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Original Article

Performance of soybean varieties (*Glycine max* L.) treated with different plant extracts

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ABSTRACT

Production of soybean has been low among the farmers over the years despite the use of synthetic yield enhancers and chemicals that control the pests and diseases of the crop. Some improved varieties have been developed. The study evaluated the performance of three soybean varieties (*Glycine max* L.) treated with different plant extracts (*Cymbopogon citratus* DC Stapf, *Hyptis suaveolens* (L.) Poit and *Centrosema pubescens* Benth). The soybean varieties (TGX-1951-3F, TGX-2019-2E and TGX-1987-62F) were evaluated in a randomized complete block design, in a field experiment. Data were collected on growth, yield, entomological and pathological parameters. Results showed that application of *C. pubescens* among other treatments improved plant performance at 40 and 60 days after planting. The treatments reduced white fly and ant pests as well as the incidence of mildew disease. Yield parameters (pod sizes, pod weight, and seed sizes) were not significantly affected by plant extracts. Observed differences in pod sizes were due to varietal effects (F=5.38, $p<0.05$). Combined treatments had effects on the TGX-1987-62F variety by producing the lowest number of infested seeds, thus suggesting their relevance in crop protection but subject to further

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trials. The best performing variety was TGX-2019-2Etreated with *C. pubescens* plant extract. The findings of this study may be useful in the sustainable production of soybean.

Keywords: Soybean, Performances, Growth, Yield, Pest and diseases, Plant extracts

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is one of the most important commodities worldwide and is planted on over 6% of land dedicated to agriculture (Hartman & Sinclair, 1988). Soybean seeds are used in a variety of ways, from protein meal to livestock feed to vegetable oil. Global production of soybean increased from approximately 17 million metric tons in 1960 to 630 million metric tons by 2020 (Pignati et al., 2017). Multiple factors have influenced this increase, including higher yield potential from breeding and major changes in management strategies. The crop is subjected to biotic stresses including pests and diseases of viral, bacterial and fungal origins that cause single and combined infections in the plant. These factors cause direct plant damage and affect the productivity with significant yield losses (Pignati et al., 2017) Globally, yield losses due to arthropods, diseases, and weeds are estimated to account for about 35% in major crops. Losses may exceed 50% in developing regions where pest control options are limited (Oerke, 2016). In some cases, damage by pests, arthropods in particular, can lead to even higher losses or total crop failure (Lingappa et al., 2014).

Adoption of some cultural practices, sometimes even with the use of resistant cultivars, may not provide the desired level of crop protection alone, thus the need for supplemental control measures in the form of plant extracts. Agrochemicals are used to boost crop performances. However, overuse and misuse of agrochemicals has harmful effects on humans and the environment thus impacting negatively on biodiversity (Prakash et al., 2015). Plant extracts have been studied to boost performances of crops including growth and yield enhancement or crop protection (Prakash et al., 2015; Simonetti et al., 2015). Different studies have reported positive effects of some plant extracts on the production of maize (Mourão et al., 2017), melon (Dalcin et al., 2017), bean plant (Hillen et al., 2012) and tomato plant (Santos-Neto et al., 2016), among others. The use of improved varieties bred to meet specific breeding objectives has been pursued to increase food security, while maintaining a sustainable healthy environment. Some improved varieties have been developed and recommended for farmers. However, despite this, production of soybean has been discouraging for the farmers in this study area due to the high cost of procuring agrochemicals. There is a need to evaluate the performances of selected improved varieties in relation to compatible plant extracts that may be used as substitutes for agrochemicals. This would lower the cost of production and widen the profit margin for farmers. This study evaluated the performance of soybean varieties (*Glycine max* L.) treated with different plant extracts (*Cymbopogon citratus* DC Stapf, *Hyptis suaveolens* (L.) Poit and *Centrosema pubescens* Benth). These materials are cheaply available and environmentally friendly. Previous studies have shown that the plants are useful in crop protection and yield enhancement (Mandal et al., 2017; Mourao et al., 2017).

MATERIALS AND METHODS

Study Location

The experiment was conducted during the August to October cropping season of 2024 at the Joseph Sarwuan Tarka University (JOSTUM), Makurdi, Benue State. Makurdi town lies between latitude 7°44'N and longitude 8°32'E covering an area of 820km^2 with an estimated population of 348,990 people (National Population Commission of Nigeria, 2011).

Meteorological Data

Makurdi's rainfall ranges from 1290mm to 1585mm with an average temperature of 26°C (Nigerian Meteorological Agency, Headquarters, Tactical Air Command, Makurdi-Airport).

Physicochemical Data of Soil

The physicochemical properties of the soil samples from the experimental sites as obtained from the Department of Soil Science, JOSTUM, show the soil to be sandy loam made up of 77.6% sand, 13.2% silt and 9.2% clay. On the average, it has the following properties: 5.90pH, 10.7g kg^{-1} organic carbon, 0.05% nitrogen, and 7.61mg kg^{-1} phosphorus.

Collection and Preparation of Samples

Seeds of three varieties of soybean (TGX-1951-3F, TGX-2019-2E and TGX-1987-62F) were sourced from the Seed Store of the Department of Plant Breeding, Joseph Sarwuan Tarka University Makurdi. These varieties were used as test plants based on their superior high yielding performances in previous years' germplasm trials. Seeds were packaged in clean and sterile nylon envelopes and transported to the field for planting. Fresh leaves of *C. citratus*, *H. suaveolens* and *C. pubescens* were collected from different locations in the NorthBank area in Makurdi metropolis. Plant identification was done by taxonomists in the above-named institution. Harvested leaves were sun dried for one week, and pounded using a mortar and pestle into powdered form. Materials were sieved and packed into polythene bags.

Field Preparation

The research plot measured 15x20m and was cleared and divided into (3) three equal blocks of equal sizes. After tilling operation, the clearing of bushes was done manually with hoe and cutlass (Omoigui et al., 2023). These three blocks were all planted with a distance of 0.7m between ridges and a spacing of 1.02m between each plant.

Experimental Design

The Randomized Complete Block Design was used in a 3*5*5*3 factorial experiment. It consisted of 3 blocks, 3 varieties of soybean plants treated with powdered leaf extracts of 3 plant species T1- T3 (T1=*C. citratus*; T2=*H. suaveolens;* T3=*C. pubescens*) applied singly and in combined forms. Negative and positive controls were also applied making a total of 5 treatment structures, each replicated 5 times. Thus. each variety received 5 treatments (T1=*C. citratus*; T2=*H. suaveolens;* T3=*C. pubescens*; Tn=Negative control (no treatment); Tp=Positive control using Cyhalothrin as synthetic pesticide). This gave 75 experimental units per block with a total of 225 experimental units where each unit received 2 seeds of soybean and a treatment. In combined forms, each variety received 3 treatment combinations (T1/T2; T2/T3 and T1/T2/T3) each replicated thrice (27 experimental units per block) making a total of 81 experimental units (Olasan et al., 2023).

Treatment Application

A 15L knapsack was used for applying the treatments at a single level of 10% extract prepared by adding100g of powdered extract into 10L of water for 12h. Treatments were applied at 14 DAP (Days after planting) (Sarkar et al.,2012).

Data Collection

Data were collected on two plant stands of an experimental unit. The following categories of parameters were assessed: growth (6), yield (6), entomology (10) and pathology (9). A total of 31 parameters were assessed as described below. Number of plants before treatment application was taken as the number of standing plant at 14 DAP (day after planting). Plant vigour before treatment application: was determined using a Likert scale of 1-3 (where 1=poor, 2=average, 3=good). Plant height at 40 days (in cm) was taken as the height of the two plants was measured using the meter rule. Number of leaves at 40 days was counted as the total number of leaves of two plants counted. Leaf length was taken as the length of the largest leaf at 40 days (cm): Number of branches at 40 days was counted as the total number of branches of two plants was counted (Sarkar et al., 2012). Total number of pods and seeds of two plants were counted**.** Length of 5 randomly selected pods and seeds was measured using the meter rule**.** Weight of all pods and seeds produced by two plants was measured using a digital weighing balance (Hoffman et al., 2018). Data were collected on insect pests feeding on the plants as described below:

(a) Traces of pests before treatment application (recorded as 1=Yes or 0=No)
(b) Types of pest before treatment application
(c) Types of pests found at 40 days
(d) Pest abundance at 40 days (1=very low, 2=low, 3=average, 4=high, 5=very high). The keys used were: Very low=<2 pests; Low=2-5 pests; Average=6-10 pests; High=11-20 pests; Very high=> 20 pests
(e) Pollinator abundance at 40 days: This was recorded at day 40 on a scale of 1-5 where 1=very low, 2=low, 3=average, 4=high, 5=very high. The keys used were: Very low=<2 pollinators; Low=2-5 pollinators; Average=6-10 pollinators; High=11-20 pollinators; Very high=>20 pollinators

(f) Number of damaged leaves at 60days
(g) Number of aphids, ants, spiders and beetles at 60 days
(h) Number of eggs, larva, caterpillar, worms at 60 days: Total number of eggs, larva and caterpillars seen was recorded per experimental unit at day 60
(a) Total number of insects (Amoabeng et al., 2013; Castillo-Sánchez et al., 2015)

Data were collected on plant pathology as described below:

(a) Traces of disease before application (coded as 1=Yes or 0=No)
(b) Types of disease before application (using a plant disease album)
(c) Plant performance at 60 days (physical assessment of the overall plant wellness on a scale of 1-3 scale where 1=poor, 2=average, 3=good)
(d) Traces of disease at 60 days
(e) Disease Severity at 60 days (recorded on a scale of 1-3 where 1=low, 2= moderate, 3= severe)
(f) Types of disease at 60 days:
(g) Number of damaged/infested pods
(h) Number of damaged/infested seeds
(i) Traces of infection in seed (coded as 1=Yes or 0=No) (Amoabeng et al., 2013; Castillo-Sánchez et al., 2015; Miles et al., 2017)

Data Analysis

Data analysis was done on the Microsoft Excel Spreadsheet and the Minitab software (16.0). Data were summarized and described using mean and standard error. Correlation analysis was done using the Pearson's method. Multivariate statistical analysis was performed. Mean separation of the ANOVA was done using the Fisher method at 95% confidence limit.

RESULTS

Preliminary data on pest and diseases prior to treatment (Table 1) showed abundance of pest species between six and seven (6-7) while four (4) disease symptoms were recorded for each of the three varieties. Table 2 shows the presence and intensity of pests found in plants treated with plant extracts 60 DAP. It was recorded that TGX-2019-2E) variety treated with *C. pubescens* had no pest infestation while only caterpillar was visible on the untreated form. Other varietal x treatment combinations recorded between one and five (1-5) insect types. Treatments reduced whitefly and spider among the insects. Table 3 presents the presence and intensity of disease symptoms at 60 DAP. TGX-2019-2E had no cases of diseases symptoms when treated with plant extracts. TGX-1987-62F had no cases of diseases symptoms when treated with any of *H. suaveolens* and *C. pubescens* extracts. The latter variety (TGX-1987-62F) recorded no diseases symptoms when treated with mixed combinations of any two or all extracts. Treatments reduced mildew disease symptoms. The best performance was seen with TGX-2019-2E treated with *C. pubescens* as it recorded the highest scale (3) followed by TGX-1951-3F treated with *H. suaveolens*. Table 4 presents the correlation matrix among indices of growth, yield, pest and diseases. There was a very high positive correlation between plant performance and pollinator abundance (R=0.738) with significant relationship (p<0.05). A moderate positive and significant correlation was recorded between number of pollinators and pod yield (R=0.669, p<0.05).

Table 1. Preliminary data on pest and diseases before treatment application

Variety	Aphid	Leafhopper	Whitefly	Caterpillar	Ants	Beetles	Spider	Total pest	Total disease
TGX-1951-3F	+++	+	-	+	+++	++	+	6	4
TGX-2019-2E	++	+++	++	+	+	++	+	7	4
TGX-1987-62F	++	+++	++	+	+++	-	++	6	4

Table 2. Types, presence and intensity of pests found 60 DAP, post treatment

Treatment	Aphid	Leafhopper	Whitefly	Caterpillar	Ants	Beetles	Spider	Total pest type
VIT1	+++	+	+	+	-	-	-	4
VIT2	++	-	-	-	+	-	-	2
VIT3	++++	+++	-	++	-	+	-	4
VITn	-	+	-	+	+	-	-	3
VITp	+	-	-	-	-	-	-	1
V2T1	+	-	-	+	+++	+	-	4
V2T2	++	-	-	-	+	+	+	4
V2T3	-	-	-	-	-	-	-	0
V2Tn	-	-	-	+	-	-	-	1
V2Tp	+++	-	-	+	-	+	-	3
V3T1	+	+++	-	+	+	+	-	5
V3T2	++	-	-	+	+++	-	-	3
V3T3	+	-	-	-	+++	-	+	3
V3Tn	++	+	-	-	+	-	+	4
V3Tp	+	-	-	-	+++	+	-	3
V1T1T2	+	++	-	-	+	+	-	4
VIT2T3	-	+	-	+	+	-	-	3
VIT1T2T3	++	-	-	-	+	-	-	2
V2T1T2	++	+	-	++	++	-	-	4
V2T2T3	+	-	-	-	+++	++	-	3
V2T1T2T3	+	+	-	++	++	-	+	5
V3T1T2	+++	+	-	-	+	-	-	3
V3T2T3	+	-	+	-	+	+	-	4
V3T1T2T3	+	+	-	++	+++	-	-	4

Legend:

(+) = presence of pest in varying degrees

(-) = absence of pest in varying degrees

V1=TGX-1951-3F; V2=TGX-2019-2E; V3=TGX-1987-62F; T1=*Cymbopogon citratus*; T2=*Hyptis suaveolens*; T3=*Centrosema pubescens*; Tn=water + detergent; Tp=Cyhalothrin

Table 3. Presence and intensity of diseases found at 60 DAP, post treatment

Varietal*Treatment interaction	Blight	Wilt	Spot	Mildew	Total disease type
VIT1	✓	✓	✓		3
VIT2	✓	✓	✓		3
VIT3		✓✓✓	✓✓		2
VITn	✓			✓	2
VITp					0
V2T1					0
V2T2					0
V2T3					0
V2Tn				✓	1
V2Tp					0
V3T1		✓			1
V3T2					0
V3T3					0
V3Tn					0
V3Tp					0
V1T1T2	✓	✓	✓		3
VIT2T3		✓✓	✓		2
VIT1T2T3					0
V2T1T2					0
V2T2T3					0
V2T1T2T3		✓			1
V3T1T2					0
V3T2T3					0
V3T1T2T3					0

Legend:

(+)= presence of pest in varying degrees; (-) = absence of pest in varying degrees
V1=TGX-1951-3F; V2=TGX-2019-2E; V3=TGX-1987-62F; T1= *Cymbopogon citratus*
T2=*Hyptis suaveolens*; T3=*Centrosema pubescens*; Tn=water + detergent; Tp=Cyhalothrin
✓ =presence of pest

Table 4. Correlation matrix among indices of growth, yield, pest and diseases

	Pest abundance	Pollinator abundance	Disease severity	Plant performance	Plant Height
Pollinator abundance	R=0.523				
Disease severity	R=0.534	R=0.252			
Plant performance	R=0.159	R=0.738 *p*<0.05	R=0.236		
Plant height	R=-0.113	R=0.390	R=0.330	R=0.602 *p*<0.05	
Pod yield	R=0.150	R=0.669 *p*<0.05	R=0.121	R=0.599 *p*<0.05	R=0.687 *p*<0.05

R=Correlation coefficient
P=Probability value

Table 5 presents the vegetative growth performances of the three soybean varieties in single and combined treatments of plant extracts at day 40 after planting. TGX- 1951-3F had the tallest height (65.7cm) with *H. suaveolens* extract. TGX-2019-2E had the tallest height (70.3cm) with a mixed treatment of *C. citratus* + *H. suaveolens* extracts. The maximum height of TGX-1987-62F was 59.4cm with *C. citratus* extract. Among the three varieties, TGX-1951-3F produced the highest number of leaves (252 leaves) when the three extracts were combined. TGX-2019-2E had the longest leaves (16cm) when treated with a combination of *C. citratus* + *H. suaveolens* extracts. However, no significant varietal and treatment effects were recorded in the three vegetative growth parameters evaluated (p>0.05). Table 6 presents the yield performances of the three soybean varieties in single and combined treatments of plant extracts at day 40 after planting. Varieties had equal maximum pod sizes (4.5cm) and seed sizes (0.5cm) in different treatments. TGX-2019-2E had the highest pod weight (73.3g) with any of *H. suaveolens* or *C. pubescens* extracts. However, no significant varietal and treatment effects were recorded in the yield parameters evaluated (p>0.05). As shown in Figure 1, the lowest number of infested seeds (7 seeds) was observed in TGX-1987-62F variety treated with a combination of the three treatments.

Table 5. Single and combined effects of treatments on vegetative growth at 40 DAP

Varieties	T1	T2	T3	T1*T2	T2*T3	T1*T2*T3	Negative Control	Positive Control
				Plant height (cm)				
V1	37.0	83.67	65.71	30.00	53.00	76.00	48.33	46.00
V2	46.33	45.67	48.00	70.25	64.25	63.75	49.00	45.75
V3	59.40	38.50	41.00	26.33	57.50	28.00	42.50	41.00
Grand mean	47.58	55.95	51.57	42.19	58.25	55.92	46.61	44.25
				No of leaves				
V1	93.8	248.67	187.14	93.6	103.0	252.5	91.33	280.0
V2	132.3	182.0	230.0	192.75	225.0	240.0	149.0	198.25
V3	154.0	209.0	198.0	63.50	172.5	132.0	188.75	167.50
Grand mean	126.7	213.22	205.05	116.62	166.83	208.17	143.03	215.25
				Leaf sizes (cm)				
V1	12.0	14.67	15.86	10.00	8.00	8.67	11.33	12.00
V2	10.33	11.33	10.00	16.00	14.75	14.75	10.00	10.00
V3	11.00	15.00	10.50	14.75	9.50	14.00	10.00	11.7
Grand mean	11.11	13.67	12.12	13.58	10.75	12.47	10.44	11.25

Plant height, F (Treatment)=0.44, p=0.860 (p>0.05); No significant difference in treatments (all had the same effect)
Plant height, F (Variety)=1.78, p=0.204 (p>0.05); No significant difference among varieties (all alike)
No of leaf, F (Treatment)=1.91, p=0.143 (p>0.05); No significant difference in treatments (all had the same effect)
No of leaf, F (Variety)=0.89, p=0.434 (p>0.05); No significant difference among varieties (all alike)
Leaf size, F (Treatment)=0.65, p=0.709 (p>0.05); No significant difference in treatments (all had the same effect)
Leaf size, F (Variety)=0.11, p=0.897 (p>0.05); No significant difference among varieties (all alike)

Legend:

V1=TGX-1951-3F; V2=TGX-2019-2E; V3=TGX-1987-62F; T1=*Cymbopogon citratus*; T2=*Hyptis suaveolens*; T3= *Centrosema pubescens*; Tn=water + detergent; Tp=Cyhalothrin

Table 6. Single and combined effects of treatments on pod sizes

Varieties	T1	T2	T3	T1*T2	T2*T3	T1*T2*T3	Negative Control	Positive Control
				Pod Sizes (cm)				
V1	4.1	4.17	4.14	3.2	3.38	4.5	4.17	4.5
V2	4.5	4.33	4.5	4.38	4.5	4.5	4.5	4.38
V3	4.3	4.38	4.5	4.38	4.5	4.5	4.25	4.38
Grand mean	4.3	4.29	4.38	3.99	4.13	4.50	4.31	4.42
				Pod Weight (g)				
V1	48.0	55.0	52.86	30.0	45.0	75.0	48.33	80.0
V2	73.33	60.0	60.0	62.5	61.25	68.75	80.0	53.75
V3	58.0	63.75	56.25	25.0	60.0	34.17	51.25	52.5
Grand mean	59.78	59.58	56.37	39.17	55.42	59.31	59.86	62.08
				Seed Sizes (cm)				
V1	0.49	0.5	0.5	0.39	0.38	0.5	0.48	0.5
V2	0.5	0.48	0.5	0.5	0.5	0.5	0.5	0.5
V3	0.5	0.49	0.5	0.33	0.5	0.33	0.5	0.5
Grand mean	0.50	0.49	0.50	0.41	0.46	0.44	0.49	0.5

Pod size, F (Treatment)=0.99, p=0.479 (p>0.05); No significant difference in treatments (all had the same effect)
Pod size F (Variety)=5.38, p=0.018 (p<0.05); Significant difference exits among varieties (Not alike)
Pod weight, F (Treatment)=0.89, p=0.539 (p>0.05); No significant difference in treatments (all had the same effect)
Pod weight, F (Variety)=2.61, p=0.108 (p>0.05); No significant difference among varieties (all alike)
Seed sizes, F (Treatment)=1.32, p=0.309 (p>0.05); No significant difference in treatments (all had the same effect)
Seed sizes, F (Variety)=1.38, p=0.285 (p>0.05); No significant difference among varieties (All alike)

Legend:
V1=TGX-1951-3F; V2=TGX-2019-2E; V3=TGX-1987-62F; T1=*Cymbopogon citratus*; T2=*Hyptis suaveolens*; T3 =*Centrosema pubescens*; Tn=water + detergent; Tp=Cyhalothrin

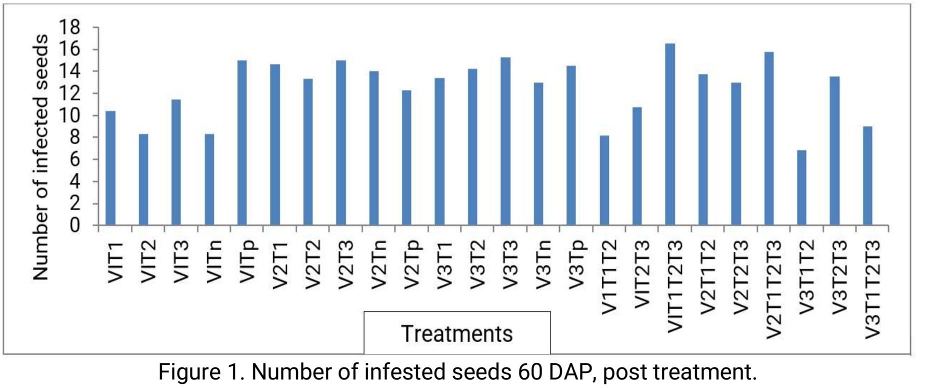

Figure 1. Number of infested seeds 60 DAP, post treatment.

Legend:
V1=TGX-1951-3F; V2=TGX-2019-2E; V3=TGX-1987-62F; T1=*Cymbopogon citratus*; T2=*Hyptis suaveolens*; T3= *Centrosema pubescens*; Tn=water + detergent; Tp=Cyhalothrin

DISCUSSION

Although treatments did not improve any aspect of growth and yield of the crop, there were significant reductions in pest infestation and disease symptoms of the crop under the influence of the plant extracts. These biotic factors tend to reduce growth and yield performances as well as the general wellness of the crop in the field. Similar reports were given in other studies (O'Neal and Johnson, 2011; Pignati et al., 2017; Mendelsohn et al., 2019).

Results showed that *C. pubescens* extract was the best among the three extracts. Although no bioassay was carried out in this work, the available results were consistent with other findings on *C. pubescens* reported to possess useful antimicrobial and pesticidal properties (Mandal et al., 2017; Ahmad et al., 2018). Similar findings were reported by Olasan et al. (2023) who found that common weed plants, *Senna occidentalis* and *Setaria palmifolia* had grain protectant effects in Cowpea. In the present work, *H. suaveolens* also showed evidences of crop protection effects in the results. Both *C. pubescens* and *H. suaveolens* leaves may possess useful active ingredients needed in crop protection. The common bioactive compounds in botanical pesticides are majorly secondary metabolites such as steroids, alkaloids, tannins, terpenes, phenols, flavonoids and resins that possess antifungal, antibacterial, antioxidant or pesticidal properties (Jnaid et al., 2016; Plata-Rueda et al., 2017). According to Ahmad et al. (2017), the plant part used is dependent on the targeted bioactive compounds and their abundance within that particular part. It thus suggests that active ingredients such as alkaloids, terpenoids, tannins may be present in large quantities in the leaves of *C. pubescens* and *H. suaveolens*. Similarly, botanical compounds with pesticidal activity that have successfully been isolated and commercialized include *azadiractin* from neem (*Azadirachta indica*) and *pyrethrin* from *pyrethrum* (*Tanacetum cinerariifolium*) (Joseph and Sujatha 2012; Castilo-Sanchez et al., 2015).

Soya varieties TGX-2019-2E and TGX-1951-3F were tolerant to insect infestation to a large extent possibly due to genetic factors. This agrees with other findings that the extent of economic damage depends upon the type of pathogen/pest, plant tissue being attacked, number of plants affected, severity of attack, environmental conditions, host plant susceptibility, plant stress level, and stage of plant development (Hartman & Sinclair, 2018). The activity of *C. pubescens* may further strengthen the tolerance of the selected varieties to insect attack. This is because the study found TGX-2019-2E as the best performing variety in physical appearance when treated with *C. pubescens* extracts.

The results showed that the pest population may influence the population of pollinators. The latter plays a huge role in the pollination, fertilization and yield of crops. This assertion was confirmed true as a high positive correlation was established between plant performance and pollinator abundance in this work. Also, a moderately positive and significant correlation was established between number of pollinators and pod yield. This suggests the need to carefully control the pesticidal action of any material to prevent its adverse effect on beneficial organisms. Commercialized pesticides from plants such as pyrethrum, neem and sabadilla are some of the least toxic especially to non-targets organisms such as pollinators and fish (Dubey et al., 2010). This attribute makes botanical pesticides effective, reliable and acceptable in sustainable crop protection. In addition, they do not leave residues on crop produce and the environment thus contributing to environmental conservation and ensuring the safety of consumers (Dubey et al., 2010). The interaction between botanical pesticides and pests is naturally biochemical therefore pests are unlikely to develop resistance (Joseph & Sujatha, 2012). The efficacy of these biopesticides is dependent on the species of the source plant, whether dry or fresh, the solvents used for extraction and the extraction methods (Gurjar et al., 2012). Botanical pesticides exhibit varied modes of action on the target pests such as repellence, toxicity, growth regulation and structural modification making them suitable alternatives in crop pest management (Kushram et al., 2017).

The study found that the pest population may increase disease incidence. This is because pests may act as vectors of some disease-causing viruses, bacteria and fungi that attack crops. Pests pierce through foliar structures and create wounds for parasites to colonize infected plants (Stevenson et al., 2017). Combinations of the extracts were found to be more effective against pathogens of bacterial and fungal origins than single extracts. The synthetic pesticide performed better in the control of plant pests although the differences were not significantly established. Application of plant extracts in single or combined forms had no significant effects on the plant growth, number of leaves and leaf sizes. Application of plant extracts in single or combined forms had no significant effects on yield parameters (pod sizes, pod weight, and seed sizes) but treatment combinations influenced the quality of pods and seeds produced

CONCLUSION

The best performing variety was TGX-2019-2E treated with *C. pubescens* plant extract. The treatments reduced white fly and ants as pests as well as the incidence of mildew disease. Yield parameters (pod sizes, pod weight, and seed sizes) were not significantly affected by plant extracts. Observed differences in pod sizes were due to varietal effects. Combined treatments had effects on TGX-1987-62F variety by producing the lowest number of infested seeds, thus suggesting their relevance in crop protection but subject to further trials. The information given in this report may be useful in the sustainable production of soybean.

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AUTHOR CONTRIBUTIONS

OJO and CUA; conceptualized and designed the work. NAN and DS carried out field and laboratory practical together with data collection. OJO analyzed the data and wrote the manuscript. CUA proofread the work.

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AVAILABILITY OF DATA AND MATERIALS

The data that support these findings are available from the corresponding authors upon reasonable request.

ETHICAL CONSIDERATIONS

This article did not include human subjects or animal studies.

COMPETING INTEREST

The authors declare no competing interest.

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