Comparative Efficacy of Plant Leaf Oils and Carbofuran in the Management of Lepidopterous Maize Stemborers

Uwah Ekaette Mfonobong[1,*]

[1]Entomology with specialization on insect pests of field crops, University of Calabar, Nigeria.

Research Article

Open Access &

Peer-Reviewed Article

DOI: 10.14302/issn.3070-2232.jf-24-5236

Corresponding author:

Uwah Ekaette Mfonobong, Entomology with specialization on insect pests of field crops, University of Calabar, Nigeria.

Keywords:

Carbofuran, Field bioassay, Environment, synthetic pesticide

Received: August 07, 2024

Accepted: July 24, 2025

Published: July 25, 2025

Citation:

Uwah Ekaette Mfonobong (2025) Comparative Efficacy of Plant Leaf Oils and Carbofuran in the Management of Lepidopterous Maize Stemborers. Journal of Farming - 1(2):27-41. https://doi.org/10.14302/issn.3070-2232.jf-24-5236

Abstract

Field bioassay to determine the efficacies of *Andrographis paniculata* (Acanthaceae) and *Vernonia amygdalina* (Asteraceae) in the management of maize stemborers was carried out at a plot of land located at satellite town, Calabar, Cross River State. The treatments consisted of leaf oils (1.0, 1.5 mls) of *A. paniculata*, *V. amygdalina,* a synthetic pesticide, Carbofuran at 1.0g and 1.5g a.i/ha which served as a standard, and an untreated control. The research was laid out in a Randomized Complete Block Design with three treatments and four replications. Treatments were applied at 5 and 7 weeks after planting and data were collected at 6 and 8 weeks after planting and at harvest. Parameters assessed included percent dead heart, plant heights, percent lodged stems, tunnel length, number of exit holes, egg mass, borer population and grain yield in kilograms. The result obtained showed that plots treated with leaf oils of *A. paniculata*, *V. amygdalina* and carbofurans significantly reduced ($P < 0.05$) the number of dead hearts, plant heights, percent lodged stems, tunnel length, number of exit holes, egg mass, borer population compared to the untreated (control). The result also revealed significant increase ($P < 0.05$) in grain yield in treated plots as plots treated with *A. paniculata* produced 17.81 kg, plots treated with *V. amygdalina* produced 18.26 kg, plots treated with carbofuran produced 20.47 kg compared to untreated plots which produced 8.56 kg. The results also indicated the percentage abundance of stemborer species collected in the cultivated plots, it showed that *Busseola fusca* was most abundant with a percentage of 32, followed by *Sesemia calamistis* with a percentage of 25, *Eldana saccharina* 24% and *Chilo partellus* 19%. In conclusion, *A. paniculata* and *V. amygdalina* leaf oils could be recommended for use as alternatives to synthetic insecticides which are not environmentally friendly.

Introduction

Maize (*Zea mays* L. Merri) is a plant in the grass family *Gramineae*, a tall annual plant with extensive fibrous root system (FAO.2002). It is the third most important cereal crop in the world after wheat and rice (FAO, 2002). In Nigeria, maize is known and called by different vernacular names like Masara (Hausa), Agbado (Yoruba), Oka (Igbo), Ibikpod (Efik). Maize is one of the major staple food crops widely cultivated and consumed in Africa due to its rich carbohydrate content (Rouanet, 1992).

In Nigeria, maize is grown in all agro-ecological zones mostly for its seeds either as dry grains or green maize with an estimate national production of 7.7million metric tonnes (Olaniyan, 2015). It is also called corn especially in the United State of America which is referred to as Corn Belt. It is usually stored to provide food reserve during off season and also as seed material for planting. Preparation and uses of maize alone or in combination with other food materials as staple food or snacks in Nigeria include: Ogi (in hot and cold forms), tuwo, donkumu, maasa, couscous, nakia, agbe, kokoro, elekube, abari, among others.

Maize is the most important cereal crop in sub-Saharan Africa. It is a staple food for an estimated 50% of the population (IITA, 2009). It is an important source of carbohydrate, protein, iron, vitamin B and minerals. Africans consume maize in many forms (such as porridges, pastes and beer). Green maize fresh on the cob is eaten baked, roasted or boiled. Every part of the maize plant has economic value: the grain, leaves, stalk, tassel, and cob can all be used to produce a large variety of food and non-food products (IITA, 2009). In sub-Saharan Africa, maize is mostly grown by small-scale farmers, generally for subsistence as part of mixed agricultural systems.

In Nigeria, maize crop is the first among the cereal crops grown (Romain, 2001). Cultivated throughout the ecological zones of Nigeria, maize is also demonstrated with a high yield potential in savanna regions (Mugo *et al*., 2005). It is the most cost-effective and highest yield plant resource in the world (Robert *et al.,* 2014). It serves as a material for the production of livestock forage, fodder and feed in Sub-Saharan Africa (Davies & Pedigo, 1990), as well as raw material for manufacture of many industrial products (Romain, 2001) and has also been used as biofuel and is a raw material for brewing beer and for producing starch (Romain, 2001;Misra, 2009).

The most important field pests of maize are lepidopterous stem and cob borers belonging to the families of *Noctuidae* and *Pyralidae* (Usua, 1968). They are: the African stalk borer (*Busseola fusca* Fuller), the spotted stem borer (*Chilo partellus* Swinhoe), the pink stem borer (*Sesamia calamistis* Hampson) and the sugar cane borer (*Eldana saccharina* Walker). Stem borers interfere with the movement of water and metabolites through the plant's vascular system, which stunts its growth and development. Attacks during the first eight weeks after sowing result in “dead heart” and late damage (beyond eight weeks after sowing) leads to stem lodging. Both types of damage to the crop cause drastic loss in maize yield (Bosque-Perez, 1995).

Therefore, feeding activities can cause fenestration, thereby reducing the photosynthetic area of the leaves that result to poor yield (Ofor *et al*., 2009). Generally, the yield losses due to stem borers range from 10 to 100% (Bosque-Perez & Mereck 1990). Damage resulting from stem borer infestation on maize plant can cause between 20-40% losses during cultivation, and 30-90% at post-harvest and storage (Robert *et al*., 2014). They also reported that increased damage on young maize plants is as result of the soft nature of the stems and leaves. In Nigeria, 14.0% yield loss for early maize as a result of stem borer activities was reported (Okweche *et al.,* 2013).The prevalence of *B. fusca* followed by *S. calamistis* on the early- and/or late-sown maize at Makurdi, Benue State, Calabar, Cross River State, and South-western Nigeria has been established (Balogun *et al*, 2001; Okweche *et al*. 2010; Okweche & Umoetuk, 2012).

Controlling these insect pests is difficult because most part of their life cycles is spent inside the plant which serves as a physical protection to insecticide application (Vitale 2007). Synthetic insecticides have been used extensively in the past by farmers for the control of stem borers, but however, they have not been effective and are not easily biodegradable besides being expensive. (Clieve, 2003). However, in recent times much attention has been given to biopesticides especially in controlling insect pests both in the field and in the store (Ileke, 2015). The use of botanicals for the control of agricultural pests is considered to be environmentally friendly and also reduce the cost of insecticides in pest management (Maddonni *et al.,* 2016).

Materials and Methods

Experimental Sites

This research was carried out in the late planting season of 2017. It was conducted from August 2017-November 2017, at a plot of land located at Satellite town, Calabar Municipal. Cross River State.

Preparation of Land and Planting

A portion of land measuring 50 x 50 m was cleared and pulverized using shovel and demarcated into plots. It was subsequently tilled using shovel to soften the land.The maize variety (white dent corn) obtained from the University of Calabar farm, was used for the study. The seeds were conveyed in a sealed polythene bag to the experimental site, and were later poured into a plastic basin. Water was added to the seeds in the basin, the seeds that floated on water were discarded as they were non-viable seeds while the ones that sank to the bottom were planted. Three seeds were planted manually at a spacing of 75 × 25 cm and a planting depth of 3 cm (Plate 1). The seedlings were thinned to two plants per stand at two weeks after planting. Hand weeding was carried out at 2 and 6 weeks after planting using weeding hoes and cutlasses (Plate 2) Compound fertilizer N.P.K (20:10:10) was applied in a ring at the rate of 90 kg N/ha, 45 kg P2O5/ha and 45 kg K2O/ha, this was to ensure normal growth and development of the plants (Ciampatti & Vyn, 2010)

Extraction of biopesticidal plants

Fresh leaves of *Andrographis paniculata* and *Vernonia amygdalina* were harvested from University of Calabar Farm. The leaves were identified by a known traditional healer and certified at the herbarium

Plate 1. The experimental farm after demarcation and planting

Plate 2. Weeding of experimental farm at two weeks after planting

of Department of Botany, University of Calabar. The leaves were washed thoroughly with tap water and air-dried at room temperature 27-30^{o} c, to prevent loss of chemicals due to direct exposure to sunlight for twenty one days. The dried leaves were ground to a fine powder using Molino De Granos manual grinder and sieved through using a kitchen strainer. The powders were kept in sealed polythene bags at room temperature until when needed, to prevent quality loss (Chayengia *et al.,* 2010).

Extraction of plant leaf oils

The leaf oils were extracted using soxhlet extractor (Plate 3), in the Department of Pure and Applied Chemistry, University Of Calabar, Calabar. A retort stand and clamp were used to support the soxhlet extract apparatus, following this, the solvent (250ml) of n-hexane was added to a round bottom flask which was attached to a soxhlet extractor apparatus condenser on a heating mantle. Fourteen grams (14g) of the powder was weighed using electronic weighing balance (AE Adams PW 254, AdamLab, U.S.A) into a 25x80mm thimble which was placed inside the extractor. The solvent was heated using a heating mantle and evaporate moving through the apparatus to the condenser. The condensate then dripped into the reservoir containing the thimble. Once the level of solvent reached the siphon, it poured back into the flask and the cycle began again. The process ran for a total of 16 hours and n-hexane was evaporated at 40-50^{o} using a thermostatic water bath (F.-Nr., $L_{508.0271}$) to obtain a syrupy residue.

The oils were formulated by measuring 1.0 and 1.5mls of the oils into plastic containers, each of which was diluted with 2 mls of water and mixed with 1ml of soap (surfactant). The resulting solutions were stirred continuously using a wooden spatula for 5 minutes. Each of the solutions was then poured into a hand pump sprayer shortly before application in the farm.

Purchase of synthetic pesticide (carbofuran)

The commercial formulation of Furadan (Carbofuran 3% G) was obtained from a pesticide shop in Watt Market Calabar, Cross River State. Furadan 3G is a granular formulation that contains 3% pure furadan.

Experimental Design

Plate 3. Extraction of plant leaf oils

The plots were divided into sub-plots to enhance the application of the different treatments and arranged in Randomized Complete Block Design with four replications and water treated which served as controls. The land was demarcated into eight blocks containing thirty-two sub plots. Each plot measured 4 × 2 m separated by adjacent plots measuring 0.5 m path while 1.0 m path was used to separate blocks.

The maize variety, white dent corn obtained from University of Calabar Farm was planted in the fourth week of August, 2017 (late planting). For each spray regime, the bio-insecticides were formulated as earlier described and applied with a hand pump sprayer, while the control sub-plots were sprayed with water only. Treatments used included oil of *Andrographis paniculata* (King of bitters), oil of *Vernonia amygdalina* (Bitter leaf) and carbofuran which served as a standard check and control which were sprayed with water only.

Treatments were applied 5 and 7 weeks after planting and were done by using hand pump sprayer. The carbofuran granules 1.0g and 1.5g were weighed using a weighing balance (AE Adams) and were applied by hand into furrow 4 cm from the plant.

Data collection

Data were collected on the following parameters; percent dead heart, egg mass and plant height at seedling stage. At harvest, 10 plants were randomly selected for tunnel length, borer population and species, percent lodged stems, number of exit holes and yield. Stemborer species were identified with reference (Polaszek 1998).

Determination of maize plant dead heart

The dead hearts of the maize plants caused by the activities of the stemborers were obtained at six weeks after planting. This was done in each of the treated and untreated plots by checking carefully for the plants suffering dead hearts. The number of the plants with dead hearts in each plot were counted and expressed as a percentage of the total number of plants within each plot.

Determination of maize plant heights

The heights of the plants on both the treated and untreated plots were determined at eight weeks after planting. The measurement was done by using a tailors measuring tape, and was obtained by measuring the whole length of the plant starting from the base of the first internode to the leaf whorl. The results were noted and recorded in centimeters (cm).

Determination of borer egg mass

The number of eggs on the treated and untreated plots was determined at eight weeks after planting. This was carried out with the aid of a 5 x 100mm hand held magnifier. The leaves, stems and sheaths were carefully checked for oviposition sites and egg deposits. The number of eggs found was noted and results recorded.

Determination of tunnel length of maize stems

Tunnel lengths in the stems caused by the tunneling activities of the stemborers were taken at harvest. Ten plants were randomly selected in each plot, and were split open using a kitchen knife. The tunnels found in each of the stems were traced using ropes (hair thread), the length of the ropes were then measured (in cm) with a measuring tape and the results were recorded.

Determination of population of borers and borer species

Borer population and species were determined at harvest. This was done after ten plants were randomly selected and the stems split. Population of the stemborers was recorded as the average number of larvae recovered in each plots. Stemborer species were determined after all the species were identified with reference Polazek (1998). The number of each species realized were counted separately and recorded.

Determination of percent lodged maize stems

The average number of lodged stems caused by the activities of the borers was also counted at harvest.This was done by quantifying and expressing stem lodging as a percentage of the total number of stems in each plot.

Determination of number of exit holes

The number of exit holes created by the borers was also investigated at harvest. Ten plants were randomly selected in each plot to check for exit holes. This was carried out by checking the stems carefully for exit holes and was done with the aid of a hand lens. The total number of exit holes in each plot were noted and recorded.

Determination of maize yield

Grain weight (yield) per plot was measured at harvest. It was carried out by harvesting all the maize cobs in each plot and packed in heaps. The harvested maize in each plot were dehusked and the maize cobs obtained were put in jute bags, the jute bags in each plots containing the maize cobs were placed on a 60 kilogram flat stainless plate spring mechanical balance. The weight of the grains in each plot were consequently noted and recorded. The computation was done to tonnes per hectare.

Data analysis

The data obtained was subjected to descriptive statistics to calculate the mean values and standard errors using the Microsoft excel, version 2010. The effects of the treatments on dead hearts, plant heights, egg mass, tunnel length, exit holes,borer population and maize yield, were analysed using ANOVA to check for the significant differences between mean values of the crops planted against the treatments. This was done using SPSS statistical software.

Results

Effects of plant leaf oils on dead hearts

The results obtained for the effect of insecticides (*Andrographis paniculata* leaf oil, *Vernonia amygdalina* leaf oil and carbofuran) on dead hearts in the study at six weeks after planting is shown in Table 1. The application of *A. paniculata* leaf oil and *V. amygdalina* leaf oil were as efficacious as carbofuran treatment in the reduction of deadheartt incidence when compared with untreated control (Plate 4). However, carbofuran treated plots produced lowest incidence of deadheart, followed by *A. paniculata* leaf oil at all rates. In carbofuran treated plots, the incidence of dead hearts reduced with increased rate of treatment, whereas, in *A. paniculata* treated plots, the incidence of dead hearts increased with increase rate of treatment application. Moreover, the *V. amygdalina* leaf oil treated plots showed no increase in number of dead hearts with increased concentration, as plots treated with different concentrations of the oils produced similar results. Thus, in all the treated plots, carbofuran treated plots at the rate of 1.5g had the lowest incidence of dead heart (0.75%) while *V. amygdalina* leaf oil treated plots at all rates and *A. paniculata* leaf oil at 1.5 ml had highest incidence of dead heart (1.25%).

Table 1. Percent dead hearts on treated and untreated maize plots six weeks after planting.

Treatment	Average percent dead hearts ± S.E		
	0.0*	1	1.5
A. paniculata	4.50 ±0.65	1.00 ± 0.41	1.25 ± 0.48
V. amygdalina	4.50 ±0.65	1.25 ± 0.48	1.25 ± 0.48
Carbofuran	4.50 ±0.65	1.00 ± 0.41	0.75 ± 0.48

Conclusion

Although the oils of *A. paniculata* and *V. amygdalina* rate applied did not completely eliminate stemborer species, it was effective in controlling their population on maize. Population of stemborers was reduced in plants treated with the oils which led to improved plant growth and yield. This study indicated that *A. paniculata* and *V. amygdalina* leaf oils can be applied to control maize stemborers in the field.

References

1. Abdullahi, N., Kabir, A. & Yushau, O. (2011). Studies on the efficacy of lime peel oil in protectiong stored maize against adult maize weevil (*sitophilus zeamais*). *Journal of Entomology*, 8:398-403.
2. Adebayo, T. A., Gbolade, A. A. & Olaife, J. I. (1999). Comparative study of toxicity of essential oils to larvae of three mosquito species. *Nigerian Journal of Natural Producing Medicine*, 3: 74-76.
3. Adedire, C. O. (2002). Use of nutmeg, *Myristica fragrans* powder and oil for the control of storage bruchid, *Callosobruchus maculatus*. *Journal of Plant Diseases and protection*, 109: 193-199.
4. Adedire, C. O. Obembe, O. O., Akinkurolele, R. O. & Oduleye, O. (2011a). Response of *Callasobruchus maculatus* (*Coleoptera: Chrysomelidae: Bruchidae)* to extracts of cashew kernels. *Journal of Plant Diseases and Protection,* 118(2): 75-79.
5. Adedire, C. O. Akinkurolele, R. O. & Ajayi, O. O. (2011b). Susceptibility of some maize cultivars in Nigeria to infestation and damage by maize weevil, *Sitophilus zeamais* (Motsch) (*Coleoptera: Curculionidae)*. *Nigerian Journal of Entomology*, 28: 55-63.
6. Adegbite, A. A. & Adesiyan, S. O. (2001). Effect of Carbofuran (Furadan) on the performance of four nematode susceptible varieties of soybean (*Glycine max (*L.) Merr. *Tropical Oilseeds Journal*, 6: 11-23.
7. Adegbite, A. A. & Agbaje, G. O. (2007). Efficacy of carbofuran in control of root-knot nematode (*Meloidogyn incognita* Race 2) in hybrid yam varieties in Southwestern Nigeria. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, 6(6): 2083-2094.
8. Adekunle, O. K. & Fawole, B. (2003). Chemical and non chemical control of *Meloidogyne incognita i*nfecting cowpea under field conditions. *Journal of Agricultural Research*, 4 (1): 94-99.
9. Ajayi, V. A. Akem, C. M, Adesiyan, S. O. (1993). Comparison of nematicidal potential of *Vernonia amygdalina* leaf extract and carbofuran on the growth and yield of root-knot nematode infested soybean. *Afro-Asian Journal of Nematology*, 3(2): 119-127.
10. Akah, P. A. & Ekekwe, R. K. (1995). Ethnopharmacology of some of the Asteraceae family used in the Nigerian traditional medicine. *Fitoterapia.* 66:352-355
11. Akunne, C. E. Ononye, B. U. & Mogbo, T. C. (2013). Evaluation of the efficacy of mixed leaf powders of *Vernonia amygdalina* (L.) and *Azaradichta indica* (A. Juss) against *Callosobruchus maculatus* (F.) (*Coleoptera: Bruchidae*). *Advances in Bioscience and Bioengineering*, 1(2): 86-95.
12. Amira, C. A. & Okubadejo, N. U. (2007). Frequency of complementary and alternative medicine utilization in hypertensive patients attending an urban tertiary care centres in Nigeria. BMC. *Complementary Alternative Medicine*, 7: 30-48.

13. Angioni, A., Barra, A., Coroneo V., Dessi, S. & Cabras, P. (2006). Chemical composition, seasonal variability, and antifungal activity of *Lavandula stoechas* essential oils from stem/leaves and flowers. *Journal of Agricultural Food Chemistry*, 54: 005-009.

14. Arun, K.., Shikha, U., Mantu, B., & Bhattacharya, P. Y. (2009). A review of essential oils as biopesticides in insect pest management. *Journal of Pharmacology and Phytotherapy*, 5: 005-009.

15. Atkinson, P. R. (1980). The biology, distribution and natural host plants of *Eldana Saccharina* Walker (*Lepidoptera: Pyralidae*). *Journal of Entomological Society*, 43: 171-194.

16. Awan, A. J., & Aslam, M. S. (2014). Family *Acanthaceae* and Genus *Aphelanndra*: Ethnopharmacology and Phytochemical Review. *International Journal of Pharmacy and Pharmaceutical Review*, 6(10): 44-55.

17. Bakkali, F., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential oils- A review. *Food and Chemical Toxicology*, 46: 446-475.

18. Balogun, O. S. & Tanimola, O. S. (2001). Preliminary studies on the occurrence of stem borer and incidence of stalk rot under varying plant population densities in maize. *Journal of Agricultural Resource Development*, 1: 67-73.

19. Bosque-Perez, N. A. & Mareck, J. H. (1991). Effect of the stemborer *Eldana saccharina* (*Lepidoptera: Pyralidae)* on the yield of maize. *Bulletin of Entomological Research*, 81: 243-247.

20. Bosque-Perez, N. A. & Mereck, J. H. . (1990). Distribution and composition of lepidopterous maize stemborers in Southern Nigeria . *Bulletin of Entomological Research*, 80: 363-368.

21. Bosque-Perez, N. A. & Schlthess, F. (1998). Maize: West and Central Africa,. In Polaszek, *Africa cereal stemborers: economic importance, taxonomy, natural enemies and control* (pp. 11-24). Wallingford, U.K: CAB International.

22. Bosque-Perez, N. A. (1995). Major insect pests of maize in Africa: Biology and Control. IITA (*lepidoptera: Pyralidae*) in Southern Africa. *Insect Science and its Application*, 11: 481-488.

23. Chaiyasit, D., Choochote W., Rattanachanpichai, E., Chaithong, U., Chaiwong, P., Jitpakdi, A., Tippawangkosol, P., Riyong, D. & Pitsawat, B. (2006). Essential oils potential adulticides against two populations of *Aedes aegypti,* the laboratory and natural field strains in Ching Mai Province, Northern Thailand. *Parasitological Resources*, 99: 715-721.

24. Challand, S. & Willcox, M. (2009). A clinical trial of the traditional medicine *Vernonia amygdalina* in the treatment of uncomplicated malaria. *Journal of Alternate Complementary Medicine*, 15: 1231-1237.

25. Chang, S. T. & Cheng, S. S. (2002). Antitermite activity of leaf essential oils and their constituents from *Cinnamomum osmophloeum. Journal of Agricultural Food Chemistry*, 50: 1389-1392.

26. Chayengia, B., Patgiri, P., Zeenat, R. & Saurabh, S. (2010). Efficacy of different plant products against *Sitophilus oryzea* (Linn.) (*Coleoptera: Curculionidae*) infestation on stored rice. *Journal of Biopesticides*, 3: 604-609.

27. Ciampatti, I. A. & Vyn, T. J. (2010). A comprehensive study of pH density conservation on nitrogen uptake dynamic of maize plants from vegetative to reproductive stages. . *Journal of crops resources*, 21: 97-103.

28. Clieve, J. (2003). Global review of commercialized transgenic crops: 2002 feature: BT maize. *International Service for the Acquisition of Agri-Biotech Applications*, 7: 223-227.

29. Cugala, D., Overholt, W. A., Giga, D. & Santos, L. (1999). Performance of *Costesia sesamia* (Cameron) and *Costesia flavipes* (Cameron (Hymenoptera: Braconidae) as biological control agents against cereal stemborers in Mozambique. *African Crop Science Journal*, 7: 1-6.
30. Davies, P. M. & Pedigo, L. P. (1990). Yield response of corn stands to stalk borer (*Lepidoptera*: *Nuctuidae*) injury imposed during early development. *Journal of Economic Entomology*, 83: 1582-1586.
31. Dike, M. C., Ajiboye, T. O. & Ajayi, O. (1999). Survey of millet stemborer *Acigona ignefusalis* (Hampson) (*epidoLptera*: *Pyralidae)* and other insects on late maturing pearl millet in Nigeria. *Journal of Arid Agriculture*, 9: 1-8.
32. Drinkwater, T. W., Walters, M. C & Van Rensburg, J. B. (1979). The application of systemic insecticides to the soil for the control of the maize stalk borer, *Busseola fusca* (*Lepidoptera: Noctuidae*) and *Cicadulina mbila* (Naude) (*Hemiptera: Cicadellidae), the vector of maize strak virus, Phytophylactica.* 11:5-12.
33. Egwuatu, R. I. & Ita, C. B. (1982). Some effects of single and split application of carbofuran on the incidence of damage by *Locris maculate*, *Busseola fusca* and *Sesamia calamistis* on maize. *Tropical Pest Management*, 28:72-77.
34. El-Mahmood, A. M. & Amey, J. M. (2007). In vitro antibacterial activity of *Parkia biglobosa* (Jacq) root bark axtract against some microorganisms associated with urinary infections. *African Journal of Biotechnology*, 6: 1272-1275.
35. Enan, E. E. (2005). Molecular and pharmacological analysis of an octopamine receptor from American cockroach and fruit fly in response to plant essential oils. *Archives of Insect Bichemistry and Physiology*, 59: 161-171.
36. Enobakhare, D. A. & Law-Ogbono. (2002). Efficacy of leaf powders of *Ocimum grattisimum* and *Vernonia amygdalina* as grain protectants against *Sitophilus zeamais* in three varieties of maize. *Journal of Agriculture, Forestry and fishery*, 3: 22-27.
37. Erasto, P., Grierson, D. S. & Afolayan, A. J. (2007). Evaluation of antioxidant activity and the fatty acid profile of the leaves of *Vernonia amygdalina* growing in South Africa. *Journal of Food Chemistry*, 104: 636-642.
38. FAO. (2002). *Food and agricultural organization production year book.* 2000:54
39. Gbolade, A. A. (2001). Plant-derived insecticides in the control of malaria vector. *Journal of Tropical Medical Plants*, 2: 91-97.
40. Georghiou, G. P., Green, H. M., Mobeng, W. K. (1990). Overview of insecticide resistance. Managing resistance to agro-chemicals from fundamental research to practical strategies. *American Chemical Society Sympossium Series*, 42: 18-41.
41. Hamowia, A. M. & Safran, A. M. . (1994). Pharmacologial studies on *Vernonia amygdalina* (Del) and *Tithonia diversifolia* (Gray). *Journal of veterinary medicine*, 42: 91-97.
42. Harborne, J. B. (1987). Chemical signals in the ecosystem. *Annual Botany*, 60:(4) 39-57.
43. Harris, K. M. & Nwanze, K. F. (1992). *Busseola fusca (Fuller),* the African maize borer*: A handbook of information bulletin 33, International crops research for the semi-arid tropics, Patancheru, India. 84 pp.*
44. Hollingworth, R. M. & Wright, N. (1984). In P. S. Magee, *Pesticide synthesis through rational*

approaches, ACA Symposium series (pp. 255: 103-125). Washigton, DC: American Chemical Society.

45. Howard, P. H. (1989). *Handbook of environmental fate and exposure data for organic chemical* (Vol. III). Chelsea M. I.: Lewis Publishers.
46. Igile, G. O., Oleszek, W., Burda, S. & Fafunso, M. (1995). Flavanoids from *Vernonia amygdalina* and their antioxidant activities. *Journal of Agricultural Food Chemistry*, 42: 2445-2448.
47. IITA. (2009). Seasonal abundance and distribution of sugarcane stemborers in Nigeria. *Journal of Economic Entomology*, 61: 693-696. Retrieved from www.maize-project-details.aspx IITA
48. Ileke, K. D., Odeyemi, O. O. & Ashamo, M. O. (2012). Insecticidal activity of *Alstonia boonei* De wild powder against cowpea bruchid, *Callosobruchus maculatus* (Fab.) (*Coleoptera*: *Chrysomelidae*) in stored cowpea seeds. *International Journal of Biology*, 4(2): 125-131.
49. Ileke, O. (2015). Entomotoxicant potential of bitterleaf, *Vernonia amygdalina* powder in the control of cowpea bruchid, *Callosobruchus maculatus* (*Coleoptera: Chrysomelidae*) infesting stored cowpea seeds. *Journal of Environmental Resources*, 3(3): 226-234.
50. Isman, M. B., Wam, A. J. & Passreiter, C. M. (2008). Insecticidal activities of essential oils to tobacco cutworm, *Spodoptera litura*. *Fitoterapia*. pp. 72: 65-68.
51. Jacobson, M. (1982). Plants, insects and man- their inter-relationship. *Journal of Economic Botany*, 36: 346-354.
52. Jarukamjorn, K. & Nemoto, N. (2008). Pharmacological aspects of *Andrographis paniculata* on health and its major diterpenoid constituent andrographolide. *Journal of Health Science,* 4: 370-381.
53. Jembere, B., Obeng-Ofori, D. & Hassanali, A. (1995). Product derived from the leaves of *Ocimum kilimandscharicum* (Labiates) as post-harvest grain protectants against the infestation of three major stored products of insect pests. *Journal of Entomological Resources*, 85: 361-367.
54. Johri, R. K. & Singh, C. (1997). Medicinal uses of *Vernonia species*. *Journal of Medicinal and Aromatic Plant Science*, 19: 744-752.
55. Khan, Z. R., Chiliswa, P. Ampong-Nyarko, K. Smart, L. E. Polaszek, A. Wandera, J. & Mulaa, M. A. (1997). Utilization of wild graminaceous plants for the management of cereal stemborers in Africa. *Insect Science and its Application*, 17: 143-150.
56. Khan, Z. R., Pickett, J. A., Wadhams, L. J. & Muyekho, F. (2001). Habitat management strategies for the control of cereal stemborers and striga in maize in Kenya. *Insect Science and its Application*, 21: 275-380.
57. Kim,S. I., Park, C., Ohh, M. H., Cho, H. C. & Ahn, Y. J. (2003). Contact and fumigant activities of aromatic plant extracts and essential oils against *Lasioderma serricorne* (*Coleoptera*: *Anobiidae*). *Journal of Stored Product Resources*, 39: 11-19.
58. Kordali, S., Aslan, I., Calmasur, O. & Cakir, A. (2006). Toxicity of essential oils isolated from three *Artemisia species* and some of their major components to granary weevils, *Sitophilus granarius* (L) (*Coleoptera: Curculionidae*). *Industrial Crops Production*, 23: 162-170.
59. Kostyukovsky, M., Rafaeli, A., Gileadi, C., Demchenko, N. & Shaaya, E. (2002). Activation of octopaminergic receptors by essential oil constituents isolated from aromatic plants: possible mode of action against insect pests. *Pest Management Science*, 58: 1101-1106.

60. Kumar, R. A., Sridevi, N., Vijaya, S., Nanduri, O. & Rajagopal, S. (2004). Anticancer and immunostimulatory compounds from *Andrographis paniculata. Journal of Ethnopharmacology*, 92(2): 291-295.

61. Landolt, P. Hofstetter, R. & Buddick, L. (1999). Plant essential oils as arrestants and repellants for neonate larvae of the codling moth (*Lepidoptera: Tortricidae*). *Journal of Environmental Entomology*, 28: 954-960.

62. Lee, S., Tsao, R., Peterson, C. & Coats, J. (1997). Insecticidal activity of monoterpenoids to the western corn root worm (*Coleopters: Chrysomelidae*), two spotted spider mite (*Acari: Tetranychidae*) and housefly (*Diptera: Muscidae*). *Journal of Economic Entomology*, 90: 883-892.

63. Maddonni, G., Alfredo, G. & Otegui, M. (2016). Insect host plant relationship: the spotted stalk borer *Chilo partellus* (Swinhoe) (*Lepidoptera: Pyralidae*) and its principal host sorghum. *Insect Science Application*, 6: 315-322.

64. Marismuth, S., Gurusubramanian, G. & Krishna, S. (1997). Effect of exposure of eggs to vapours from essential oils on egg mortality, development and adult emergence in *Earias vittela* (F.) (*Lepidoptera: Nuctuidae*). *Journal of Biological, Agricultural Horticulture*, 14: 303-307.

65. Masaba, S. C. (2000). The antimalarial activity of *Vernonia amygdalina* (Del) Compositae. *Journal of Tropical Medical Hygiene*, 694-695.

66. Masotti, V., Juteau F., Bessiere, J & Viano, J. (2003). Seasonal and phenological variations of the essential oil from the narrow endemic species Artemisia molinieri and its biological activities. *Journal of Agricultural Food Chemistry*, 51: 7115-7121.

67. Misra, R. (2009). *Nutrition and well-being A to Z corn-or-maize based diets.* Retrieved from www.corn-or-maize-based-diets.html

68. Mohammed, A., Shohreh, S., Amirhossein, A., Maryann, G. & Mohammed, S. (2010). Anti-diabetic effects of aqueous fruits extract of *Diospyros lotus* L. on streptpzotocin-induced diabetic rats and the morphologic changes in the liver, kidney and heart. *Journal of Pharmacognosy*, 4: 95-100.

69. Moses, O. & Dorathy, O. (2011). Pesticidal effect of some plant materials for the control of weevils (*Callosobruchus maculatus*) in some varieties of cowpea during storage. *Academic Journal of Entomology*, 5(4): 97-99.

70. Mugo, S., Degroote, H., Bergvinson, D., Songa, J., Mulaa, M. & Gichuki, S. (2005). Developing Bt maize for resourse poor farmers. Recent advances in the IRMA project. *African Journal of Biotechnology*, 4: 1490-1504.

71. Musa, A., Oyerinde, A. & Owolabi, F. (2009). Evaluation of the efficacy of mixed leaf powders of *Vernonia amygdalina* L. and *Ocimum gratissimum* against *Callosobruchus maculatus*. *Academic Journal of Entomology*, 2(2): 85-87.

72. Negahban, M., Moharramipour, S. & Sefidkon, F. (2007). Fumigant toxicity of essential oil from *Artemisia sieberi* Besser against three stored product insects. *Journal of Stored Product Resources*, 43: 123-128.

73. Ngoh, S., Choo, L., Pang, F. Huang, Y., KIni, M. & Ho, S. (1998). Insecticidal and repellant properties of nine volatile constituents of essential oils against the American cockroach *Periplaneta americana* (L.) . *Journal of Pesticide Science*, 54: 261-268.

74. NRI (1996). Insect Pest of Nigerian crops. Identification, biology and control. Natural Resources Institute. Chatham, UK. pp. 36-48

75. Ntonifor, N.N & Mueller-Harvey, R. H. (2010). Extracts of tropical African spices active against *Plutella xylostella*. *Journal of Food Agriculture and Environment*, 8: 498-502.

76. Obhiokhenan, A. A., Usua, E. J. & Umoetuk, S. B. . (2002). Distribution of lepidopterous stemborers of maize (*Zea mays* L.) in ecological zones of Cross River State of Nigeria. *Global Journal of Agricultural Science*, 1: 89-92.

77. Obodofin, A. A., Fatoba, T. A. & Fatunsin, G. F. (2014). Insecticidal activity of the aqueous leaf extract of *Andrographis paniculata* as protectant of cowpea from *Callosobruchus maculatus* infestation. *Central European Journal of Experimental Biology.*, 3: 29-33.

78. Ofor, M. O., Ibeawuchi, A. M. (2009). Crop protection problems in production of maize and guinea corn in Northern Guinea Savanna of Nigeria and control measures. *Journal of Nature and Science*, 7(12):8-14.

79. Ogunwole, E. O. (1987). Efficacy of carbofuran against lepidopterous stemborers of maize. *Nigerian Journal of of Agronomy*, 2(2):27-32.

80. Okweche, S. I. & Umoetok, S.B. (2012). The distribution of maize stemborers in Cross River State, Nigeria. *International Journal of Plant Animal and Environmental Science*, 2(1): 82-86.

81. Okweche, S. I. (2010). Field infestation of three maize (*Zea mays* L.) genotypes by lepidopterous stemborers in Makurdi, Nigeria. *Global Journal of Agricultural Science*, 9: 41-45.

82. Okweche, S. I., Ogunwole, E. O. & Adeyemo, M. O. (2013). Parameters, interrelationships with yield and use of carbofuran to control stemborers in maize at Makurdi in the Nigerian Southern Guinea Savannah. *Greener Journal of Agricultural Sciences*, 3(10):702-708.

83. Olaniyan, E. (2015). Maize: panaceae for hunger in Nigeria. *African Journal of Plant Science*, 9 (3): 155-174.

84. Ologunde, M. O., Akinyemi, A. O., Adewusi, S. A., Afolabi, O. A., Shepard, R. L. (1992). Chemical Evaluation of exotic seed planted in the humid lowlands of West Africa. *Journal of Tropical Agriculture*, 69: 106-110.

85. Overholt, W. A., Maes, V. N & Goebel, F. R. (2001). Field guide to stemborer larvae of maize and sorghum. Nairobi, Kenya: Science press.

86. Oyedele, A. O., Orafidiya, L., Lamikanra, A. & Olaifa, J. I. (2000). Volatility and mosquito repellency of *Hemizygia welwitschii* oil and its formulations. *Journal of Insect Science and its Application*, 20:123-128.

87. Ozols, G. & Bicevskis, M. (1979). Respects for the use of *Ips tyrographus* attractant. In E. M. Shumakov, *Biologia Aktualis Veshchestva Zashiva Rastenij* (pp. 49-51).

88. Pascual, M., Slowing, K., Carretoro, E., Sanchez, D. & Villar, A. (2001). Traditional uses, chemistry and pharmacology: A review. *Journal of Ethnopharmacology*, 76:201-214.

89. Pillmoor, J. B., Wright, K. & Terry, A. S. (1993). Natural products as a source of agrochemicals and leads for chemical synthesis. *Journal of Pesticide Science*, 39:131-140.

90. Polaszek, A. (1998). *African Cereal Stemborers: Economic Importance, Taxonomy, natural Enemies and Control.* Wallingford, UK: CABI.

91. Prajapati, V., Tripathi, A. K., Aggarwal, K. K. & Khanuja, S. P. (2005). Insecticidal repellent and oviposition deterrent activity of selected essential oils against *Anopheles stephensi, Aedes aegypti* and *Culex quiquefasciatus*. *Journal of Bioresource Technology*, 96:1749-1757.

92. Price, D. N. & Berry, M. S. (2006). Comparison of effects of octopamine and insecticidal essential oils on activity in the nerve cord, foregut, and dorsal unpaired median neurons of cockroaches. *Journal of Insect Physiology*, 52: 309-319.

93. Re, L., Barocci, S., Mencarelli, A., Vivani, C., Paolucci, G.,Scarpantonio, A., Rialdi, L. & Mosca, E. (2000). Linalool modifies the nicotinic receptor-ion channel kinetics at the mouse neuromuscular junction. *Journal of Pharmacology Resources*, 42:177-181.

94. Rensburg, J. B. & Walters, M. C . (1978). The efficacy of systemic insecticides applied to the soil for the control of *Cicadulina mbila* (*Hemitera: Cicadeliidae*), the vector of maize streak disease, and the maize stalk borer, *Busseola fusca* (*Lepidoptera: Noctuidae*). *Phytophylactica*, 10: 49-52.

95. Rensburg, J. B., Walters, M. C. & Giliomee, J. H. (1989). Selective oviposition by the maize stalk borer, *Busseola fusca* (Fuller). *Journal of Entomology Society*, 52:105-108.

96. Rice, J. & Coats, J. R. (1994). Insecticidal properties of several monoterpenoids to the housefly (*Diptera: Muscidae*), red flour beetle (*Coleoptera: Tenebrionidae*) and Southern corn rootworm (*Coleoptera: Chrysomelidae*). *Journal of Economic Entomology*, 87:1172-1179.

97. Robert, W. N., Stella, C. K. & Ruth, M. (2014). Damage of stemborers species to *Zea mays*, *Sorghum bicolor* and three refugia graminae. *African Journal of food Science and Technology*, 5 (2):37-45.

98. Rouanet, G. (1992). *Maize: The Tropical Agriculturist.* London: CTA, Macmillion.

99. Seshu, K. V. & Sum, K. o. (1992). Yield infestation relationship and determination of injury level of the stemborer *Chilo partellus* (Swinhoe) in three varieties of maize, *Zea mays* L. *Maydica*, 37:371-376

100. Sithole, S. Z. (1990). Status and control of the stemborer, *Chilo partellus* (*Lepidoptera*: *Pyralidae*) in Southern Africa. *Insect Science and its Application*, 11:481-488.

101. Sukesh, K. S. (2011). Phytochemical investigation and antibacterial activity of *Gymnema sylvestri* and *Andrographis paniculata* from Western ghats. *International Journal of Pharmaceutial Medicine*, 3:254-260.

102. Umoetuk, S. A., Ukeh, J. A. & Udo, I. A. (2013). Evaluation of the insecticidal and deterrence properties of pepper fruit, *Dennetia tripetala* and Ginger, *Zingiber officinale* against maize weevil, *Sitophilus zeamais*. *Journal of Biology, Agriculture and Healthcare*, 3(6):76-82.

103. Usua, E. J. (1968). The biology and ecology of *Busseola fusca* and *Sesamia species* in South Western Nigeria: distribution and population studies. *Journal of Economic Entomology*, 61:830-833.

104. Usua, E. J. (1997). Distribution of stemborers of maize in the Eastern states of Nigeria. *Nigerian Journal of Sciece and Education*, 4:1-15.

105. Usua, E. J. (1966). *Stemborers of maize in Western Nigeria with particular reference to Busseola fusca and Sesamia species (Lepidoptera: Noctuidae).* M.Sc. thesis, University of Nigeria. 169pp.

106. Vitale, J., Boyer, T., Vaiene, R. & Sanders, J. H. (2007). The economic impact of introducing BT technology in small holder cotton production systems of West Africa: A case study from Mali.

AgBioforum, 10(2):71-81

107. Watanaba, K., Umeda. K., Kurita, Y., Takayama, C. & Miyakado, M. (1990). Two insecticidal monoterpenes telfairine and aplysiaterpernoid from the red alga, *Plocamium telfairiae*: Structure elucidation, biological activity and molecular topographical consideration by a semi-empirical molecular orbital study. *Pesticide Biochemical Physiology*, 37: 275-286.