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Comparative efficacy of two plant extracts and cypermethrin against field insect pests of *Amaranthus hybridus* L.

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Abstract. *Insect infestations are major constraints to vegetable production in Nigeria causing low yields and poor quality of produce. A study was conducted at the experimental farm of the National Horticultural Research Institute (NIHORT) Ibadan, Nigeria, to compare the efficacy of ethanol seed extracts of Azadirachta indica A.Juss (neem), Annona muricata L(soursop) and cypermethrin against field insect pests of Amaranthus hybridus L. under rain fed conditions. Four major insect species were observed causing damage to A. hybridus during the study and they include: cotton bollworm (Heliothis armigera Hubner), okra leaf roller (Sylepta derogata Fabricius), lagriid beetle (Lagria villosa Fabricius) and variegated grasshopper (Zonocerus variegatus Linnaeus). Ethanol seed extracts of A. indica were as effective as cypermethrin and more effective than A. muricata seed extracts in protecting A. hybridus against insect damage. Plots treated with A. indica extracts and cypermethrin significantly (p<0.05) reduced leaf damage, observed insect density and enhanced leaf yield compared to plots treated with A. muricata and control. There was no significant difference (p>0.05) between A. indica and cypermethrin treated plots on observed insect density, leaf damage and leaf yield. A. indica has proved to be efficient as cypermethrin and can be successfully used for the control of field insect pests of A. hybridus.*

Keywords: neem seed, soursop seed, ethanol extracts, insect pests, *Amaranthus hybridus*, chemical insecticide

Abbreviations: NIHORT - National Horticultural Research Institute, FAO - Food and Agricultural Organization, FCF - Federal College of Forestry, ANOVA - Analysis of Variance, LSD - Least Significant Difference, PLD - Percentage leaf damage, NPTP - Number of perforation per each treated plot, TPAL - total number of perforation on all assessed leaves, WAT - Weeks after treatments

Introduction

Amaranthus hybridus L. of family Amaranthaceae commonly called green amaranth is a herbaceous annual vegetable plant grown in Nigeria mainly for its edible leaves (Ojeifo et al., 2006; Akubugwo et al., 2007). A. hybridus is one the most common leafy vegetables consumed in Nigeria especially in the South west part of the country. According to FAO (2005) report and Smith and Eyzaguirre (2007), amaranth generally contains relatively high amount of nutrients such as calcium, magnesium, iron, vitamin C and other essential nutrients like gluten free carbohydrate that are required for good health (Achigan-Dako et al., 2014; Jimoh et al., 2018). They can be easily grown in wide range of environments making them suitable for reducing malnutrition in sub-Saharan Africa (Achigan-Dako et al., 2014).

Amaranth leaves are used for cooking soups and stews in different forms, it has a slight sweet and delicious flavor and can be used for salads (Herbst, 2001). In East Africa, amaranth leaves are recommended for boosting red blood cell count (Alemayehu et al., 2015). In Nigeria, it is a common vegetable that is used for preparation of different soups or stew for serving carbohydrates food like pounded yam, fufu and amala (Akin-Idowu et al., 2013). Regular consumption of green amaranth reduces

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cholesterol levels, blood pressure, and enhances the antioxidant activity and immunity in the body (Martirosyan et al., 2007). *Amaranthus* leaves are rich in calories ranging from 27 to 53 kcal/100 g of fresh leaves and have high nutrient value ranging from 4 to 6 g of protein, 0.2 to 0.6 g of fat, and 4 to 7 g of carbohydrates/100 g of fresh leaves (Uusikua et al., 2010). The popularity of green amaranth is due to its early maturity, high nutritive value and palatability (Banjo, 2007).

Insect pest infestation is one of the major factors that constraints the production of quality and marketable *A. hybridus* in Nigeria. All parts of *A. hybridus,* the leaves, stem, buds, flowers, fruits and seeds, are source of food for a wide range of pests leading to yield reduction (Aderolu et al., 2013). Leaf damage by defoliating insects reduces the yield and the market value which consequently leads to economic loss. Several insect species like Amaranth stem weevil (*Hypolixus truncatulus* Fand H. *nubilosus* B), Beeworm moth, (*Spoladea recurvalis* F.), leaf miner (*Liriomyza huidobrensis* B.), aphid, (*Myzus persicae*) and plant bugs (*Cletus* sp.) have been reported to attack *Amaranthus* spp (Atanu Seni, 2018). According to Rajeshkanna et al. (2017) a total of 92 insect pests belonging to 11 orders have been recorded from cultivated amaranthus. The most abundant insect pests associated with *Amaranthus* in Nigeria are: *Hymenia recurvalis* (Lepidoptera), *Hypolixus truncatulus*, *Lixus truncatulus* and *Gastroclisus rhomboidalis* (Coleoptera) (Aderolu et al., 2013). The lepidopterous insect pests of *Amaranthus* include *Psara bipunctalis, Sylepta derogata, Hymenia recurvalis, Helicoverpa armigera* and *Spodoptera littoralis* (Okunlola et al., 2008; Ebert et al., 2011).

The common practice in the management of insect pests of vegetable crops is application of synthetic pesticides which poses health threat to the consumers and environmental risk (Farinde et al., 2007). The use of chemical insecticides in the management of vegetable pests and levels of pesticide residues that are left in fresh vegetables are of great worry (Akan et al., 2013). Application of synthetic insecticides for the management of insect pests of different vegetable crops is still a common practice due its efficiency and quick action (Dadang et al., 2009). However, due to the several problems associated with the use of synthetic pesticides in crop production and concern for food safety, it has necessitated the search for alternative control options that are ecologically friendly (Hamman et al., 2012). The natural products derived from plants have enormous competence to replace the synthetic pesticides (Kanwal et al., 2021). The use of botanical pesticides has proved to be one of the prime means to protect crops, plant products and the environment from pesticide pollution (Kanwal et al., 2021). Botanical extracts degrade more rapidly than chemical pesticides and thus are considered environmentally friendly and likely non-toxic to beneficial insects (Kanwal et al., 2021). According to Guleria and Tiku (2009), most botanical pesticides degrade very fast like within few hours or days. Among the plants possessing bio-pesticidal properties, *Azadirachta indica* (neem) has proved to be a very important asset on account of its insecticidal properties against a number of insect pests (Ugwu et al., 2014a). *Annona muricata* has also been reported to possess insecticidal properties which are attributed to the annonaceous acetogenins that are extracted from its leaves, bark and seeds (Leatemia and Isman, 2004). *A. indica* and *A. muricata* extracts have been reported very effective against legume flower thrips (*Megalurothrips sjostedti)* and legume pod borer (*Maruca vitrata)* on cowpea in the field (Ugwu, 2020). Moreover, seed extracts of *A. indica* have also been reported very effective against *Sylepta derogata* on okra in the field (Ugwu et al., 2012). Several other studies have reported the insecticidal properties of *A. indica* and *A. muricata* on different insect species both in storage and in the field (Jaramilloa, 2000; Lala et al., 2014; Ishuwa et al., 2016). However, there is dearth information on their comparison with the synthetic insecticide against field insect pests of vegetable.

Hence, this study was aimed at comparing the efficacy of *A. indica* (neem), *Annona muricata* (soursop) seed extracts and cypermethrin against field insect pests of *A. hybridus* with a view of reducing the problems associated with excessive use of synthetic insecticides in vegetable production in Nigeria.

Material and methods

Experimental site and procedures

The experiment was carried out at the National Horticultural Research Institute (NIHORT) Ibadan, Oyo state, Nigeria during the 2019 planting season. NIHORT is situated within latitude 7°40'N, longitude 3°84'E and 195 altitude (Makinde et al., 2010). The study area is in the forest savanna transition zone with a bimodal rainfall pattern having long rainy season which usually starts in late March while the short rainy season extends from September to early November after a short dry period of one to two weeks in August (Makinde et al., 2010).

The seeds of *A. hybridus* were purchased from Agro seed store at Mokola, Ibadan. Ripe *A. indica* seeds were collected from the mother plant on the ground at Forestry Research Institute of Nigeria, Ibadan, while *A. muricata* seeds were collected from NIHORT Ibadan. The seeds of *A. indica* were extracted from ripe fruits by soaking in water for 24 hours and macerated with hand to remove the pulps. The extracted seeds were air dried for 2 weeks. The seed coats were later removed and oven dried for 3 days at 60˚C. The *A. muricata* seeds were extracted from ripe fruits and the drying followed the same procedure as with *A. indica*. Dried seeds were ground in electric blender and two hundred grams (200 g) of each powdered sample were separately put into Soxhlet extractor and extracted with 250 ml of absolute ethanol.

The experimental plot was 12 m × 10 m and was divided into subplots of 3 m × 2 m with an alley of 1 m × 1.5 m. The plot was cleared mechanically using a plough and was ploughed twice and allowed to stay for two weeks before harrowing. After harrowing, the seedbed was prepared using hoe and poultry manure was applied on the prepared seedbed as a base nutrient. *A. hybridus* seeds were sown on the seedbed a day after preparation using drilling method. The seeds were mixed with fine sand to enhance even distribution. Weeding was done manually at two weeks intervals to reduce competition for nutrients between the desired plants and the unwanted plants and to enhance yield. The experiment was laid out in a Randomized Complete Block Design (RCBD) in three replicates. The seed extracts *(A. indica* and *A. muricata*) were applied with the aid of a hand sprayer at the rate of 10 ml per 1 liter of water, while cypermethrin was applied at the rate of 5 ml per 1 liter of water at two weeks intervals in four applications and no treatment was applied on the control plot.

Data collection and Analysis

Data were collected on 20 tagged plants from each sub plot. Insect densities were recorded on each sub plot very early in the morning at weekly intervals for 12 weeks. Number of perforations on the leaves was equally recorded on the sampled leaves. The collected insect samples were preserved in 75% ethanol and later taken to the Entomology and Biology laboratory of Federal College of Forestry (FCF) Ibadan for proper identification through close observation of the specimen using insect identification keys. The larvae stage of the insects collected were reared into adults in the laboratory before identification. *A. hybridus* leaves were harvested at the vegetative phase from the tagged plants at three weeks intervals three times before the termination of the experiment and their fresh weights were recorded. The data collected were subjected to Analysis of Variance (ANOVA) and LSD (Least Significant Difference) was used to separate the significant means. Percentage leaf damage(PLD) was calculated using the formula:

$$PLD = \frac{NPTP \times 100}{TPAL} \quad (1)$$

where PLD is percentage leaf damage, NPTP is number of perforation per each treated plot, while TPAL is total number of perforation on all assessed leaves.

Results and discussion

Effects of the treatments on leaf damage of Amaranthus hybridus by insect pests

Ethanol seed extracts of *A. indica* and *A. muricata* were effective in protecting *A. hybridus* leaves against attack by insect pests in the field. *A. hybridus* leaf damage by insects was assessed by number of perforations on the leaves. The weekly assessment on leaf damage on *A. hybridus* leaves revealed that number of perforations on *A. hybridus* leaves increased as the week progressed (Table 1). Both extracts recorded less number of perforation on the leaves all through the weeks compared to control. *A. indica* ethanol seed extracts proved more effective in protecting the *Amaranthus* leaves against insect attack than *A. muricata* extracts and cypermethrin. The number of perforations on the leaves of *A. hybridus* in the plots treated with *A. indica* extracts were not significantly different (p>0.05) compared to the plots treated with cypermethrin but were significantly lower (p<0.05) compared to plots treated with *A. muricata* and control all through the study period. Insect damage on the leaves of *A. hybridus* was observed two weeks after germination when the seedlings were still very tender. Initial readings on the number of perforations collected before the application of the treatments showed that plots used for *A. muricata* extracts application recorded significantly higher number of perforations compared to all other plots with mean value of 2.77. However, there were no significant variations on the number of perforations recorded among other plots.

Table 1. Weekly mean number of perforations on leaves per *Amaranthus hybridus* plant over time

		Weeks after Treatments (WAT)								
Treatments	Initial reading before application of treatments	1	2	3	4	5	6	7	8	9
Annona muricata	2.77a	3.35^{a}	3.63^{b}	4.43^{b}	4.87^{b}	5.50^{a}	6.10^{a}	6.67^{a}	7.06^{b}	7.58^{b}
Azadirachta indica	2.43b	2.63^{b}	2.80^{c}	2.80^{c}	2.80^{c}	3.27^{b}	3.34^{b}	3.47^{b}	3.47^{c}	3.47^{c}
Cypermethrin	2.33b	2.67^{b}	3.07^{c}	3.53^{bc}	3.53^{c}	3.93^{b}	3.98^{b}	4.42^{b}	4.45^{c}	4.51^{c}
Control	2.43b	3.63^{a}	4.61^{a}	5.92^{a}	5.92^{a}	6.73^{a}	7.61^{a}	8.13^{a}	9.53^{a}	10.33^{a}
LSD	0.26	0.62	0.45	1.28	0.99	1.45	1.68	2.05	1.50	2.01

Means with the same superscript letters within the same column are not significantly (P > 0.05); P <0.05 is significant

At first week after treatment applications, the plots treated with *A. indica* recorded the least number of perforations with mean value of 2.63, followed by the plots treated with cypermethrin which had 2.67 number of perforations and plots treated with *A. muricata* extracts with mean value of 3.35. The highest number of perforations was observed in control plots (3.63). The effectiveness of the treatments followed a similar pattern as the week progressed with the plots treated with *A. indica* recording the least number of perforations all through the weeks, followed by plots treated with cypermethrin and plots treated with *A. muricata*, while the control plots recorded the highest number of perforations on the *A. hybridus* leaves. There were no significant differences (p>0.05) on the number of perforations recorded between the plots treated with *A. indica* extracts and cypermethrin from week 1 to week 6 and week 8 of the treatment applications. At week 7 of the study, the number of perforations was lower in plots treated with *A. indica* extracts than plots treated with cypermethrin with mean values of 3.47 and 4.45, respectively. Similarly, at week 9, plots treated with *A. indica* extracts recorded lower number of perforations on *A. hybridus* leaves than plots treated with cypermethrin with mean values of 3.47 and 4.51 respectively. However, they were not statistically different, indicating that *A. indica* seed extracts are as efficacious as cypermethin (synthethic insecticide) in protecting *A. hybridus* against insect pests attack. The overall assessment on the comparative efficacy of *A. indica* extracts, *A. muricata* extracts and cypermethrin against insect pests of *A. hyridus* revealed that *A. indica* was as effective as cypermethrin and more effective than *A. muricata* extracts in protecting insect damage on *A. hybridus* in the field (Table 2). Plots sprayed with ethanol extracts of *A. indica* recorded 45.69% leaf damage reducing insect damage on the leaves by 54.31%, while plots treated with cypermethrin recorded 54.88% leaf damage reducing insect damage by 45.12% compared to control.

Table 2. Effects of the treatments on the leaf damage of *Amaranthus hybridus* by insect pests

Treatments	Mean number of perforation/plant after treatments	% Damage leaf after treatments	% Damage leaf after treatment compared to control	% Reduction of leaf damage compared to control
Annona muricata	49.19[b]	28.44[b]	79.69[b]	20.31[b]
Azadirachta indica	28.2[c]	16.3[c]	45.69[c]	54.31[a]
Cypermethrin	33.87[c]	19.58[c]	54.88[c]	45.12[a]
Control	61.72[a]	35.68[a]	100[a]	0[c]
LSD	6.28	4.12	11.63	12.02

Values with the same superscript letters within the same column do not differ statistically (P > 0.05); P <0.05 is significant

Plots sprayed with *A. muricata* extracts showed slightly higher efficacy over control plots. With recorded 79.69% leaf damage it reduced only 20.31% insect damage on *A. hybirdus* compared to control plots. The findings from our study have demonstrated that ethanol seed extracts from *A. indica* were very potent agianst field insect pests of *Amaranthus hybridus*. The efficacy of *A. indica* seed extracts was comparable to cypermethrin in protecting *A. hybridus* against field insect pests.

The results of this study corroborate the earlier report by several authors who reported that *A. indica* based extracts exhibited very high efficacy against several insect pest species. *A. indica* extracts have been reported to be effective against mosquito larvae, control of aphids and whiteflies (Aliero, 2003; Nzanza and Mashela, 2012). Moreover, several *A. indica* based products have been reported to be very effective against various stages of instect pests both in the field and storage. Solangi et al. (2011) reported that extracts of neem oil, neem seed powder solution, showed repellent effects against *Bactrocera zonata*. Similarly, Rehman et al. (2009) reported that *A. indica* was very effective in reducing the oviposition rate of *B. zonata, B. dorsalis* and *B. olae.* Different concentrations of *A. indica* oil emulsifiable concentrate of 5, 10 and 20% were also reported to exhibit a high degree of insecticidal activity against *Maruca vitrata* larvae (Jackai and Oyediran, 1991). Similarly, Aderolu et al. (2012) reported that *A. indica* leaf ash, wood ash and modified neem leaf extracts were effective in reducing insect population and leaf damage on *A. hybridus* in the field and enhanced *Amaranthus* yield. However, *A. indica* based extracts have been reported to exhibit higher efficacy against several insect species than synthetic insecticides.

A. indica based products were found more effective than synthethic insecticides against white flies and aphids in the field (Basedow et al., 2002). Similarly, Ugwu et al. (2014b) also reported that *A indica* ethanolic seed extracts exhibited higher efficacy over cypermethrin against *Sylepta derogata* on okra in the field. Ojo and Ugwu (2012) also reported that ethanol seed extracts of *A. indica* were more effective than cypermethrin against insect pests of *Adansonia digitata* seedling in the field. The molecular components of *A. indica* based products which comprise complex mixture of molecules of hydrocarbons, phenolic compounds, terpenoids, alkaloids, and glycosides contribute to their insecticidal efficacy (Hossain et al., 2013). *A. indica* particles act on the life cycle of insects in various phases making it difficult for pests to resist the physiological effects of neem-based extracts (Mordue-Lunt and Nisbet, 2000).

The efficacy of cypermerthrin was slighly higher than *A. muricata* against insect pests of *A. hybridus* in this study. However, *A. muricata* exhibited significant degree of effectiveness against *Heliothes armigera, Sylepta derogata, Lagria villosa* and *Zonocerus variegatus* encountered on *A. hybridus* compared to the control. In contrast, *A. muricata* has been reported to possess high insecticidal properties aginst several insect pests both in the field and storage. Ugwu (2020) reported that petroleum ether seed extracts of *A. muricata* were more effective than Lambda-cyhalothrin against *Maruca vitrata* and *Megalurothrips sjostedti* on cowpea in the field. Similarly, Padma et al. (1998) reported that *Annona muricata* based products were more effective than synthetic insecticides in the control of different order of insect pests. The bio-activity of *Annona muricata* has been attributed to their chemical compounds such as annonaceous acetogins, muri-catenol, annomuricatin, javoricin, montanacin, montecristin, and coronin, donhexocin, which prevent development of insect pests (Jaramilloa et al., 2000). According to Lala et al. (2014) extracts of *A. muricata* and *A. squamosa* contain alkaloid and flavonoid compounds that perhaps confer their biological insecticidal proprieties.

Effect of treatments on the population density of major insect species observed in the field

Four major insect species were observed attacking *A. hybridus* leaves in the field during the study, they include: *Heliothes armigera, Sylepta derogata, Lagria villosa* and *Zonocerus variegatus*. The population of the insect species observed attacking A. *hybridus* leaves varied in the plots treated with different treatments (Figure 1). The populations of all the insect species were lower in plots treated with *A. indica* extracts (12.82%), followed by plots treated with *A.muricata* extracts (22.76%) indicating that these plant extracts possess repellent properties.

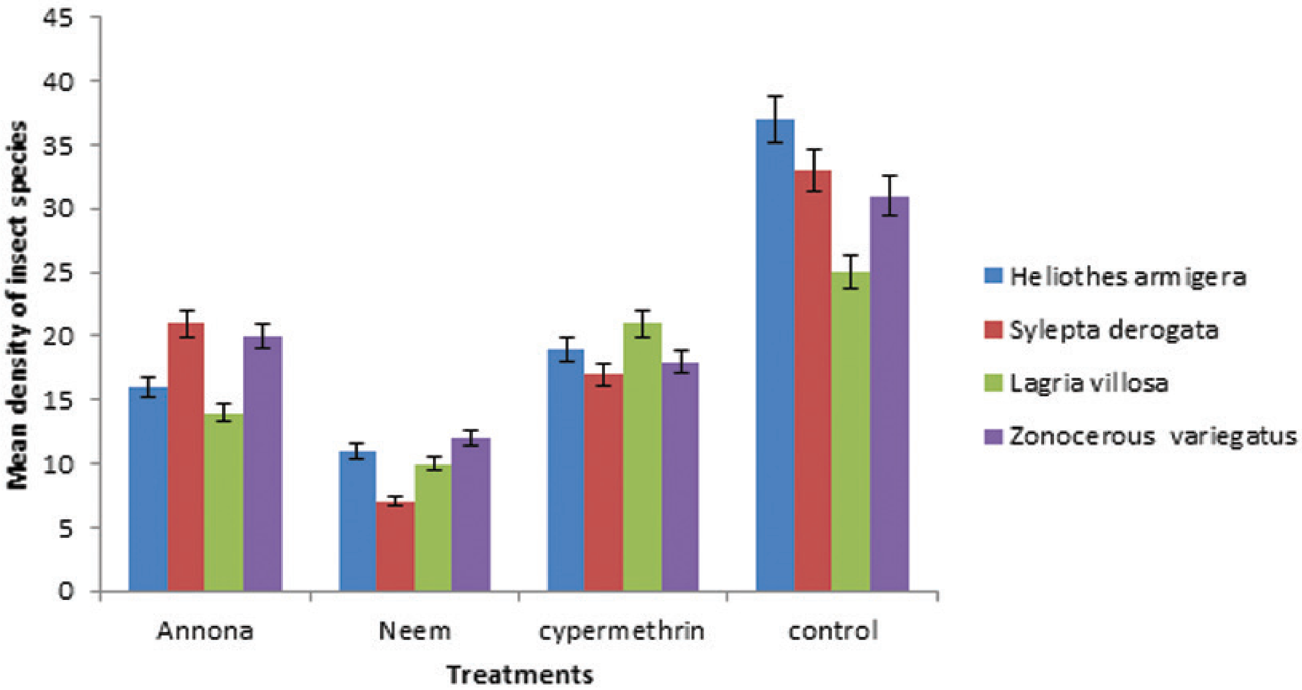

Figure 1. The population density of insect species observed in the field

The results of our study are in agreement with the findings made by Kanwal et al. (2021) who observed that *A. indica* seed oil was found to be more effective in reducing the population of white butterfly (*Pieris brassicae)* on cabbage than Novastar (Bifinthrine + Abamectin) and Range star (Lamba cyhalothrin). Similarly, Singh et al. (1987) reported that *A. indica* exhibited repellent effects against 2nd and 3rd instar larvae of *Pieri sbrassicae* on cabbages.

Plots treated with cypermethrin recorded 24.04% of the four insect species encountered while the density of all the insect species encountered was higher in control plots (40.38%) (Figure 1), implying that the treatments applied had effects against the insect species. The population of

H. amigera were slightly higher in the plots treated with *A. indica* (neem), while *Sylepta derogata* population was higher in plots treated with *A. muricata* implying that insects responded to the treatments differently. The density of *H. amigera* was slightly higher than other insect species in the population accounting for 26.6% of the total insect population recorded during the study. *Zonocerous variegatus* accounted for 25.96% of the total insect population recorded, *S. derogata* accounted for 25%, while *L. villosa* was the least accounting for 22.24% of the total population of the four insect species. The four major insect pests observed causing leaf damage to *Amaranthus hybridus* during this study were in line with other reports from other researchers. Okunlola et al. (2008) and Ebert et al. (2011) reported *H. amigera, H. recurvalis* and *Sylepta derogata* to be major insect pests causing damage to *Amaranthus* species in the field. Similarly, Paul et al. (2016) and Shubhakaxmi (2018) reported that *H. armigera and S. derogata* were major pests causing damage to *A. hybridus* during their study. Similarly, Aderolu et al. (2013) reported that *H. armigera* and *S. derogata* were among the major insect pests causing damage on *A. hybridus* in Ibadan South west Nigeria. *Zonocerus variegatus* and *Lagria villosa* are polyphagous insects that attack wide range of plant species by feeding on plant leaves.

Effects of the treatments on the yield of A. hybridus leaves

Plots treated with *A. indica* extracts gave higher leaf yield than those of the *A. muricata* and cypermethrin treated plots while untreated plots (control) gave the lowest yield (Table 3). The best yield was observed on plots treated with extracts of *A. indica*, however, there was no significant difference ($p<0.05$) on the yield of *A. hybridus* leaves between the plots treated with *A. indica* and cypermethrin. All treated plots ($p<0.05$) recorded significantly higher *A. hybridus* leaf yield compared to the control variant. These results are in agreement with the earlier report by Aderolu et al. (2012) who reported that application of ash, wood ash and modified neem leaf extracts enhanced *Amaranthus* leaf yield.

Table 3. *Amaranthus hybridus* leaf yields in response to different treatments

Treatments	Average yield(g)
A. indica	130. 60^{a}
A. muricata	75. 10^{c}
Cypermethrin	128. 20^{a}
Control	20. 90^{d}
LSD	3.67

Means with the same superscript letters within the same column do not differ statistically ($P>0.05$); $P<0.05$ is significant

Conclusion

The ethanol seed extracts of *A. indica* have proven to be effective as cypermethrin for the management of insect pests of *A. hybridus* in the field in this study. *A. indica* ethanol seed extracts were more efficacious than *A. muricata* in protecting *A. hybridus* leaves against insect damage. The use of *A. indica* plant extracts will reduce reliance on conventional chemical products and contribute to food safety as well as to reduce environmental pollution associated with the use of chemical pesticides in food production in Nigeria.

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