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Research Article

Piper guineensis Extract in Maize-soybean, Maize-okra Intercropping Systems: Its Role in Mitigating Maize (*Zea mays*) Pests and Boosting Soil Fertility

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Abstract

Maize (Zea mays) is an important staple grown worldwide including Cameroon, for its carbohydrate rich grains in addition to minerals and vitamins, therefore providing food for human consumption, and fodder for livestock. Production in Cameroon especially Buea which is the main hub is constraint by several factors among them, pests including the Fall Army Worm (FAW), Snail (*Limicolaria* sp.) and soil infertility are of high importance. The use of botanicals has been successful in mitigating pests on crops while intercropping economic crops with legumes increases soil fertility. This study therefore aimed at evaluating the efficacy of extract of *Piper guineense* on maize-okra, and maize-soybean intercropped on the incidence and severity of these pests and soil primary macronutrients. The experiment was a randomized complete block design with six treatments replicated three times at the Faculty of Agriculture and Veterinary Medicine, University of Buea. FAW, snail incidence and severity, maize grain weight, and soil primary macronutrients were recorded. Data collected was subjected to statistical analysis ($P< 0.05$). FAW and snail incidence and severity differed significantly ($P<0.05$). FAW incidence was highest in the control (69.2%) and lowest in Maize + soybean + *Piper* (21.8%) while snail was highest in control (62.8%) and lowest in Maize + soybean + *Piper* (15.4%). The severity of fall armyworm was highest in control (41.3%) and lowest in Maize + soybean + *Piper* (12.7%), while that of snail was highest in control (18%) and lowest in Maize + soybean + *Piper* (4.3%). The maize grain yield differed significantly ($P<0.05$), with the highest in Maize + soybean + *Piper* (5.2 t/ha) and lowest in Maize + okra (2.8 t/ha). Total nitrogen differed significantly with the highest in Maize + soybean + *Piper* (0.19%) and lowest in Maize + okra (0.13%). Maize yield was positively correlated with total nitrogen (r = 0.77) and negatively correlated with maize pests (r = -0.73 for FAW, r = -0.76 for snail). Thus maize-soybean intercropping using *Piper* as insecticide is of high importance and a good sustainable alternative to synthetic inputs for maize pest control, optimizing primary macronutrient and maize yield.

Keywords

Fall Armyworm, Snail, Nitrogen Fixation, Secondary Metabolites, Total Nitrogen

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1. Introduction

Maize is one of the versatile crops cultivated in Cameroon's IV agro-ecological zones [1]. With its numerous beneficial uses, the commercial production of this crop is being encouraged as millions of francs are spent on importation. Maize production is constrained by combinations of poor mineral nutrition [2] and insect pests [3, 4]. Insect pests destroy 20% of the world's total crop production annually [5-7]. The emergence of the invasive fall armyworm (FAW) (*Spodoptera frugiperda*) in Africa has overshadowed the maize stem borer *Busseola fusca* as the primary insect pest of maize [8-11]. In addition, other pests that attack maize include snails (*Limacolaria* aurela, *limacolaria zebra*), corn earworm, and cutworm [12]. The fight against insect pests remains a matter of concern for farmers. About 3.5 billion kilogrammes of chemical pesticides are used annually to combat insect pest problems [13]. These chemical insecticides are reported to be unfriendly to the environment and pose health hazards to humans, which result from, among other things, their neurotoxicity, reproductive toxicity, and cancerogeneity [14-16].

Intercropping and the use of plant extracts as botanicals have been proposed as a solution to prevent the environment and farmers from the effects of chemical pesticides as soil and pest control alternatives [17]. The practicability and efficiency of intercropping has been shown in many studies [18, 19]. The efficiency of intercropping results to an increase in habitat and diversity of organisms. This leads to complex interactions, including controlling insect gradations and unwanted crop losses. Insect pests were reported to settle on crops only when host factors such as visual stimulus, taste, and smell are satisfied, and this is more likely in monocultures where the chances of meeting a wrong stimulus are lower [20]. Soybean legume crop, with highest nitrogen fixing ability, tremendously improve soil fertility [21-23]. Thus soybean in intercrop system, playing a pivotal role in improving soil fertility through nitrogen fixation is paramount in increasing maize yield [24, 25]. Okra with potential strength to serve as pull crop in push-pull technique in intercropping system is regnant [10, 26].

Using synthetic chemicals is expensive for farmers with many negative effects [27-29]. Thus requiring sustainable integrated soil and pest management strategists. With this effect, promoting botanicals to minimize health and environmental effects and increase the production of maize is of prime importance [16, 30]. Botanical pesticides are now being encouraged due to their high knockdown activities, biodegradable, low mammalian toxicity, safe to the environment, and also, insect resistance has not been recorded [31-33].

Thus, this research is aimed at (1) using extract of *Piper*s in combination with maize-okra intercropping to manage pests, (2) using extract of pipers in combination with maize-soybean intercropping to manage pests and increase soil fertility and boost maize yield.

2. Materials and Methods

2.1. Experimental Site

This study was conducted at the Teaching and Research Farm of the Faculty of Agriculture and Veterinary Medicine, University of Buea. The site is located at the foot of Mount Cameroon, South West Region, Cameroon, situated between latitudes 4°3'N and 4°12'N of the equator and longitudes 9°12'E and 9°20'E. The soil is derived from weathered volcanic rocks dominated by silt, clay, and sand [34]. Buea has a mono-modal rainfall regime with about 85% relative humidity. The mean monthly air temperature is 24.5℃ and soil temperature at 10cm depth is 18.5℃ with an elevation of about 1200 m above sea level [34, 35].

2.2. Preparation of 0.2% Aqueous Extract of *Piper guineense*

Dried fruits of African black pepper, *Piper guineense*, were harvested from the forest in Ebobe Balue Village, Dikome Sub Division, Ndian Division, South West Region of Cameroon. It was dried in the oven at 50 °- 60 °C for 3 days. 30 g of the *Piper* was weighed using an electronic balance and blended into powder using a kitchen blender. The powder was poured into a 5-liter plastic galloon, and 3 liters of clean water was added and allowed overnight for 24 hours. The mixture was thoroughly stirred, sieved through a 50 µm sieve to collect the liquid extract and 5 g of detergent (SABA®, Douala-Cameroon) added. The 5-liter mark was made by adding water to make a 2% aqueous extract of *Piper.*

Field application of *Piper* emulsion was performed during early morning periods. 0.2% *Piper* aqueous extract was prepared in a 15 L knapsack water sprayer. The mixture was stirred vigorously to achieve homogeneity in a knapsack sprayer and uniformly sprayed in the whorl, on stems and leaves of maize on the required plots.

Figure 1. *Piper guineense: 10% extract (C), concoction stored for 24 hours (D), weighing of the seeds using an electronic balance (B) and dry seeds ready for extract preparation (A).*

2.3. Mortality Test of Piper Seed Aqueous Extract Against FAW and Maize Stem Borer

A mortality test was conducted on FAW larvae at the laboratory of the Faculty of Agriculture and Veterinary Medicine, University of Buea, Cameroon. The mortality test was performed to determine the appropriate concentration of the Piper seed aqueous extract for use to obtain the best field result. For the laboratory test, FAW larvae of similar sizes were randomly collected from maize fields in Buea, and six larvae of each insect pest were placed in each Petri dish. Maize leaves were harvested from the fields, and 2g (fresh weight) was added to each Petri dish as the food substrate for the larvae. Five different concentrations of Piper seed aqueous extract were prepared; 2% 1%, 0.5%, 0.2%, 0.01%, and 0.005%. A syringe was used to apply the different concentrations of the *Piper* seed aqueous extract into Petri dishes containing FAW and stem borer larvae, and their toxicity was observed over one hour.

2.4. Experimental Design

Meter tape was used to measure 200 m^2 of the experimental field. The field was manually cleared and sprayed with systemic herbicide (GLYCOT®, Glyphosate 42% SL). The experimental design was a randomized complete block design with six treatments (Table 1) replicated three times (Figure 2). Eighteen plots measuring 2 m x 2.5 m were demarcated and raised 25cm high with hoes. Plots within a replicated were separated by 1 m and one replicate to the other by 1 m. Planting spots were marked with a planting distance of 75 cm x 50 cm, and pegs placed at the spots. This gave 4 inter and 5 intra rows amounting to 20 stands per plot. Each stand had two plants resulting to 40 plants per plot.

Replicate 1	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Replicate 2	**T3**	**T4**	**T5**	**T6**	**T1**	**T2**
Replicate 3	**T5**	**T6**	**T1**	**T2**	**T3**	**T4**

Figure 2. *Randomize complete block design with six treatments and three replicates.*

Table 1. *Codes and full meaning of treatments.*

Codes	Treatments
T1	Control (Sole maize)
T2	Sole maize + *Piper*
T3	Maize + soybean intercrop
T4	Maize + soybean intercrop + *Piper*
T5	Maize + okra intercrop
T6	Maize + okra intercrop + *Piper*

2.4.1. Sowing

After the formation of ridges and pegging of planting spots, the field was sprayed with a contact herbicide, insecticide, and fungicide against weed, insect, and fungal attacks on seeds (Table 2). The PAN12 hybrid Maize, a medium maturity variety from South Africa with a germination percent of 95%, was sown according to the experimental design. Three seeds were sown per stand at depth of 3 cm into the soil. At two weeks after germination, the seedlings were thinned to two plants per stand. In the maize-soybean intercrop, two soybean seeds were sown as strip intercrop with planting distance of 50 cm by 50 cm. This gave 6 inter and 5 intra rows aggregating to 30 stands. While in the maize-okra intercrop, 2 okra seeds were sown in the maize rows at a distance of 32.5 cm by 50 cm making 3 inter and 5 intra rows tantamount to 15 stands.

2.4.2. Crop Maintenance

Cultural Practices

3 seeds were thinned to 2 per stand after 2 weeks for better vigour and to reduced crop competition. Plots were weeded weekly using a hoe and a cutlass. This was to eliminate weeds that compete for nutrients and sunlight with economic crops. Earthing-up with soil after each weeding operation to avoid exposure of pant roots, which could pose deleterious effects on crops, was done. The plants were mulched with dry grass after each weeding operation. Manual watering of plots at field capacity thrice a week to avoid water stress was carried out.

Table 2. *Botanical, herbicide, their rate, and frequency of application.*

Pesticide	Name of pesticide	Active ingredient	Rate	Frequency
Botanical	*Piper guineense*	Piperamides	80 ml/15l	6:30-7 am Weekly
Herbicide	GLYCOT 42% SL	Glyphosate	100 ml/15l	Once before sowing
Insecticide	Cypercal 50EC	Cypermethrine	26 ml/ 15l	Once before sowing
Fungicide	Cotzeb	Mancozebe	80 g/15l	Once before sowing

a) Fertilizer application; Fertilizer was applied 2 weeks after planting. 10g of NPK (20:10:10) was applied per stand of two maize plants. This is to reduce intercrop competition at an early stage of growth.
b) Botanical pesticide application.

The botanical plots T2, T4, and T6 (Table 1) were sprayed with locally produced black pepper.

2.5. Data Collection

2.5.1. Pest Data

Data collection started three weeks after seeding (WAS), and it was done on a weekly base until tasselling. Incidence and severity of pests in each of the treatments were recorded. The number of fall armyworm and snail was counted early between 6:30-7 am. Data was collected on six randomly maize-tagged plants for incidence and severity [36].

$$\text{Pest Incidence (\%)} = \frac{\text{Number of affected plants}}{\text{total no of sampled plants}} \times 100$$

2.5.2. Soil Sample Collection and Analysis

6 pre-subsoil samples were randomly collected at 0–20 cm depth (using a 3.5 cm diameter auger). The soil samples were air-dried at room temperature, mixed thoroughly to form one composite sample of 500 g, and sieved properly using a 2 mm sieve. While post-treatment soil samples were also collected air-dried at room temperature and sieved properly using a 2 mm sieve.

The soil particle size analysis was determined using the pipette method with a sodium hexametaphosphate dispersing agent [37]. Soil pH was determined potentiometrically in both water (H_2O) and 1M Potassium chloride (Kcl) solutions after twenty-four hours in soil suspension (solid/liquid =1/2.5 w/v) [38]. Exchangeable bases were extracted with neutral Ammonium acetate solution. Potassium (K) was determined by flame photometry, and exchangeable acidity was determined by the KCL extraction method [38]. The total Nitrogen (N) content was determined by the macrokjeldahl digestion method [39, 40], while available Phosphorus (P) was determined by the Bray II method [38, 41].

Table 3. Pest severity rating for Fall Armyworm and stem borer on maize.

Severity rating	Symptom severity	% of damage
0	No visible symptom	0
1	Few tiny windows are seen on leaves	1-20
2	Moderately damaged with large holes on leaves	21-40
3	Huge holes with 50% of young leaves skeletonized	41-60
4	The whorl partly destroyed	61-80
5	Plant with the whorl destroyed	81-100

2.5.3. Yield Data

The dry weight of maize grains per tagged plant, relative to the number of tagged plants, for the number of stands per plot was calculated and later converted to hectares.

2.6. Data Analysis

The data was entered into a Microsoft Excel worksheet 2016 and then uploaded to IBM SPSS Statistics (SPSSv26). To examine the influence of treatments (n6) as categorical predictors, variables were subjected to univariate analysis of variance (ANOVA, P<0.05). Duncan Multiple Range Test (DMRT) P<0.05 was used to differentiate significant data means.

3. Results

3.1. Effect of Treatments on Maize Fall Armyworm and Stem Borer

3.1.1. Effect of Treatments on Maize Pests Incidence and Severity at 4 Weeks After Seeding

From Table 4 below, the fall armyworm incidence ranged from 21.8-69.2%and differed significantly ($F_{5, 12}$ = 19.997, P = 0.000) across treatments with the highest in control (69.2%) and lowest in Maize + soybean intercrop + *Piper* (21.8%). The fall armyworm severity ranged from 12.7-41.3%and differed significantly ($F_{5, 12}$ = 66.704, P = 0.000) across treatments with the highest in control (41.3%) and lowest in Maize + soybean intercrop + *Piper* (12.7%). The snail incidence ranged from 15.4-62.8% and differed significantly ($F_{5, 12}$ = 36.048, P = 0.000) across treatments with the highest in control (62.8%) and lowest in Maize + soybean intercrop + *Piper* (15.4%). The snail severity ranged from 4.3-18.0% and differed significantly ($F_{5, 12}$ = 17.212, P = 0.000) across treatments with the highest in the control (18.0%) and lowest in Maize + soybean intercrop + *Piper* (4.3%).

3.1.2. Effect of Treatments on Maize Pests Incidence and Severity at 6 Weeks After Seeding

From Table 5 below, the fall armyworm incidence ranged from 11.5-62.8%and differed significantly ($F_{5, 12}$ = 22.851, P = 0.000) across treatments with the highest in control (62.8%) and lowest in Maize + soybean intercrop + *Piper* (11.5%). The fall armyworm severity ranged from 5.3-27.3%and differed significantly ($F_{5, 12}$ = 31.347, P = 0.000) across treatments with the highest in control (27.3%) and lowest in Maize + soybean intercrop + *Piper* (5.3%). There was no incidence or severity of snail that was recorded.

Table 4. Effect of treatments on fall armyworm and stem borer incidence and severity at 4WAS.

Treatment 4 WAS	Fall armyworm		Snail (*Limicolaria* spp)	
	Incidence	Severity	Incidence	Severity
Control (Sole maize)	69.2 ± 10.2^a	41.3 ± 4.0^a	62.8 ± 5.9^a	18.0 ± 2.0^a
Sole maize + *Piper*	29.5 ± 9.7^b	15.3 ± 2.5^b	21.8 ± 5.9^c	6.3 ± 1.5^c
Maize + soybean intercrop	60.3 ± 5.9^a	37.0 ± 3.6^a	51.3 ± 5.9^b	12.3 ± 3.2^b
Maize + soybean intercrop + *Piper*	21.8 ± 5.9^b	12.7 ± 1.5^b	15.4 ± 3.9^c	4.3 ± 1.2^c

Treatment 4 WAS	Fall armyworm		Snail (*Limicolaria* spp)	
	Incidence	Severity	Incidence	Severity
Maize + okra intercrop	66.7±7.9[a]	42.3±3.1[a]	53.9±3.9[ab]	13.3±2.5[b]
Maize + okra intercrop + *Piper*	34.6±7.7[b]	16.3±2.5[b]	25.6±8.0[c]	6.7±2.1[c]

Values within the column with the same letters are not significantly different according to Duncan Multiple Range Test, $P < 0.05$.

***Table 5**. Effect of treatments on fall armyworm and stem borer incidence and severity at 6 WAS.*

Treatment 6 WAS	Fall armyworm		Snail (*Limicolaria* spp)	
	Incidence	Severity	Incidence	Severity
Control (Sole maize)	62.8±5.9[a]	27.3±3.1[a]	0	0
Sole maize + *Piper*	21.8±9.7[b]	7.7±2.5[b]	0	0
Maize + soybean intercrop	51.3±5.9[a]	22.7±3.1[a]	0	0
Maize + soybean intercrop + *Piper*	11.5±5.9[b]	5.3±2.5[b]	0	0
Maize + okra intercrop	52.6±5.9[a]	23.0±3.0[a]	0	0
Maize + okra intercrop + *Piper*	21.8±11.8[b]	8.7±3.5[b]	0	0

Values within the column with the same letters are not significantly different according to Duncan Multiple Range Test, $P < 0.05$.

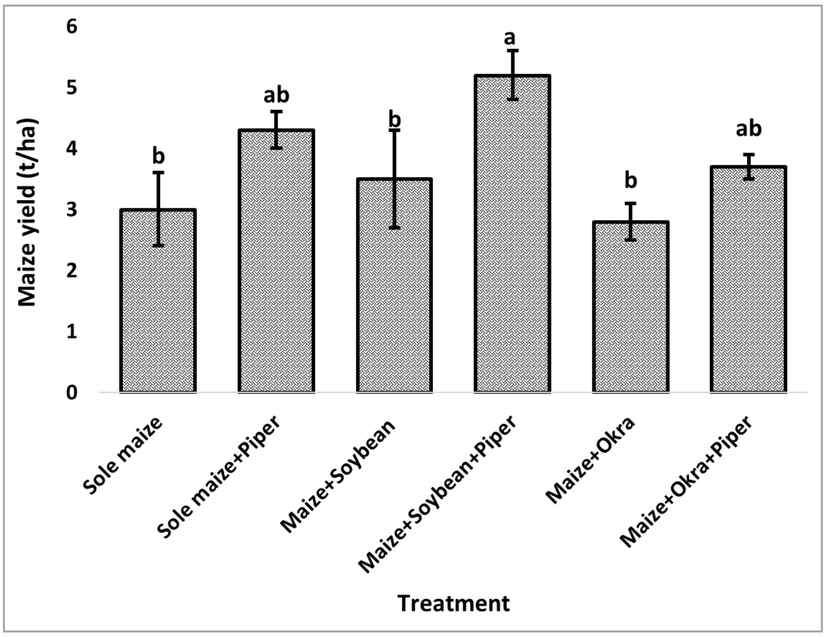

***Figure 3**. Effect of treatments on the yield of maize. Different letter columns are significantly different (p<0.05), Duncan Multiple Range Test.*

3.2. Effect of Treatments on Maize Yield

The yield of maize ranged from 2.8 to 5.2 t/ha and differed significantly ($F_{5, 12} = 3.475$, $P = 0.036$) across treatments with the highest in Maize + soybean intercrop + *Piper* (5.2 t/ha) and the lowest in maize + okra intercrop (2.8) (Figure 3).

3.3. Baseline Soil Primary Macronutrient Properties

Table 6. *Baseline soil primary macronutrient properties.*

Soil properties	value
Soil pH [H_2O]	5.30
Soil texture	Clay loam
Total nitrogen	0.15%
Available phosphorus	10 mg/kg
Potassium	0.45 cmol/kg

3.3.1. Effect of Treatments on Total Nitrogen (%)

The total nitrogen from the maize field ranged from 0.13-0.18% and differed significantly ($F_{5, 12}$ = 8.700, P = 0.001) across treatments with the highest in Maize + soybean intercrop + *Piper* (0.19%) and the lowest in maize + okra intercrop (0.13%) (Figure 4).

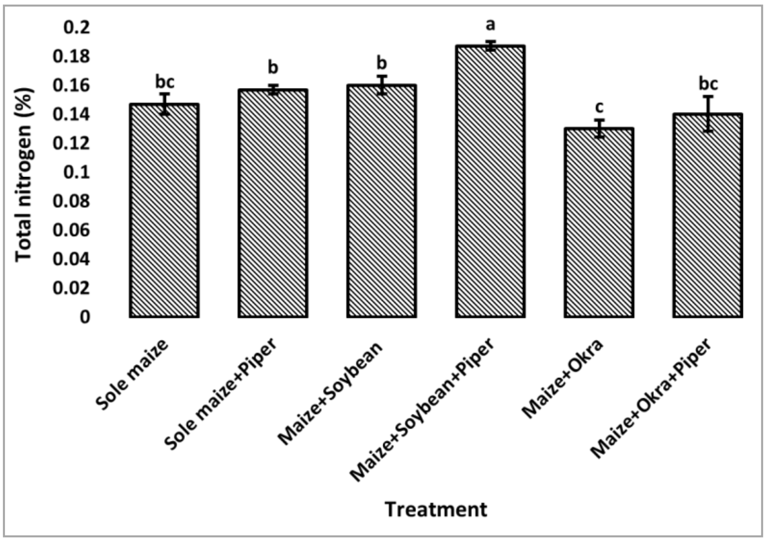

Figure 4. *Effect of treatments on total nitrogen (%). Different letter columns are significantly different (p<0.05), Duncan Multiple Range Test.*

3.3.2. Effect of Treatments on Soil Phosphorus, Potassium, pH, and Texture Parameters

From Table 7 below, the available phosphorus ranged from 14.03-15.30 mg/kg and did not differ significantly ($F_{5, 12}$ = 0.450, P = 0.806) across treatments with the highest in Maize + soybean intercrop + *Piper* (15.3 mg/kg) and lowest in control (14.03 mg/kg). The soil potassium ranged from 1.23-1.37 cmol/kgand did not differ significantly ($F_{5, 12}$ = 1.440, P = 0.279) across treatments with the highest in Maize + soybean intercrop + *Piper* (1.37 cmol/kg) and lowest in control (1.23 cmol/kg). The soil pH ranged from 4.93-5.53 and did not differ significantly ($F_{5, 12}$ = 2.038, P = 0.145) across treatments with the highest in sole maize + *Piper* (5.53) and lowest in Maize + okra intercrop + *Piper* (4.93).

Table 7. *Effect of treatments on soil parameters of phosphorus, potassium, pH, and texture.*

Treatment	Available phosphorus (mg/kg)	Potassium (cmol/kg)	pH (H_2O)	Soil texture
Control (Sole maize)	14.03±1.16[a]	1.23±0.06[a]	5.33±0.38[a]	Clay loam

Treatment	Available phosphorus (mg/kg)	Potassium (cmol/kg)	pH (H_2O)	Soil texture
Sole maize + *Piper*	14.80±1.38[a]	1.33±0.06[a]	5.53±0.25[a]	Clay loam
Maize + soybean intercrop	14.70±2.43[a]	1.37±0.15[a]	5.03±0.25[a]	Clay loam
Maize + soybean intercrop + *Piper*	15.30±0.44[a]	1.37±0.06[a]	5.30±0.27[a]	Clay loam
Maize + okra intercrop	14.27±0.45[a]	1.23±0.06[a]	5.43±0.21[a]	Clay loam
Maize + okra intercrop + *Piper*	15.17±0.49[a]	1.27±0.12[a]	4.93±0.31[a]	Clay loam

Values within the column with the same letters are not significantly different according to Duncan Multiple Range Test, $P< 0.05$.

3.4. Correlation of Maize Yield with Total Nitrogen, FAW, and Snail Severity

From Figure 5 below, a strong positive correlation (r = 0.7663) existed between maize yield and total nitrogen, implying that the more the total nitrogen in the soil, the more plants pick it up, giving better yield. A negative correlation (r = -0.7299) was observed between the severity of FAW and maize yield as well as the correlation between snail severity and maize yield was negative (r = -0.7572), indicating that the more plants are damaged by pests, the less yield will be achieved (Figure 6).

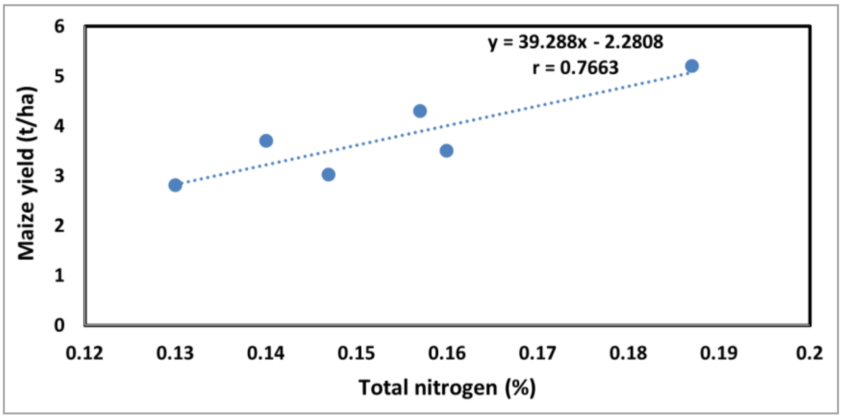

Figure 5. *Correlation of the number of damaged plants with yield.*

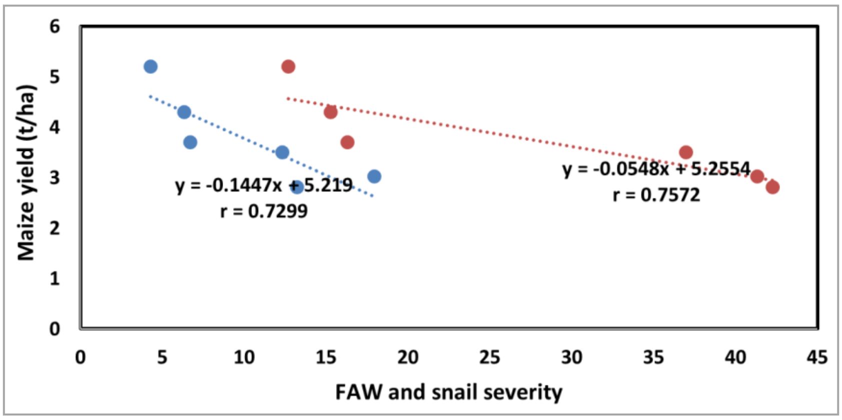

Figure 6. *Correlation of the number of damaged plants with yield.*

4. Discussion

4.1. Effect of Treatments on Maize Pests

The result of this study showed low fall armyworm incidence on maize plants treated with *Piper guineensis*, which is in line with other works, further exhibiting the botanical's ability to reduce the pest incidence [19, 42]. As reported by other studies, there was a decline in the severity of pest on maize plants treated with *Piper* [16].

The strength of the *Piper* to extenuate the incidence and severity of fall armyworm and snailcomes from its genetic constituent [43, 44]. *Piper* embodies plant secondary metabolites isobutyl amides with active ingredients (natural lipophilic amides, piperine, and piperiline) as a neurotoxin and deterrent [45]. Similarly, colossal levels of antifeedant secondary compounds were reported in plants in the Piperaceae family that deter herbivores [46]. *Piper* subsumed soaringphenylpropanoid quantity that inhibited the functioning of cytochrome P_{450} [47]. *P. guineense*has a very high knockdown activity, minimizing the incidence and severity on maize plants due to the compound piperamides. Piperamides with insecticidal active ingredients such as piperine and chavicine and piperidine and alkaloids act as neurotoxins inthe Central Nervous System (CNS) of insects [48, 49]. They act on the sodium (Na^+) channel in a mechanism distinct from the sodium channel modulators or blockers of the pyrethroids [48, 50]. Results from [50, 51] showed that the lethal concentration (LC_{50}) of Piperamides is at 0.00018g/l and 0.00053g/l, respectively for Lepidoptera pests, while [1] showed that 0.003g/l concentration could control the Diamondback moth, *Plutellaxy lostella.*

The intercrop okra and soybean were utilized to investigate the push-pull farming system and was successful in controlling maize pests in this study as reported by the research Njume *et al* [26]. Nevertheless, the push-pull technique depends on the family of the crop and crop morphology. As demonstrated in this study, okra attracts more pests to devastate maize plants rather than push them away. In contrast, the soybean intercrop's low incidence and severity are likely due to the confusing olfactory and visual cues received from the intercrop plants that probably served as the push component repelling fall armyworm away from the maize plants, which is consistent with this study [52]. The deterrent of pests like snail in the case of soybean (Legumes) has been reported by [53, 54], that leguminous plants have shown positive results in the control of maize Lepidoptera pest.

4.2. Effect of Treatments on Maize Yield

The better maize yield results for soybean intercrop in this work lined alongside other results [11, 55, 56] when they intercropped maize with beans, showing the potential ability of legumes to boost production [18]. Fornent ability to curb maize pests, soybean biomass doles out a cogent quantity of nitrogen via biological nitrogen fixation that reinforces soil fertility and plant nutrition [21, 22], which might have also enhanced the maize yield in the soybean intercropped plots in this study. In addition to the blanket fertilization of the treatments, organic matter and other nutrients were increased by the nutrient-rich decomposing soybean biomass, likely reducing soil P-sorption and enhanced soil biota and nitrogen fixation that presumably aided maize yield [57, 58]. Hence, the improved maize yield in the plots intercropped with soybean could be due to a combination of low maize pests' incidence and severity and improved maize nutrition resulting from nitrogen fixation by the companion soybean plants [24, 25, 59, 60]. A lower yield was recorded in control, which is consistent with the objective of this study. Despite the control receiving blanket fertilization, the low yield could be attributed to the high incidence and severity rate of pests that hinder the plants' ability to flourish healthily and give good yield [16]. Also, low yields were observed in maize + okra intercropping plausibly due to the okra's ability to compete with maize plants for nutrient uptake and the absence of a control mechanism for maize pests, as reported by other works [26].

4.3. Effect of treatments on soil parameters.

The soil primary macronutrients increase above the baseline soil primary macronutrient, which is consistent with the objectives of this study after the blanket fertilization. Most significantly was the higher increase in total nitrogen at maize + soybean intercrop above other treatments showcasing the soybean's ability for biological nitrogen fixation [55, 56]. The other primary macronutrients like phosphorus and potassium were not significantly different across treatments possible due to the blanket fertilization in all treatments. The observed variations in soil primary macronutrients reflect the fertilizer amendments, with improved soil fertility for maize+ soybean intercrop [24, 61, 62]. This further highlights the challenges of poor soil fertility in arable systems and emphasizes the need for soil fertility improvement strategies. Fornent ability to curb maize pests, soybean biomass doles out a cogent quantity of nitrogen via biological nitrogen fixation that reinforces soil fertility and plant nutrition [23, 25, 63], which might have also enhanced the maize yield in the soybean intercropped plots in this study. In addition to the blanket fertilization of the treatments, nutrients were increased by the nutrient-rich decomposing soybean biomass, likely reducing soil P-sorption and enhanced soil biota and nitrogen fixation that presumably aided maize yield [64, 65].

5. Conclusion

Botanical *Piper* extract and maize-soybean intercrops were found to be equally effective in reducing maize pests compared to the other treatments in this study. The result is consistent with the hypothesis of this study which states that

Piper botanical can control maize pests. The performance of maize is consistent with the study's premise, suggesting that maize-soybean intercropping increases maize production. As a result, the locally manufactured botanical *Piper* extract and maize-soybean intercrops treatments have demonstrated abilities to control maize pests and boost maize development parameters without causing egregious environmental effects. Intercropping maize with soybeanand okra increases yield by bringing forth three produce compared to solitary maize planting, demonstrating resource use efficiency.

Abbreviations

ANOVA	Analysis of Variance
CNS	Central Nervous System
DMRT	Duncan Multiple Range Test
FAVM	Faculty of Agriculture and Veterinary Medicine
FAW	Fall Army Worm
WAS	Weeks After Seeding

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Author Contributions

This work was carried out in consensus with all authors. Author DTA and PNE design the experiment, collected data, processed data, performed statistics, literature searches, and wrote the first manuscript draft. Author TTO and RNN coordinated field site, manuscript preparation, and performed literature searches. Author BASB assisted in field establishment and management and data collection.

The manuscript was comprehended and affirmed by all authors.

Conflicts of Interest

The authors declare no conflicts of interest.

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