0.31ab	2.61 ± 0.15abc
	T2	0.83 ± 0.06abc	1.47 ± 0.06b	2.08 ± 0.42ab	2.51 ± 0.32abc
	T3	0.98 ± 0.08a	1.91 ± 0.13a	2.71 ± 0.16ab	2.80 ± 0.31ab
	T4	0.94 ± 0.05ab	1.96 ± 0.12a	2.11 ± 0.10abc	2.29 ± 0.09abc
Means (V1)		0.86 ± 0.11a	1.63 ± 0.27a	2.19 ± 0.49a	2.45 ± 0.34a
V2	T0	0.82 ± 0.10abc	1.49 ± 0.08b	2.15 ± 0.20abc	2.25 ± 0.38bc
	T1	0.80 ± 0.06bc	1.97 ± 0.12a	2.48 ± 0.35ab	2.88 ± 0.17ab
	T2	0.89 ± 0.05abc	1.97 ± 0.13a	2.75 ± 0.21ab	2.84 ± 0.49ab
	T3	0.92 ± 0.07abc	2.05 ± 0.06a	2.87 ± 0.23a	2.91 ± 0.06a
	T4	0.91 ± 0.09abc	2.05 ± 0.06a	1.98 ± 0.52bc	2.65 ± 0.27abc
Means (V2)		0.87 ± 0.09a	1.77 ± 0.31b	2.45 ± 0.45b	2.71 ± 0.35b
Interaction		ns	***	***	ns
Treatments		***	***	**	***
Varieties		ns	***	*	**
Cv (%)		8.25	5.95	13.77	10.21

P: 0'***' 0.001'**' 0.01'*' 0.05; ns: not significant; MAP: months after planting; Cv: Coefficient of variation; T0: control; T1: aqueous extract; T2: methanol extract; T3: acetone extract; T4: insecticide BASTION-SUPER; V1: improved variety TMS 92/0057; V2: local variety Miboutou. The values followed by the same letter are not significantly different according to Tukey's test at (*P < 0.05*).

Effect of Thevetia peruviana seed extracts on the number of living root scale insects

The results on the number of living root scale insects per plant (ARTS/P) show that it changes with the age of the cassava in the different treatments (Fig. 1). It appears that on both varieties of cassava, a high number of root scale insects is observed at 6 and 9 MAP compared to 3 and 12 MAP. At 3 MAP, there is a very significant treatment effect (*P < 0.001*).

The variety effect is highly significant (*P < 0.01*). At this time, the interaction is not significant (*P < 0.05*). At 6 MAP, only the treatment effect is very highly significant (*P < 0.001*). A high average number of root scale insects is observed on Miboutou variety (125 ARTS/P) in control plot than on the 92/0057 variety treated with aqueous extract (84.13 ARTS/P). A very highly significant effect is recorded between varieties (*P < 0.001*), treatments (*P < 0.001*) and variety x treatment interaction (*P < 0.01*) at 9 MAP. It can be seen in the Fig. that the variety 92/0057 in plots treated with acetone extract (71.38 ARTS/P) has less root scale insects Miboutou variety in control plots (118.63 ARTS/P). At 12 MAP, the variety effect (*P < 0.001*), treatment (*P < 0.01*) and variety x treatment interaction (*P < 0.05*) are significant. The Miboutou variety in control plots (75.63 ARTS/P) has the highest average number of root scale insects than the 92/0057 variety in plots treated with methanol extract (51 ARTS/P).

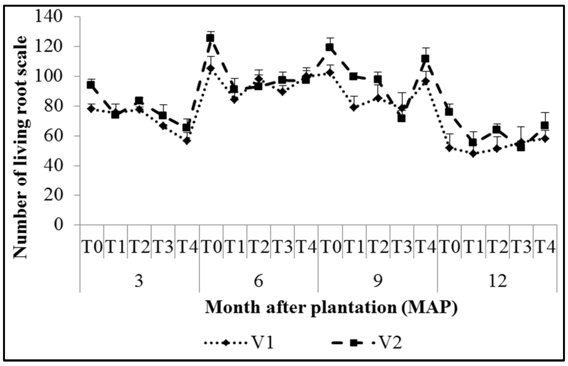

Fig. 1. Effect of treatments and cassava variety on the number of live root scale insect over time. T0: control; T1: aqueous extract; T2: methanol extract; T3: acetone extract; T4: insecticide BASTION-SUPER, V1: TMS 92/0057 variety, V2: Miboutou variety.

Number of dead root scale insect observed in the different treatments

The number of dead root scale insects varies from one treatment to another in both varieties (Fig. 2). A significant effect is observed between treatments ($P < 0.001$), varieties ($P < 0.01$) and variety x treatment interaction ($P < 0.01$). The highest number of dead root scale insects is observed in methanol extract treatment (97.5 ARTS/P) of the Miboutou variety and the lowest in control plots (19.75 and 36.88 ARTS/P) of the 92/0057 and Miboutou variety respectively. At 9 MAP, the treatment effect ($P < 0.001$) and the interaction ($P < 0.01$) are significant. Plots treated with aqueous extract (92.63 ARTS/P) of the Miboutou variety have the highest number of dead root scale insects compared to plots treated with synthetic insecticide (47.88 ARTS/P) of the 92/0057 variety. At 12 MAP, a very highly significant effect ($P < 0.001$) is observed between treatments, varieties and variety x treatment interaction. Miboutou variety treated with aqueous extract contains the highest number of dead root scale insects (64.88 ARTS/P) compared to 92/0057 variety in the control plots (19.63 ARTS/P).

Effect of Thevetia peruviana seed extracts on the number of tubers

Data on the number of tubers show a significant difference ($P < 0.05$) between varieties at 3 MAP (Table 3). At this time, the treatments and the variety x treatment interaction have no significant effects. At 9 MAP, only the variety effect is significant ($P < 0.01$). The lowest number of tubers is produced by the variety 92/0057 treated with methanol extract (3.13 ± 0.47) and the highest number of tubers in the Miboutou variety in control (6.50 ± 1.08). No significant effects between treatments and varieties were observed at 12 MAP. On the other hand, the interaction of variety x treatment is significant ($P < 0.05$). The highest number of tubers is observed in the Miboutou variety treated with the synthetic insecticide (6.34 ± 0.47). The number of tubers varies increasingly with time in varieties and treatments.

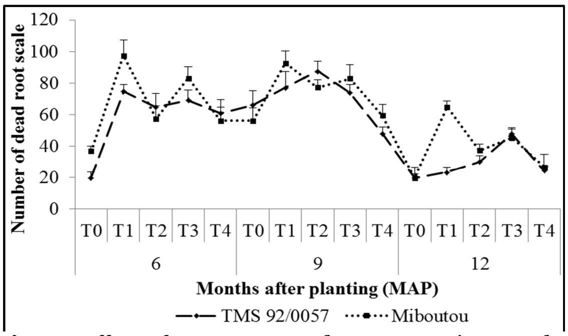

Fig. 2. Effect of treatments and cassava variety on the number of dead root scale insect over time. T0: untreated control; T1: aqueous extract; T2: methanol extract; T3: acetone extract; T4: insecticide BASTION SUPER, V1: TMS 92/0057 variety, V2: Miboutou variety.

Effect of Thevetia peruviana seed extracts on yield

The yield of fresh tubers varies according to the sampling periods (Table 4). Only the treatment effect is significant at 6 MAP. At 9 MAP, the interaction of variety x treatment is significant ($P < 0.001$), but no significant effects ($P < 0.05$) are observed between varieties and treatments. The highest yield is recorded by variety 92/0057 in treated plots with acetone extract (13.98 t ha^{-1}) compared to Miboutou variety treated plots with acetone extract (7.50 t ha^{-1}) followed by 92/0057 variety in control plots (9.30 t ha^{-1}). At 12 MAP, the treatment effect ($P < 0.05$) and the variety x treatment interaction ($P < 0.001$) are observed. The lowest yield of fresh tubers is observed in control plots of the Miboutou variety (11.50 t ha^{-1}). The highest yields are observed in the 92/0057 variety treated plots with acetone extract (15.20 t ha^{-1}) and the Miboutou variety treated plots with synthetic insecticide (15.05 t ha^{-1}).

Table 3. Effect of treatments and cassava variety on the number of tubers per plant.

Varieties	Treatments	3 MAP	6 MAP	9 MAP	12 MAP
V1	T0	2.50 ± 0.57a	2.87 ± 0.47c	4.75 ± 1.70ab	4.40 ± 0.48b
	T1	2.13 ± 0.85a	4.00 ± 0.41abc	4.50 ± 1.29ab	5.12 ± 0.63ab
	T2	1.88 ± 0.25a	4.50 ± 0.41ab	3.13 ± 0.47b	4.75 ± 0.96ab
	T3	2.13 ± 0.71a	4.63 ± 0.85a	4.87 ± 1.03ab	5.63 ± 0.75ab
	T4	2.50 ± 0.46a	3.00 ± 0.81c	4.63 ± 1.10ab	5.00 ± 0.82ab
Means (V1)		2.23 ± 0.57a	3.80 ± 0.94a	4.38 ± 1.12b	4.98 ± 0.78a
V2	T0	1.63 ± 0.25a	4.25 ± 0.29abc	6.50 ± 1.08a	4.63 ± 0.75ab
	T1	1.38 ± 0.75a	4.63 ± 0.75a	5.63 ± 0.75ab	5.34 ± 0.94ab
	T2	2.00 ± 0.12a	3.13 ± 0.48bc	5.37 ± 1.10ab	5.50 ± 0.41ab
	T3	2.25 ± 0.28a	3.75 ± 0.50abc	4.38 ± 0.94ab	5.13 ± 0.85ab
	T4	2.00 ± 0.40a	3.88 ± 0.48abc	6.13 ± 0.75a	6.34 ± 0.47a
Means (V2)		1.85 ± 0.56b	3.93 ± 0.69a	5.60 ± 0.92a	5.40 ± 0.87a
Interaction		ns	***	ns	*
Treatments		ns	*	ns	ns
Varieties		*	ns	**	ns
Cv (%)		27.16	14.91	21.52	14.11

P: 0'***' 0.001'**' 0.01'*' 0.05; ns: not significant; MAP: months after planting; Cv: Coefficient of variation; T0: control; T1: aqueous extract; T2: methanol extract; T3: acetone extract; T4: insecticide BASTION-SUPER; V1: improved variety TMS 92/0057; V2: local variety Miboutou. The values followed by the same letter are not significantly different according to Tukey's test at ($P < 0.05$).

Table 4. Effect of treatments and cassava variety on cassava yield.

Varieties	Treatments	6 MAP	9 MAP	12 MAP
V1	T0	5.56 ± 0.31a	9.30 ± 1.21c	12.90 ± 1.31bc
	T1	4.89 ± 0.24a	10.55 ± 2.67bc	13.65 ± 3.13ab
	T2	5.06 ± 0.60a	10.00 ± 1.51bc	14.60 ± 2.67ab
	T3	5.42 ± 0.39a	13.98 ± 2.69a	15.20 ± 4.73a
	T4	5.39 ± 0.43a	9.38 ± 2.98bc	14.75 ± 1.94ab
Means (V1)		5.26 ± 0.39a	10.64 ± 2.21a	14.22 ± 2.75 a
V2	T0	5.08 ± 0.24a	9.53 ± 1.36bc	11.50 ± 1.40c
	T1	5.09 ± 0.26a	12.58 ± 1.26ab	14.65 ± 2.47ab
	T2	5.55 ± 0.34a	9.84 ± 1.07bc	14.95 ± 2.60a
	T3	5.98 ± 0.31a	7.50 ± 1.53c	14.10 ± 2.13ab
	T4	5.69 ± 0.35a	9.53 ± 1.16bc	15.05 ± 2.20a
Means (V2)		5.48 ± 0.30a	9.79 ± 1.28a	14.05 ± 2.16a
Interaction		ns	***	***
Treatments		*	ns	*
Varieties		ns	ns	ns
Cv (%)		8.23	18.72	7.41

P: 0'***' 0.001'**' 0.01'*' 0.05; ns: not significant; MAP: months after planting; Cv: Coefficient of variation; T0: control; T1: aqueous extract; T2: methanol extract; T3: acetone extract; T4: insecticide BASTION-SUPER; V1: improved variety TMS 92/0057; V2: local variety Miboutou. The values followed by the same letter are not significantly different according to Tukey's test at ($P < 0.05$).

Discussion

Plant extracts used against pests in field and storage crops have shown several properties that allow them to be a part of alternative strategies to the use of synthetic pesticides (Regnault-Roger, 2008). Thus, several plants have already been the subject of work, such as *Thevetia peruviana*, whose phytochemical composition shows that the extracts of this plant are rich in coumarins, saponins, steroids, alkaloids, phenols, tannins, etc. (Hammuel *et al.*, 2011 ; Ngoh dooh *et al.*, 2014). Indeed, research has demonstrated the insecticidal and repellent effect of *T. peruviana* extracts (Mollah and Islam, 2007; Akpo *et al.*, 2017; Ndongo *et al.*, 2017). The purpose of this work is to study the efficacy of aqueous and organic extracts of *Thevetia peruviana* compared to a synthetic insecticide against cassava root scale. The results showed that no significant effects were observed between treatments for stem diameter of cassava plants at 3 MAP.

This is explained by the fact that the treatments have no effect on the growth of the plants. These results are in line with the work of Mukendi *et al.* (2014) which showed that treatments with aqueous extracts of *Azadirachta indica*, *Carica papaya* and *Tephrosia vogelii* leaves against *Ootheca mutabilis* do not have a significant effect on cowpea growth parameters. Similarly, no significant differences were observed between varieties. The establishment of the root system and the aerial part of the varieties covers their need for mineral elements in the soil and atmospheric carbonaceous matter, which would have contributed to the construction of their identical port. According to Indira *et al.* (2000) and Segnou (2002), the growth and development of the different (improved and local) cassava clones would not differ significantly during the first months. At 6 MAP, a significant difference is observed between varieties, treatments and variety x treatment interaction. The local variety has a larger diameter than the improved variety. These results are in agreement with the work of Ambang *et al.* (2007) which shows that the improved variety has a higher growth rate than the local variety. Differences in treatment at 9 and 12 MAP could also be explained by a high number of root scales in control plots that feed on sap at the roots and stem neck.

For the fresh weight of the shoots, the variety effect is observed. It is higher in the local variety (Miboutou) than in the improved variety (TMS 92/0057) at 3 MAP and 6 MAP. This could be explained by the capacity of the ecological environment to adapt strongly expressed by the local variety and the tolerance to root scale insect infestations in a species of mass selection by farmers. On the other hand, the improved variety requires specific environmental conditions of the experimental stations for the implementation of air coverage. According to Mbailao (2003), the improved variety requires a long time to adapt to its new environment. With regard to the treatment effect, a significant difference in the fresh weight of shoots at 3, 6, 9 and 12 MAP is observed. The fresh weight of shoots in the control is lower than in plots treated with seed extracts, probably due to heavy root scale insect infestation.

It could be assumed that infestation of plants by cassava root scale feeding at the root level would reduce their growth. Prüter and Zebitz (1991) show that field infestation by biting-sucking insect's results in a reduction in leaf area, weight and average growth rate.

The treatment effect is clearly significant on the number of live root scale insects during the four observation periods. The plants in the control plots were the most colonized. At 3 MAP, the lowest number of live root scale insects is recorded in plots treated with synthetic insecticide, followed by plots treated with *Thevetia* extracts.

The effect of the insecticide is very quickly observed at this time. Similarly, *T. peruviana* extracts are believed to play an insecticidal role against cassava root scale. Indeed, Ambang *et al.* (2011) have shown in their work that the leaves, fruits and roots of yellow oleander are considered as potential sources of biological compounds active as insecticides. Mourier (1997) shows the insecticidal effect of the aqueous extract of Neem on the mealybug (*Phenacoccus manihoti*) of cassava. At the end of 6 MAP and 9 MAP, an increase in the number of live root scale insects was observed compared to 12 MAP in all plots. Ndengo *et al.* (2016a) show in the work carried out in the Beni territory (North Kivu, DR Congo), on the influence of population density of African root and tuber scale on the yield of cassava varieties; where no treatment has been carried out that the population density of root scale insect is low at 3 MAP, and increases to 6 MAP to reach a peak before slightly decreasing to 12 MAP. The number of root scale insects varied from one variety to another. Local variety has the highest number of live root scale insects at all sampling periods (3 MAP, 6 MAP and 9 MAP).

Thus, it can be assumed that scale insect populations are oriented towards varieties according to their eating habits; similarly, the improved characteristic of TMS 92/0057 probably gives it the means of tolerance against the root scale. The results obtained by Ngeve, (2003) show that the improved clones were more tolerant to root scale insect than the local variety. According to Ndengo *et al.* (2016b), improved cassava clones have hosted a high population of root scale insects at 6 MAP as well as 9 MAP. Results on the number of dead root scale insects showed that it was higher on the Miboutou variety than on the improved variety 92/0057 in plots treated with *Thevetia peruviana* seed extracts compared to the control. Indeed, the remarks made on the effect of *Thevetia peruviana* seed extracts would testify to their insecticidal role.

The work of Mollah and Islam (2007) showed the effectiveness of organic extracts of *Thevetia peruviana* against *Callosobruchus maculatus*. Similarly, Theurkar *et al.* (2014) showed that the aqueous extract of the leaves of *Thevetia peruviana* would have a toxic effect on the adults of *Holotrichia serrata*. In addition, it would be important to note that the number of dead root scale insects observed on both varieties could probably also be the result of the defense mechanisms developed by them in the treated plots as well as in the control, hence the difference observed.

According to Fürstenberg *et al.* (2013), it is well established that plant-insect interactions over several hundred million years have led to a process of co-evolution; this evolutionary process has allowed plants to synthesize secondary metabolites that are bioactive towards insects. It could also be assumed that over time, the interaction between the local variety Miboutou and the root scale insects has led to the secretion of allelochemical substances by the plant, in order to defend itself against the latter's attacks.

The average number of tubers varies according to varieties and time. From 3 to 12 MAP, the average number of tubers increased from 2 to 7 in the varieties and in the different treatments. At 3 MAP, the highest number of tubers is observed in the improved variety with 2.22 ± 0.66 tubers compared to the local variety Miboutou with 1.85 ± 0.49 tubers. This would probably result from the early release of improved varieties in tuberous root production and also from a genetically integrated program.

Recurrent selection in institutions consists in transmitting characteristics of agronomic interest from selected breeding stock to new varieties (Bakayoko *et al.*, 2012). The analysis of variance of yield shows that at 9 MAP, there are no significant effects between varieties and treatments only the interaction between variety x treatment is significant. The improved variety in plots treated with acetone extract and the local variety in plot treated with aqueous extract have the highest yields. This could probably be justified by the fact that the extracts by their insecticidal effect reduced the number of root scale insects, which infested cassava plants in these plots, thus allowing the tubers to increase in volume. According to Segnou (2002), the difference in yield of fresh tuberous root is due to the volume of the clone's leaf mass, the interception of sunlight, its photosynthetic activity and its rate of translocation of nutrient reserves.

Conclusion

In this study, which aimed to study the effect of aqueous and organic extracts of *Thevetia peruviana* seeds against the cassava root scale in the field, it was found that extracts of *Thevetia peruviana* seeds can help reduce damage caused by the cassava root scale on plants and have significantly improved yield compared to the control in the field. The aqueous extract and acetone were the most effective in the field against this pest. The highest yields are observed in TMS 92/0057 treated with acetone extract (T3: 15.20 t ha^{-1}) and Miboutou treated with synthetic insecticide (T4: 15.05 t ha^{-1}). The yield of the improved variety (14.02 t ha^{-1}) was significantly lower than the yield of the local variety (14.22 t ha^{-1}). *Thevetia peruviana* seeds, through their extracts, have contributed to improving cassava production by reducing the number of cassava root scale in the field. They can therefore be used as bio-pesticides in sustainable agriculture.

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Competing interests

The authors declare that they have no competing interest.

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