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Research Article

YIELD PARAMETERS OF OKRA (*ABELMOSCHUS ESCULENTUS*) PLANT AND NUTRITIONAL CONTENTS OF THE HARVESTED OKRA FRUITS AS INFLUENCED BY THE APPLICATION OF PLANT EXTRACTS AND SYNTHETIC INSECTICIDES

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Abstract: At Ladoke Akintola University of Technology, Teaching and Research Farm, Ogbomoso, we conducted this experiment during the major planting seasons of 2019 and 2020 to determine the effects of *Petiveria alliacea* and *Azadirachta indica* extracts as botanical insecticides and synthetic insecticides (cypermethrin and dichlorvos) on the yield parameters, proximate, phytochemical, and mineral contents of okra. We included untreated plants in the experiment for comparison. We arranged the treatments in a randomized complete block design, replicating each treatment three times. We collected data on the plant height, leaf area, and yield, proximate, phytochemical, and mineral contents of the harvested okra fruits. The results revealed that cypermethrin and *P. alliacea* extracts had a higher okra plant height (36.5 cm), but all the treatments had the same effects on leaf area. However, tested plant extracts and synthetic insecticides produced the same okra fruit yield. Harvested okra fruits from plants treated with dichlorvos had the highest proximate contents, followed by *P. alliacea* and *A. indica* extracts. Meanwhile, okra fruits from plants treated with *P. alliacea* extracts had the highest phytochemical contents (5.2 mg/100 g), but okra fruits from *A. indica* and *P. alliacea* had the highest mineral contents (234.1 to 231.5 mg/100 g). Therefore, we can use the two tested plant extracts as stimulants for okra plant growth and nutritional enhancers.

Keywords: *Azadirachta indica*, Okra, *Petiveria alliacea*, phytochemical compounds, proximate contents.

Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) belongs to the family Malvaceae, and it is believed to have originated from Ethiopia in Africa [SATHISH & ESWAR, 2013]. It is now widely cultivated throughout the tropics and sub-tropics, as well as in the warmer parts of the temperate regions of the world [DURAZZO & al. 2019; ISLAM & al. 2019]. It is a nutritious vegetable (lady's finger) that is an important source of carbohydrate, protein, vitamins A, B, and C, calcium, potassium, dietary fibers, and minerals, and hence plays a vital role in the human diet [RASHWAN, 2011; GEMEDE & al. 2015; DANTAS, 2021]. Young, immature fruits can be consumed in many different forms, i.e., raw, steamed, boiled, or fried [FARINDE & al. 2007; WANKHADE & al. 2013].

Numerous phytophagous insects, diseases, and mites can attack okra during its development, leading to declines in yield quality and quantity [EKOJA, 2012; KUMAR & al. 2014]. The common strategy being employed by farmers for insect pest management is the use of synthetic insecticides; this can be attributed to their quick response in the control of field insect pests [ALAO & al. 2011; MUSA & al. 2013; ALAO & al. 2018]. Researchers have shown that most insects develop resistance to synthetic insecticides after prolonged use [SHABANA & al. 2017]. Not only that, the availability of most of these chemicals is a critical need, and

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environmental hazards resulting from their use are serious concerns [SANDE & al. 2011; BABARINDE & al. 2018]. The literature also states that the negative effects of insecticides on non-target organisms pose a serious threat to organism biodiversity [SANDE & al. 2011]. Most of these synthetic chemicals cause chronic ailments in humans as a result of exposure to or consumption of pesticide-contaminated crops [DAMALAS & KOUTROUBAS, 2015; KUMARI & al. 2014]. Insecticide residue in agricultural products, particularly vegetables, is a growing concern for producers, traders, and consumers in many parts of the world. There is pressure to minimize the use of synthetic insecticides. One of the efforts is to develop botanical insecticides as a novel alternative. People have described botanical insecticides as environmentally friendly and less toxic to humans [ISMAN, 2014; SHABANA & al. 2017]. Most botanical insecticides are less toxic, more quickly biodegradable, and do not damage the soil, water supply, or wildlife [SOKOVIĆ & al. 2010]. Many studies have examined the nutritional value of okra in the past [OGUNGBENLE & OMAEJALILE, 2010; GEMEDE & al. 2016; ROMDHANE & al. 2020], but few have examined how the addition of natural and man-made insecticides alters the nutritional value.

The Neem tree, also called the Indian lilac [SCHMUTTERER, 1990], is a fast-growing, evergreen plant that has amazing antifeedant properties. It can stop insects from wanting to eat at concentrations as low as 1 part per million [ISMAN & al. 1991]. Literature has it that the neem tree has more than 200 allelochemicals with different notable insecticidal properties [KOUL & WAHAB, 2004]. Further, the functional ingredients of neem exhibit therapeutic significance, as neem oil, bark, leaves, and their purified biochemicals are documented to have anticancer [PAUL & al. 2011] and antimicrobial [RAUT & al. 2014] properties. *Petiveria alliacea* (Phytolaccaceae) is an herbaceous plant with a typical height of about 1 m. This plant has inhibitory effects against *Trypanosoma cruzi*, insecticidal activity, acaricide activity, and antimicrobial activity against some strains [BENEVIDES & al. 2001; RUFFA & al. 2002; DUARTE & LOPES, 2005; WEBSTER & al. 2008; GUEDES & al. 2009].

There is no atom of doubt that the management practices of cultivating crops on the field might have impacts on the morphological and biochemical contents of the target crops. According to literature, applied synthetic insecticides and selected plant extracts influence watermelon's fatty acid compounds [ALAO & al. 2018]. Therefore, we conducted this experiment to examine how synthetic insecticides, *A. indica*, and *P. alliacea* affect the yield parameters and nutritional contents of okra.

Material and methods

Study site

The Ladoke Akintola University of Technology (LAUTECH) Teaching and Research Farm in Ogbomoso, Oyo State, hosted the field experiment in the cropping seasons of 2019 and 2020. This region is at longitude 4˚3′E and latitude 10˚5′N. We can describe the region as humid tropical falls in the Southern Guinea Savannah of Nigeria.

Land preparation and management

After choosing the site, we ploughed and harrowed the land to eliminate the roots of existing plants and weeds from the plot. We cleared the debris and then harrowed the land to create a suitable tilt for planting. We demarcated and arranged fifteen (15) plots in a randomized complete block design. Each plot had three plant rows. The plot's size was 3 m x 3 m, with 0.5 m spacing between the block plots and 1 m spacing between the replicates. There were five treatments, namely: Cypermethrin, Nano *P. alliacea* (leaves), Nano *P. alliacea* (root), aqueous

P. alliacea (leaves), *P. alliacea* (root), and control. We replicated each of these treatments three times and planted the okra variety (NH47-4) on each plot with three planting rows. We manually weeded with a hoe at two-week intervals.

Preparation of plant extracts

For this formulation, we used the roots of *P. alliacea* and the leaves of *A. indica*, which we air-dried separately for two weeks to prevent photodecomposition of the plant's chemical active compounds. We separately crushed the dried plant parts with a mortar and pestle into a powdered form, measuring out 700 g and mixing it with inert materials such as 20 g of black soap, 80 g of salt, 100 g of sulfur, and 100 g of camphor. We put this mixture into a 10-liter container with 3000 ml of water and vigorously stirred it with a stick, allowing it to stay overnight. We used muslin cloth for filtering, and stored the collected filtrates separately in 5-liter plastic kegs for future use.

Treatment application

We measured out 1000 ml from the stock solutions and determined the 20% v/v ratio. We further diluted each of the botanical insecticides with 800 ml of water, and separately mixed 1 ml of the two tested synthetic insecticides (cypermethrin) with 1000 ml of water. Three weeks after planting, we started applying the treatments early in the morning to prevent photodecomposition of the extracts, using a hand-held sprayer to prevent drifting. We applied the foliar treatment at 7-day intervals and conducted three weekly observations.

Analysis of proximate contents of harvested leaves

Sample preparation

We sorted the okra fruits, washed them, trimmed off the stumps with a stainless steel knife, and then cut the consumable parts longitudinally into portions of equal size. The samples were air-dried at room temperature. We ground the dried material into a fine powder, packed it into airtight polyethylene plastic bottles, and stored it in the desiccator until we needed it for analysis. We analyzed the dry samples for their proximate composition and minerals (Ca, Mg, Fe, and K). Determinations were carried out in duplicate. We express the mineral contents as mg per one hundred (100) g of dry weight (mg/100 g DW), while we express the proximate contents as a percentage. The Crop and Environmental Protection Laboratory at Ladoke Akintola University of Technology, Ogbomoso conducted this analysis.

Proximate analysis

We determined moisture, ash, crude fat, and crude fiber using the official methods of the association of official analytical chemists (AOAC, 2000), and used the micro-kjeldahl method to determine nitrogen. We then multiplied the nitrogen percentage by 6.25 to convert it to crude protein. Carbohydrate was determined by difference. The result was expressed in percentages.

Mineral analysis

The minerals in the harvested *Abelmoschus* leaves were analyzed from the solution obtained when 2.0 g of the samples were digested with concentrated nitric acid and concentrated perchloric acid in ratios of 5:3. The mixtures were placed in a water bath for three hours at 80 °C. The resultant solution was cooled, filtered into a 100-ml standard flask, and made to mark with distilled water [ASAOLU, 1995]. An atomic absorption sphectrophotometer (Buck Scientific Model 200A) was used. The result was calculated in mg/100 g.

Data collection and analysis

Data were collected on plant height, number of leaves, leaf area, and yield, which were calculated by weighing the harvested leaves and converted to t/ha. Data collected were analyzed using Analysis of Variance (AVONA), and significant means were separated with a Duncan multiple range test at a 5% probability level.

Results

Effects of insecticides on yield parameters

Table 1 revealed that insecticides had an effect on the yield parameters. Although cypermethrin-treated plants had the highest plant height (36.5 cm), they had the same significant height as plants treated with *P. alliacea* extracts. In the plots treated with *A. indica* extracts, the plant height was comparable to that of dichlorvos (35.4 cm). The untreated plants had the lowest plant height (33.4 cm). Plant extracts and synthetic insecticide-treated plants did not significantly differ in fruit yield, while untreated plants produced the least amount (452.4 kg/ha).

Table 1. Effects of insecticides on yield parameters

Insecticides	Yield Parameters		
	Leaf Area (cm)	Plant Height (cm)	Yield
Cypermethrin	90.5[a]	36.5[a]	581.6[a]
Dichlorvos	80.3[a]	35.4[ab]	576.3[a]
Petiveria alliacea	90.2[a]	36.5[a]	582.8[a]
Azadirachta indica	83.9[a]	35.8[ab]	598.1[a]
Control	83.6[a]	33.4[b]	452.4[b]

*Means with the same superscripts are not significantly the same at 5% probability

Effects of insecticides on proximate contents of okra

The results presented in Table 2 show the effects of insecticides on harvested okra's proximate contents. Harvested okra fruits from plants treated with *A. indica* had the highest protein content (21.9%), while plants treated with *P. alliacea* extracts had the same protein content (20.12%) as untreated harvested okra fruits. The lowest protein content (20.13%) was discovered in the okra plants treated with Cypermethrin. The fiber contents (7.1%) observed from okra fruits treated with Cypermethrin were significantly the same as those of harvested fruits from untreated okra fruits. The harvested okra fruits from plants treated with *A. indica* extracts had higher fiber contents (5.3%), compared to the okra fruits from plants treated with *P. alliacea* (5.2%).

The level of moisture contents in harvested okra fruits from okra plants treated with dichlorvos had the significantly highest moisture contents (12.1%), while okra fruits from untreated plants had the least moisture contents (7.1%). Between the two tested plant extracts, harvested okra fruits from plants treated with *A. indica* extracts had lower moisture contents (9.15%) than the okra fruits from plants treated with *P. alliacea*. The highest carbohydrate content (63.9%) was discovered in the okra fruits from plants treated with dichlorvos, followed by the harvested okra fruits treated with *P. alliacea* extracts. Meanwhile, okra fruits from untreated plants had the fewest carbohydrate contents (61.1%).

The highest fat content (5.30%) was discovered in okra fruits harvested from plants treated with *P. alliacea* extracts, followed by okra fruits from plants sprayed with *A. indica* extracts (4.0%). Both tested synthetic insecticides decreased the fat contents of the harvested okra fruits when compared with the fat contents observed in the harvested okra fruits from untreated okra plants.

Okra fruits from plants treated with dichlorvos had the highest ash contents (8.0%), whereas the least ash contents (6.40%) were detected in the okra fruits treated with *P. alliacea* extracts. Harvested okra fruits from plants treated with *A. indica* extracts had higher ash contents (7.50%) than those from plants treated with cypermethrin.

Table 2. Effects of insecticides on proximate contents of okra

Insecticides	Proximate contents (%)					
	Proteins	**Fiber**	**Moisture**	**Carbohydrate**	**Fat**	**Ash**
Cypermethrin	20.12^{d}	7.1^{a}	8.20^{d}	61.58^{c}	3.06^{c}	7.06^{d}
Dichlorvos	20.14^{b}	5.2^{c}	12.1^{a}	63.86^{a}	2.80^{d}	8.00^{a}
Petiveria alliacea	20.13^{c}	5.2^{c}	9.15^{c}	62.97^{b}	5.30^{a}	6.40^{e}
Azadirachta indica	21.87^{a}	5.3^{b}	10.1^{b}	61.33^{d}	4.00^{b}	7.50^{c}
Control	20.13^{c}	7.1^{a}	7.4^{e}	61.07^{e}	4.10^{b}	7.60^{b}

*Means with the same superscripts are not significantly the same at 5% probability

Effects of insecticides on phytochemical contents of okra

Table 3 shows the effects of insecticides on the phytochemical contents of the harvested okra fruits. The amount of flavonoids found in okra fruits that came from plants that had been treated with the two tested plant extracts was significantly higher than that found in okra fruits that came from plants that had been treated with cypermethrin. The same was true for okra fruits that came from plants that had not been treated. However, plants treated with dichlorvos had the highest flavonoid content (1.80%).

The harvested okra fruits from plants treated with *P. alliacea* had the highest alkaloid content, followed by those from plants treated with cypermethrin. The tested plant extracts statistically improved the alkaloid contents of harvested okra fruits when compared with harvested fruits from untreated plants.

Plants treated with *P. alliacea* extracts and untreated plants produced okra fruits with the highest saponin contents (1.51%). On the other hand, more saponin (1.44%) was found in okra fruits that had been grown on plants treated with *A. indica* than in okra fruits that had been grown on plants treated with the two synthetic insecticides that were tested.

The amount of antioxidants in okra fruits treated with the two plant extracts was significantly higher than that in cypermethrin-treated plants. However, the tested plant extracts did not improve the antioxidant contents when compared with the quantity of antioxidants in the harvested okra fruits from untreated plants.

Table 3. Effects of insecticides on phytochemical contents of okra

Insecticides	Phytochemical content (mg/100 g)			
	Flavonoid	**Alkaloid**	**Saponin**	**Antioxidant**
Cypermethrin	1.22^{a}	1.35^{b}	1.15^{c}	2.03^{e}
Dichlorvos	1.80^{a}	1.20^{c}	1.09^{d}	2.37^{a}
Petiveria alliacea	1.67^{b}	2.00^{a}	1.51^{a}	2.14^{d}
Azadirachta indica	1.45^{c}	1.11^{d}	1.44^{b}	2.22^{c}
Control	1.26^{d}	1.08^{e}	1.51^{a}	2.26^{b}

*Means with the same superscripts are not significantly the same at 5% probability

Effects of insecticides on mineral contents of okra

As shown in Table 4, the level of potassium content in the harvested okra fruits was higher than other determined minerals. Harvested okra fruits from plants treated with *A. indica* extracts had the highest potassium contents (223.0 mg/100 g), followed by the okra fruits from plants treated with *P. alliacea* extracts, while the least potassium content (179.0 mg/100 g) was detected in the okra fruits from plants treated with dichlorvos.

The calcium content observed in the okra fruits from the plants treated with plant extracts was comparably low to that of harvested fruits from untreated plants. The two synthetic insecticides performed better than the plant extracts with respect to calcium contents.

The harvested okra fruits from plants treated with dichlorvos and *A. indica* extracts had the highest sodium content (1.79 and 1.87%, respectively). The sodium content in the okra fruits from plants treated with *P. alliacea* extracts was significantly the same as that of untreated okra fruits.

Table 4. Effects of insecticides on mineral contents of okra

Insecticides	Mineral contents (mg/100 g)		
	Potassium (K)	**Calcium (Ca)**	**Sodium (Na)**
Cypermethrin	216.0^c	12.90^c	1.47^b
Dichlorvors	179.0^e	13.31^b	1.79^a
Petiveria alliacea	218.0^b	12.41^d	1.06^c
Azadirachta indica	223.0^a	9.21^e	1.87^a
Control	186.0^d	13.60^a	1.08^c

*Means with the same superscripts are not significantly the same at 5% probability

Discussion

Researchers have described the use of plant extracts as insecticides as an environmentally friendly approach to protecting crops and our environment from hazardous synthetic pesticides. Therefore, we conducted this experiment to evaluate two plant extracts (*A. indica* and *P. alliacea*) as growth stimulants for okra plants, and their effects on the proximate, phytochemical, and mineral contents.

The data clearly demonstrates that the two plant extracts had a positive impact on the height of the okra plant, compared to the untreated plants, which had the lowest height. This implies that we can use *P. alliacea* and *A. indica* as growth stimulants. This concurs with earlier research by MOYIN-JESU (2010), who reported that neem extracts sprayed on maize plants had higher maize biomass and plant height. Also, application of neem leaf extracts resulted in high vegetative growth of Cavendish bananas [YI & al. 2021]. However, the applied insecticides did not significantly affect the leaf area of okra plants, while the okra yield from plants treated with synthetic insecticides (cypermethrin and dichlorvos) was comparable to that of the tested plant extracts. This revealed that the plant extracts induced fruiting as synthetic insecticides.

The observed protein content in the harvested okra fruits ranged from 20.13 to 20.87%, which was slightly higher than the reported protein by ADETUYI & al. (2011). This is an indication that the tested plant extracts improved the protein contents of the harvested fruits. However, okra plant-treated *A. indica* extracts had the highest protein contents (21.9%), which suggests that plant extracts improved the protein contents of okra fruits. The applied treatments significantly contribute to the okra pods' increased protein content, surpassing the standard plant source protein requirement of 12% [EFFIONG & al. 2009; ALI, 2010].

ADETUYI & al. (2011) reported that the fiber content of harvested okra varieties ranged from 10.8 to 11.7%. This was higher than the observed fiber contents of the harvested okra. Additionally, the plants treated with plant extracts did not exhibit any negative effects on the observed leaf area, which was comparable to the results of plants treated with synthetic insecticides. Meanwhile, plant extract-treated plants had lower fiber contents compared to cypermethrin-treated and untreated plants. However, the obtained fiber content is relatively higher than that of leafy vegetables, particularly *Amarathus hybridus* [ADETUYI & al. 2011]. This highlights the fact that consuming okra fruits treated with *P. alliacea* and *A. indica* extracts will increase digestibility and absorption processes in the large intestine, thereby preventing constipation [OGUNGBENLE & OMOSOLA, 2015].

The fat contents of harvested okra fruits ranged from 2.80 to 5.30%. Nevertheless, okra plants treated with *P. alliacea* extracts had the highest fat contents, followed by *A. indica* extracts. This shows that the plant extracts significantly improved the fat contents of the harvested okra fruits. The observed ash content from harvested okra fruits, which ranged from 6.40 to 8%, was comparable to the reported ash contents by EKWUMEMGBO & al. (2014). However, the tested plant extracts had higher ash contents than the two synthetic insecticides. This suggests that the two tested plant extracts can be sources for increasing the ash contents of okra fruits.

According to EKWUMEMGBO & al. (2014), the carbohydrate contents of okra fruits ranged from 37.6 to 52.3, whereas the carbohydrate content of harvested okra fruits was considerably higher. This is an indication that the applied treatments improved the carbohydrate contents of the harvested okra, but there was variation in the carbohydrate contents with respect to the treatments. For instance, okra fruits from plants treated with dichlorvos had the highest carbohydrate contents, followed by okra fruits from plants treated with *P. alliacea* extracts.

The collected data suggested that the applied insecticides had an effect on the mineral contents of the harvested okra fruits. The determination of mineral contents revealed that potassium content was the highest. Potassium contents ranged from 179.0 to 223 mg/100 g, and okra fruits harvested from plants treated with *A. indica* and *P. alliacea* extracts had higher potassium contents (223.0 and 218.0, respectively). This means that the two plant extracts made the potassium content of cultivated okra fruits higher compared to okra fruits that were picked from plants that were not treated and plants that were treated with synthetic insecticides. Researchers have reported that potassium improves iron utilization [ELINGE & al. 2012], controls hypertension, and prevents excessive potassium excretion through body fluid [ARINATHAN & al. 2003]. Meanwhile, the observed calcium content in okra fruits from plants treated with plant extracts was significantly lower than the okra fruits from plants treated with synthetic insecticides, including the untreated okra fruits. This implies that the tested plant extracts had negative effects on the calcium contents of okra fruits. The amount of sodium found in okra fruit-treated plants with *A. indica* extracts was higher than in other treated and untreated plants. The only exception was the okra fruits from dichlorvos that had the same amount of sodium. Okra fruits from plants treated with *P. alliacea* extracts had the same sodium contents as okra fruits from untreated plants. This implies that the plant extracts had no negative effects on the sodium contents of the harvested okra fruits. Literature has it that both microelements and macroelements are very essential in human nutrition, and okra is the major source due to its high mineral composition [HABTEMARIAM, 2019].

With respect to the treatments, the quantities of the phytochemical contents of the harvested okra pods varied. Harvested okra fruits from plants treated with Dirchlorvos had the highest flavonoid contents, followed by the okra fruits from plants sprayed with tested plant extracts. Plants treated with *P. alliacea* had significantly higher alkaloid contents than other applied treatments and untreated plants. However, okra fruits from plants sprayed with plant extracts had the highest saponin contents. This suggests that the plant extracts improved the phytochemical contents of the harvested okra fruits. The okra fruits from plants treated with the tested plant extracts had a higher antioxidant content than those from plants treated with cypermethrin, but a significantly lower amount than those from untreated plants. Flavonoid, alkaloid, and antioxidant contents are natural chemopreventive agents in traditional medicines for humans [LIAO & YIN, 2000].

Plants treated with *P. alliacea* and *A. indica* extracts yielded okra comparable to the two synthetic insecticides tested, while untreated plants yielded the least (452.4 kg/ha). This indicates that field management of okra plants can effectively utilize the tested plant extracts. This experiment clearly shows that the two plant extracts improved the yield parameters, as did synthetic insecticides. This concurs with earlier research work.

Conclusions

This experiment clearly demonstrated that the two tested plant extract formulations acted as growth stimulants and sources of increasing the nutritional contents of the harvested okra fruits. Synthetic insecticides were bad for the environment, and okra fruits that had been treated with cypermethrin and dichlorvos were not as healthy as okra fruits that had been treated with plant extracts. This implies that the use of tested plant extracts will serve as a means of protecting our environment from hazardous chemicals like synthetic insecticides. We should conduct further tests on other crops to determine the effectiveness of these two plant extracts as growth stimulants and nutritional enhancers.

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