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Aqueous Seed and Leaf Extracts of *Thevetia peruviana* (Pers.) K. Schum as botanical control agents agrainst *Spodoptera frugiperda* J.E. Smith on Maize

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ABSTRACT

The fall armyworm (Spodoptera frugiperda) has become the major biotic constraint on maize production in Cameroon, causing yield losses of 15 to 78 %. Given the limitations of synthetic insecticides (cost, toxicity and the development of resistance), this study evaluated the insecticidal potential of Thevetia peruviana seed and leaf aqueous extracts in controlling S. frugiperda, both in the laboratory and in the field. The extracts were obtained by macerating 250 g of ground seeds or leaves in 5 L of water for 24 hours. In the laboratory, the extracts were applied by direct contact at three concentrations (25, 50, and 100 mg/mL) to group of 10 larvae. Insecticidal activity was assessed based on larval mortality recorded 24 hours after treatment, and monitored over 5 days. In the field, a split-plot design with four replicates compared four treatments control, seed extract (50 g/L), synthetic insecticide (1.66 mL/L), and leaf extract (50 g/L) on two maize varieties (CMS 8704 and a local variety) over two consecutive growing seasons. The aqueous seed extract at concentrations of 50 and 100 mg/mL caused 100% larval mortality as early as 24 hours after exposure, a result comparable to that of the synthetic insecticide, whereas the leaf extract produced no mortality at that time point (0%). However, larval mortality induced by the leaf extract reached 46.66% five days after application. In the field, the fall armyworm larval density on maize plants treated with the aqueous seed extract of T. peruviana was reduced by 100%, matching the performance of the synthetic insecticide, and by 51.85% and 44.44% on plants treated with the aqueous leaf extract during the first and second growing seasons, respectively. Substantial maize yield grains were recorded for the V1 variety (CMS 8704) in plots treated with the aqueous seed extract of T. peruviana (5 t/ha) and in those treated with the aqueous leaf extract of T. peruviana (2.75 t/ha), compared to the untreated control plots (1.25 t/ha) during the second growing season. These findings demonstrate that aqueous extracts of T. peruviana exhibit insecticidal efficacy comparable to that of synthetic insecticides and represent a promising botanical alternative for the management of S. frugiperda in maize.

Keywords: *maize, Spodoptera frugiperda, potential insecticidal, aqueous extract, Thevetia peruviana.*

1. Introduction

Corn (*Zea mays*, L.) is one of the world's most important cereal crops and plays a major role in food security in many developing countries [1]. maize ranks first globally among the most widely produced cereals, ahead of wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.), accounting for 40% of total production on its own. Its annual global production was estimated at 1,230.6 million metric tons for 2024–2025 [2]. maize production in Africa accounts for 6.5% of global production, or 84.6 million metric tons. With production estimated at approximately 2.36 million metric tons for the 2024–2025 period, Cameroon, the leading producer in Central Africa, remains far behind the top African producers and struggles to meet its domestic demand, leading to an increase in imports (30,000 metric tons imported at 7.5 billion CFA francs in 2025) [2]. However, this low production is severely constrained by numerous insect pests that significantly reduce crop yields and quality.

Among these pests, the fall armyworm (*Spodoptera frugiperda*: Lepidoptera) has emerged as one of the most destructive invasive species affecting maize production. Native to the Americas, this highly polyphagous pest was first reported in Africa in 2016 and has since spread rapidly across most countries on the continent [3, 4, 5]. Severe infestations can result in yield losses of up to 100%, particularly when attacks occur during the early stages of plant growth [6]. In Africa, crop losses caused by *Spodoptera frugiperda* amount to approximately $16 billion [7]. In Cameroon, annual yield losses due to this pest are estimated at between 15% and 78%, valued at USD 2.481 to 6.187 million [8]. Control of the fall armyworm relies primarily on synthetic insecticides. Although chemical control effectively reduces pest populations, its intensive use raises serious concerns regarding environmental pollution, the destruction of beneficial organisms, pest resistance, and potential risks to human and animal health [10].

Furthermore, the high cost, limited availability, and difficulties associated with handling and storing chemical pesticides often limit their accessibility to smallholder farmers in many African countries. In light of all this, it has become imperative to prioritise alternative control methods that are environmentally friendly and safe for both human and animal health. Consequently, the use of formulations based on natural plant-derived substances as insect pest control agents has received increasing attention in recent years. These plants with insecticidal potential can generally be used and handled more safely than synthetic insecticides [11]. These substances have the advantage of being biodegradable with a short residual period, non-toxic to humans and animals at low doses, and they also possess systemic activity. *Thevetia peruviana (*Apocynaceae) is a plant known for its high content of bioactive secondary metabolites, particularly alkaloids, flavonoids, and terpenoids, which may exhibit insecticidal activity. Previous studies have reported the insecticidal activity of extracts derived from its seeds agrainst several insect pests [12, 13, 14, 15]. However, seed availability remains limited in some regions, as the plant produces seeds only once a year and their pesticidal activity may decrease during storage [16]. In contrast, leaves are more readily available throughout the year and may serve as a permanent, more sustainable, and practical alternative source of bioactive compounds. Similarly, according to Ouattara (2006), removing 50% of a tree's leaves does not significantly affect its survival [17]. Nevertheless, there is little information on the comparative insecticidal potential of seed and leaf extracts from *T. peruviana* agrainst the fall armyworm. The overall objective is to evaluate the insecticidal potential of aqueous extracts from the seeds and leaves of *T. peruviana* in controlling *Spodoptera frugiperda* under laboratory and field conditions.

2. Materials and Methods

2.1 Study Site

Laboratory work was conducted at the Laboratory of Phytopathology and Plant Protection at the University of Yaoundé I (latitude 3°52'00“ N; longitude 11°31'00” E). Field trials were conducted in Edéa (Littoral Region, Cameroon), in agroecological zone IV (dense humid forests, monomodal rainfall of 2,500–4,000 mm, temperature 22–29 °C, humidity 85-90%, sandy-clay ferralitic soils) [18].

2.2 Preparation of aqueous extracts from seeds and leaves of *Thevetia peruviana*

The fruits were collected in Edéa; the seeds were then extracted by manual crushing, ground in a mortar, macerated in distilled water for 24 hours, and filtered. The fresh leaves were crushed and macerated according to the same protocol [19].

2.3 Phytochemical analysis of the various aqueous extracts

The content of secondary metabolites (polyphenols, flavonoids, saponins, tannins, terpenoids, alkaloids) was determined using the methods described by Ribérau-Gayon, 1968 [20]; Boizot & Charpentier, 2006 [21]; and Mimica-Duckic et al., 2010 [22].

2.4 Identification of *Spodoptera frugiperda*

The presence of *S. frugiperda* in the field was confirmed by visual diagnosis based on detailed observations of symptoms [23]. To this end, all plants showing signs of infestation (presence of feeding tunnels on leaves and stems and holes in the leaves) were examined for *S. frugiperda.* Thus, a morning collection of larvae was carried out. The larvae were preserved in 70° alcohol and sent to the entomology laboratory at the University of Yaoundé I for identification using dichotomous keys**.**

2.5 Contact Toxicity Test

Stock solutions with a concentration of 500 mg/mL were prepared by steeping 50 g of paste (seeds or leaves) in 100 mL of distilled water for 24 hours, then filtered and diluted to concentrations of 25, 50, and 100 mg/mL. *S. frugiperda* larvae were collected from the experimental site located in a suburb of the city of Edéa. These larvae were placed in a ventilated plastic box measuring 9 × 7 × 1.5 cm^3. Eight treatments were tested: seed extracts (T1: 25, T5: 50, T7: 100 mg/mL), leaf extracts (T2: 25, T6: 50, T8: 100 mg/mL), reference insecticide (T3: 0.08 mL), and untreated control (T4). Ten larvae per treatment in three replicates (360 larvae in total) were exposed by spraying (~15 mL), then transferred to ventilated boxes using a brush along with the corn leaves. Mortality was assessed daily for 5 days. Corrected mortality was calculated using Abbott's formula (1925) [24]: $Mc = ((Mo - Mt) / (100 - Mt)) \times 100$

Mc: Corrected mortality; Mt: Mortality in the control box; Mo: Mortality in the treated boxes.

2.6 Experimental Design and Field Application of Extracts

A split-plot design with 4 replicates was used over 2 growing seasons [25]. Main factor: varieties (V1: CMS 8704, V2: local variety); Secondary factor: 4 treatments (T1: control; T2: 50 g/L aqueous seed extract + 10 g/15 L soap; T3: 40 g/L imidacloprid + 40 g/L lambda-cyhalothrin at 1.66 mL/L; T4: leaf extract 50 g/L + soap). Experimental plots measuring 2 × 2 m (3 rows × 4 plots), separated by 0.5-m-wide aisles, with blocks spaced 1 m apart. Total area: 200 m^2. The solutions were then poured into a 15-L backpack sprayer and applied with the addition of 10 g of powdered soap as a wetting agent [26] weekly at 3, 4, 5, and 6 weeks after sowing (WAS) in the evening to all parts of the corn plants. The dose of the synthetic insecticide was that recommended by the manufacturer, namely 25 mL in 15 L of water, or 1.66 mL/L [27].

2.7 Field parameters measured during the two growing seasons

Larval density was assessed by weekly counts on 8 labeled plants per subplot (1 week before treatment [WBT] and 4 WBT). Stem height and the number of leaves were measured from 3 to 7 days after sowing (WAS). Dry grain yield was determined 90 days after sowing (JAS) following drying and threshing.

2.8 Statistical Analysis of the Data

The collected data were subjected to one- and two-way analysis of variance (ANOVA) using R software version 3.4.3. Multiple comparisons of means were performed using Duncan's test at the 5% level. A principal component analysis (PCA) was conducted to identify the highest-performing variety × treatment combinations.

3. Results

Phytochemical analysis of the various aqueous extracts

The screening revealed the presence of polyphenols, flavonoids, tannins, terpenoids, alkaloids, and saponins (Table 1).

The aqueous seed extract was found to be significantly richer in terpenoids (59.54%), tannins (56.18%), polyphenols (80.67%), saponins (39.02%), and alkaloids (45.61%) compared to the aqueous leaf extract (41.61%, 46%, 68.96%, 32.44%, and 35.71%). Flavonoids, on the other hand, are present but in nearly identical amounts (51% and 51.2%) in the two aqueous extracts, respectively.

Table 1: Bioactive compounds identified in aqueous extracts

Compound families	Percentage content (%)	
	Seeds	Leaves
Flavonoids	51	51.2
Saponins	39.02	32.44
Tannins	56.18	46
Terpenoids	59.54	41.61
Polyphenols	80.67	68.96
Alkaloids	45.61	35.71

Laboratory Mortality Rate of the Legionnaire Caterpillar

Significant differences ($P < 0.05$) were observed among the treatments (Fig. 1). The aqueous seed extract at concentrations of 50 and 100 mg/mL, as well as the synthetic insecticide, caused 100% mortality as early as 24 hours. No mortality was observed with the leaf extract at 24 hours. After 5 days of exposure, the corrected mortality rates for the seed extract were 23.33% (25 mg/mL), 100% (50 mg/mL), and 100% (100 mg/mL), and for the leaf extract, 0% (25 mg/mL), 46.66% (50 mg/mL), and 96.66% (100 mg/mL). The lethal doses for the seed extract are LD_{50} = 11.69 mg/mL and LD_{90} = 54.11 mg/mL, compared to LD_{50} = 757.48 mg/mL and LD_{90} = 11,271.13 mg/mL for the leaf extract.

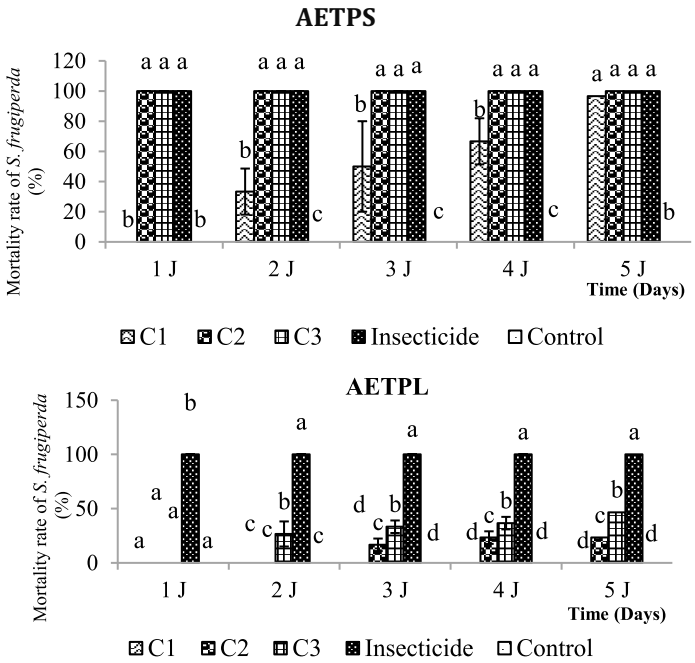

Fig. 1. Mortality rates of *S. frugiperda* larvae at different treatment doses; AETPS: aqueous extract of *T. peruviana* seeds; AETPL: aqueous extract of *T. peruviana* leaves; C1: 25 mg/mL; C2: 50 mg/mL; and C3: 100 mg/mL. Histograms marked with the same letter are not significantly different according to Duncan's test at the 5% significance level.

The presence of the armyworm on corn plants is shown in Figure 2.

Fig.2. Presence of S. frugiperda on corn plants; a) CMS 8704 variety; b) local variety.

Effect of Treatments and Varieties on Legionnaire Caterpillar Density

Both varieties were found to be susceptible to *S. frugiperda*. A significant difference ($P < 0.05$) was observed in the treatment × variety interactions during both growing seasons (Fig. 3). At 4 WAT (weeks after treatment), variety V2 in the plots treated with seed extract (V2T2: 0 caterpillars) and the synthetic insecticide (V2T3: 0 caterpillars) had the lowest densities, compared to 4 caterpillars (season 1) and 8 caterpillars (season 2) in the controls (V2T1).

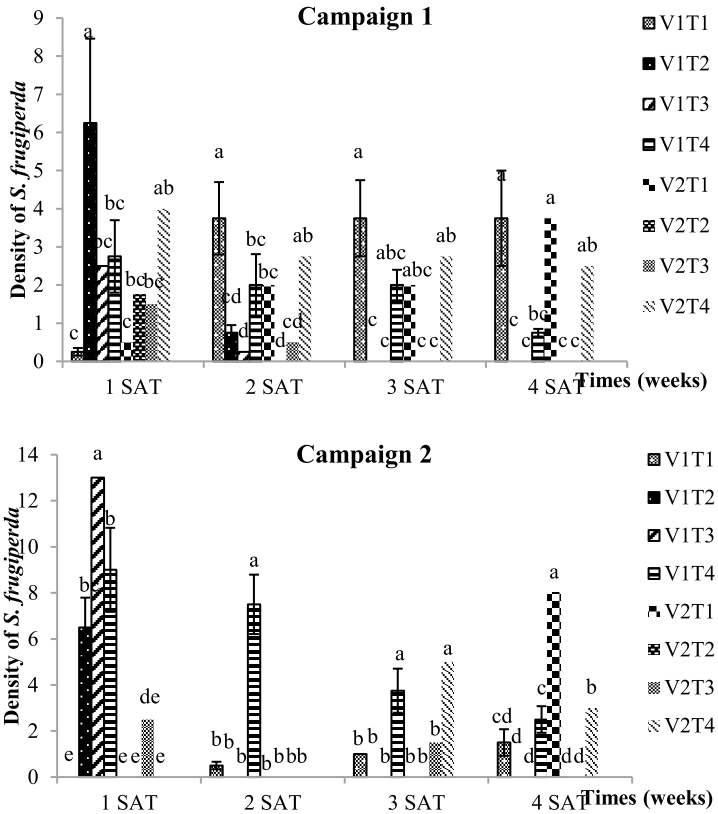

Fig. 3. Effect of treatments and varieties on S. frugiperda density over time

For each period, histograms marked with the same letter are not significantly different according to Duncan's test at the 5% significance level. T1: Control; T2: AETPS (aqueous extract of *T. peruviana* seeds); T3: Chemical insecticide; T4: AETPL (aqueous extract of *T. peruviana* leaves); 1 WAT: 1 week before treatment; 2 WAT: 2 weeks after treatment; 3 WAT: 3 weeks after treatment; 4 WAT: 4 weeks after treatment.

Effects of Treatments and Varieties on Stem Height

During the first growing season, the variety × treatment interaction was significant ($P < 0.05$) at all measurement periods. At 7 WAS, variety V2 from the plots treated with synthetic insecticide (118.59 ± 26.58 cm) recorded the greatest plant height compared to variety V1 from the plots treated with aqueous extract of *T. peruviana* seeds (94.65 ± 13.09 cm) and the aqueous leaf extract of *T. peruviana* (60.06 ± 13.22 cm). During the second growing season, a significant difference was also observed in the variety × treatment interaction ($P < 0.05$). At 7 WAS, the improved variety V1 in plots treated with the synthetic insecticide (147.01 ± 27.94) showed greater height compared to the local variety V2 in plots treated with the aqueous extract of *T. peruviana* seeds (102.76 ± 39.98 cm), the aqueous extract of *T. peruviana* leaves (70.12 ± 13.00 cm), and the control (51.56 ± 8.33 cm) (Table 2).

Effects of Treatments and Varieties on the Number of Leaves

Analysis of variance of the results presented in Table 2 reveals significant variety × treatment interactions ($P < 0.05$) during both growing seasons. At the 7 WAS stage during the first growing season, variety V2 in the plots treated with aqueous extract of *T. peruviana* leaves (9.50 ± 1.56 leaves) and aqueous extract of *T. peruviana* seeds (8.59 ± 1.70 leaves) had the highest number of leaves compared to variety V1 in the plots treated with the chemical insecticide (8.09 ± 1.25 leaves) and the control (8.58 ± 1.28 leaves). At 7 WAS, variety V1 in the plots treated with aqueous *T. peruviana* seed extract (9.65 ± 1.40 leaves) had the highest number of leaves compared to variety V2 in the control plots (8.18 ± 0.96 leaves) during the second growing season.

Table 2: Effect of treatments and varieties on the number of leaves over time

Varieties	Traitements	Stem height Campaign 1 (7 WAS)	Stem height Campaign 2 (7 WAS)	Number of leaves Campaign 1 (7 WAS)	Number of leaves Campaign 2 (7 WAS)
V1	T1	64.58±18.26cd	94.08±33.24bc	8.58±1.28cd	8.58±1.28cd
V1	T2	94.65±13.09b	139.43±32.29a	8.93±1.10abc	9.65±1.40a
V1	T3	76.81±14.96bc	147.01±27.94a	8.09±1.25d	9.31±1.73ab
V1	T4	60.06±13.22cd	77.31±12.85cd	8.46±1.39cd	8.46±1.39cd
Mean V1	—	70.40±23.88b	114.11±39.31a	8.50±1.267a	8.50±1.267a
V2	T1	61.40±10.44cd	51.56±8.33e	8.18±0.96d	8.18±0.96d
V2	T2	92.40±25.68b	102.76±39.98b	8.59±1.70bcd	8.67±1.10c
V2	T3	118.59±26.58a	92.12±23.92bc	9.28±1.85ab	9.28±1.85ab
V2	T4	61.52±12.23cd	70.12±13.00de	9.50±1.56a	9.50±1.56a
Mean V2	—	78.51±18.59a	74.91±29.78b	8.55±1.73a	8.55±1.73a
Mean of Treatments	T1	62.99±14.95b	72.82±32.20b	8.38±1.14ab	8.38±1.14ab
Mean of Treatments	T2	93.53±29.84a	121.10±40.51a	8.76±1.43a	9.17±1.35a
Mean of Treatments	T3	97.70±22.63a	119.57±37.83a	8.68±1.67a	9.04±1.50a
Mean of Treatments	T4	60.79±12.66b	73.71±13.33b	8.98±1.55a	7.37±1.00c
Varieties	—	*	***	ns	ns
Treatments	—	***	***	***	***
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 test at the 5% significance level. WAS: week after sowing; V1: improved variety CMS 8704; V2: local variety; T1: control; T2: aqueous extract of T. peruviana seeds; T3: synthetic insecticide; T4: aqueous extract of T. peruviana leaves.*

Effects of Different Treatments and Varieties on maize Yield

A highly significant effect ($p < 0.001$) was observed among the various variety × treatment interactions during both growing seasons. Variety V1 in the plots treated with chemical insecticide recorded the highest yield (4.37 t/ha; 6.5 t/ha), followed by V1 in the plots treated with aqueous extract of seeds (3.75 t/ha; 5 t/ha), then V1 in plots treated with aqueous extract of leaves (2.87 t/ha; 2.75 t/ha), and finally V1 in the control plots (2.50 t/ha; 1.25 t/ha) (Table 3).

Table 3: Effect of treatments and varieties on maize yield

Varieties	Treatments	Yield (t/ha)	
		Campaign1	Campaign2
V1	T1	2.50 ± 0.75c	1.25 ± 1.66d
	T2	3.75± 0.80abc	5.00 ± 1.00ab
	T3	4.37± 0.80c	6.50 ± 0.86a
	T4	2.75 ± 0.70bc	2.75 ± 0.90cd
Mean V1		3.17 ± 0.98a	4.00 ± 2.07a
V2	T1	2.50 ± 0.65c	1.87 ± 1.00cd
	T2	3.12± 0.98abc	3.50 ± 0.66bc
	T3	4.12± 0.90ab	4.50 ± 1.00b
	T4	2.87± 0.80abc	2.50 ± 0.66cd
Mean V2		3.32 ± 0.98a	2.97 ± 1.18a
Mean of Treatments	T1	2.5 ± 0.62b	1.56 ± 0.83c
	T2	3.43 ± 0.87ab	4.25 ± 1.11ab
	T3	4.24 ± 0.77a	5.50 ± 1.37a
	T4	2.81± 0.67b	2.62 ± 0.72bc
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 test at the 5% significance level. WAS: week after sowing; V1: improved variety CMS 8704; V2: local variety; T1: control; T2: aqueous extract of T. peruviana seeds; T3: synthetic insecticide; T4: aqueous extract of T. peruviana leaves.*

Principal Component Analysis

The PCA of the two growing seasons (explaining approximately 75% of the variance) segments the variety-treatment combinations into three performance groups (Fig 4). The first group (insecticide T3 and seed extract T2, especially on V1) is associated with the highest yields and low infestation levels. In contrast, the second group (controls T1 and leaf extract T4) is strongly correlated with high larval densities and poor agronomic performance. Finally, the third group (combining the local variety V2 with effective treatments or controls, depending on the growing season) shows average growth and yield performance.

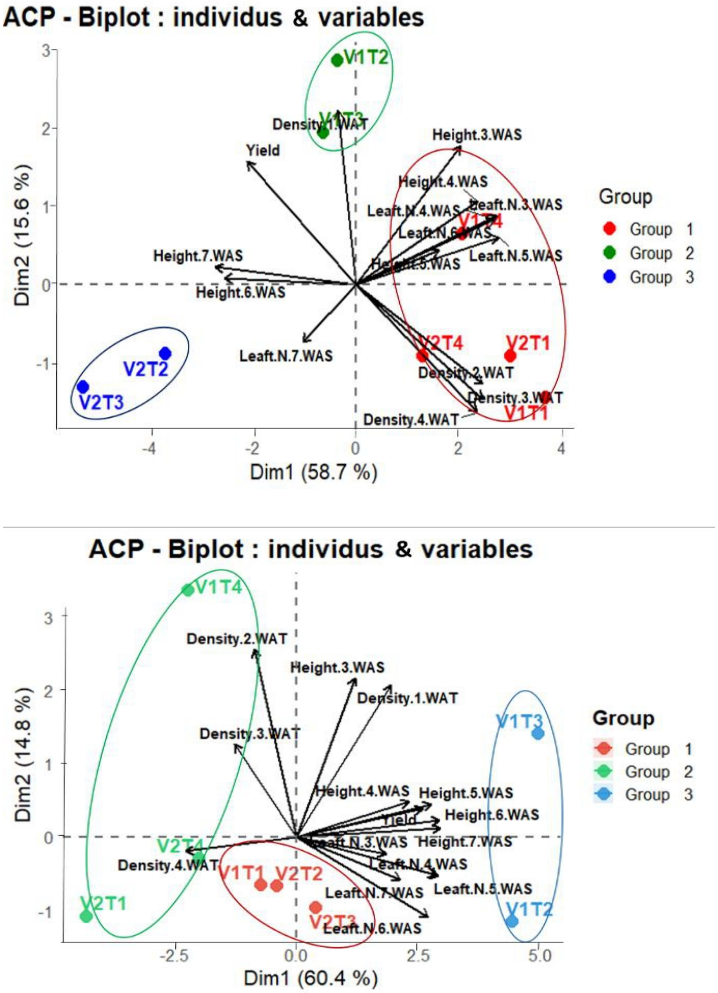

Fig. 4. *Principal component analysis incorporating growth parameters, yield, and larval density during each data collection campaign. V1: improved variety CMS 8704, V2: local variety, T1: control, T2: aqueous extract of T. peruviana seeds, T3: synthetic insecticide, T4: aqueous extract of T. peruviana leaves; WAT: weeks after treatment, WAS: weeks after sowing.*

4. Discussion

Phytochemical screening confirmed the presence of secondary metabolites such as flavonoids, saponins, tannins, terpenoids, polyphenols, and alkaloids. The results showed that the aqueous extract of *T. peruviana* seeds was richer in these compounds compared to the aqueous extract of *T. peruviana* leaves. The high content of tannins and other phenolic compounds in these extracts confers antioxidant properties that protect the plant from abiotic stress, while also exerting insecticidal, larvicidal, and direct repellent activity agrainst pests [28]. As for terpenoids, most of them act as anti-herbivore compounds. They prevent insects from feeding by repelling them. The primary role of alkaloids is to defend the plant agrainst insects. Several of these phytochemicals were also identified by Ambang et al. (2010) [12]; Mboussi et al. (2018) [14] in the seeds of *T. peruviana*; Sannjukta et al. (2019) [29]; Drissa Fondio et al. (2023) [15] in the leaves of *T. peruviana*. In the laboratory, the mortality rate of *S. frugiperda* larvae treated with aqueous extracts of *T. peruviana* was higher than that observed in the untreated control. This confirms the insecticidal activity of the extracts used. According to Boulogne (2011) [30], nearly 116 molecules have been identified as having insecticidal activity in extracts from certain plant parts. The primary compounds responsible are often terpenoids, alkaloids, and phenolic compounds. This insecticidal activity acts by contact agrainst the larvae of the armyworm. These results are consistent with those of Looli et al. (2022) [31], in which extracts of *Azadirachta indica* demonstrated contact insecticidal activity agrainst *S. frugiperda*. However, mortality rates increase with concentration and time. A significant difference was observed among the phytosanitary treatments. The aqueous extract of *T. peruviana* seeds at 50 and 100 mg/mL was as effective as the synthetic insecticide, with 100% mortality 24 hours after exposure, whereas no mortality was yet recorded with the leaf extract at that time. This difference in efficacy and speed of action appears to depend on the doses of yellow laurel organ extracts used. Indeed, *S. frugiperda* exhibits tremendous resistance to very low doses of certain pesticides, particularly the aqueous leaf extract of *T. peruviana*. The response to the bioactive compounds becomes increasingly slow, especially in late-stage larvae, which can survive for several days after treatment before dying. This is consistent with the findings of Looli et al. (2021) [32] on neem agrainst stage 2 and 3 caterpillars of the CLA. Furthermore, these results could also be explained by the concentration of the major active ingredient in *T. peruviana* (thevetine), which is reportedly more concentrated in the seeds than in the leaves. The effect of thevetine is to slow heart rate and atrioventricular conduction, increase cardiac contractions, or even cause cardiac arrest, depending on the dose [33]. The field study is an experiment conducted under real agricultural conditions, building on a laboratory test. Regarding the effect of aqueous extracts on maize growth parameters, significant differences were observed between the treatment × variety combinations. Plants treated with aqueous extracts of *T. peruviana* had the highest number of leaves compared to the control plots in variety V2 during the first growing season. Similarly, the stem height of plants treated with aqueous extracts of *T. peruviana* was greater than that of the control plots in variety V2 during the second growing season. This could be explained by the fact that the aqueous extracts act as *biofertilizers* due to the metabolites they contain (tannins, sterols, sugars, and alkaloids), which promote improved plant growth [34]. Furthermore, recent studies by Fangue-Yapseu et al. (2021) [35] have shown that extracts of *Thevetia peruviana* improve the growth of tomato plants and their agro-biochemical characteristics. Regarding the effect of treatments and varieties on the density of the armyworm in the field, aqueous extracts from the seeds and leaves of *T. peruviana* had a significant effect on armyworm control compared to the control. This effect resulted in a significant decline in the target population, which was reduced to a low level of damage on corn plants during both growing seasons. This is likely due to the presence of bioactive compounds in these substances. These compounds act as insecticides or repellents, limiting the presence or development of pests on the host plant, as noted by Ngimbous (2012) [36] in studies on the effect of *T. peruviana* and *Mucuna pruriens* plants on the cassava root mealybug in the field. Furthermore, according to Koné et al. (2018) [37], plant extracts contain molecules that are either appetite-suppressing (repellents) or toxic to plant-damaging insects (insecticides). However, the density of the armyworm was reduced by 100% with treatment using an aqueous extract of *T. peruviana* seeds—equivalent to the synthetic insecticide—and by 51.85% and 44.44% with treatment using an aqueous extract of *T. peruviana* leaves, during the two growing seasons.

These results are consistent with the findings of Djomaha et al. (2018) [38] on the efficacy of extracts from *Tithonia diversifolia*, *Lantana camara*, and *Azadirachta indica* agrainst the tomato leafminer, which showed that the three botanical insecticides were as effective agrainst the tomato leafminer, *Tuta absoluta* as the chemical compound (emamectin benzoate). However, three weeks after treatment, a resurgence of *S. frugiperda* larvae was observed in the treatment with the aqueous extract of *T. peruviana* leaves during the second growing season. This could be explained by the fact that the aqueous leaf extract of *T. peruviana*, like many natural products, has limited persistence under field conditions due to temperatures, UV radiation from sunlight, the pH of the treated plant, rainfall, and other environmental and ecological factors that exert a more or less negative influence on the active ingredient [39]. The yield values obtained during the two growing seasons for both varieties show an improvement in this parameter in the treated plots compared to the controls. This improvement in yield in the plots treated with aqueous extracts of *T. peruviana* thus demonstrates their role not only as a protective agent but also as a growth stimulator. Indeed, the variation in yield across the different treatments can be attributed, on the one hand, to the damage caused by insect pests belonging to different orders and, on the other hand, to the extent of the disease [40]. The higher yields in the plots treated with aqueous extracts of *T. peruviana* compared to the control plots are likely due to reduced pest pressure from the armyworm, as a result of the extracts' insecticidal potential, which protects the corn plants and consequently increases yield. These hypotheses are consistent with those reported in the work of Kambou and Guissou (2011) [41], in which extracts of *Capsicum* sp. and *Anarcadium* sp. increased the yields of okra and eggplant. Similarly, Gnago et al. (2010) [42], while evaluating the effectiveness of neem (*Azadirachta indica*) and papaya extracts in controlling insect pests of okra (*Abelmoschus esculentus*) and cabbage (*Brassica oleracea*) in Côte d'Ivoire, found that the plant extracts resulted in the highest fruit yields. However, no significant differences were observed among the varieties.

5. Conclusion

This laboratory study demonstrated the presence of flavonoids, tannins, alkaloids, terpenoids, polyphenols, and saponins in our extracts, which confer insecticidal properties on them. The results demonstrated the beneficial effects of aqueous extracts of Peruvian a on the mortality of Legionnaire caterpillar larvae in the laboratory and in the field compared to the control. The various natural substances significantly improved the growth parameters of maize plants, as well as grain yield. Overall, aqueous extracts of *T. peruviana* proved effective in controlling the armyworm. The aqueous seed extract performed as well as the synthetic insecticide. However, the leaf-based extract at higher doses represents an avenue worth further exploration due to its continuous availability.

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Conflicts of interest

This work was carried out with the full collaboration of all the authors, who declare that they have no competing interests.

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