Occurrence, Abundance and Control of the Major Insect Pests Associated with Amaranths in Ibadan, Nigeria

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Abstract

Beetworm Moth (BM), *Hymenia recurvalis* F. is a major defoliator of *Amaranthus* species causing severe yield loss. Control with synthetic insecticide is being discouraged for its adverse effects. Information on sustainable management of BM with ecologically friendly methods is scanty. Three *Amaranthus* species: *A. cruentus, A. blitum* and *A. hybridus* were evaluated for insect diversity and abundance during wet and dry seasons of two years following standard procedures. Data collected were Leaf Area Damage (LAD) (cm²); Infestation per plant (I) and Field Abundance (FA). Three neem extracts: 0.125 g Aqueous Neem Leaf (ANL) w/v; 0.125 g Aqueous Neem Bark Ash (ANBA) w/v and Aqueous Modified ANL+ANBA (AMAN) (1:1) all at 3l/25 m² were bioassayed against BM using λ-cyhalothrin at 2.5 ml/25m² and water as controls. Data collected were analysed using descriptive statistics, ANOVA at P>0.05, Shannon index (H), Simpson index (1-D) and evenness index (0.65) of diversity were high with few dominant species. The AMAN at 3l/25 m² w/v extract caused significant reduction of leaf damage (72 ± 0.05%) and field infestation (78 ± 0.06%) compared to the untreated control; but comparatively less effective by only 5% to λ-cyhalothrin; implying suitability as environmentally safe control measure.

Keywords: *Hymenia recurvalis*; *Amaranthus* species; Neem extracts; *Amapanthes hymeneae*

Introduction

*Amaranth (Amaranthus species)* is believed to have originated from Central and South America [1,2] where it has been cultivated for more than 8,000 years [3,4]. It has now become cosmopolitan, spreading to and becoming established in Africa, Asia (Nepal, India, China and Russia), parts of Eastern Europe and South America [5-7] and its now been grown by a large number of farmers over the past few decades [8].

In Africa, Nigeria is the largest producer and consumer of amaranth followed by Ghana, Benin Republic and Senegal in West Africa; Kenya, Uganda, Cameroon, Gabon, Tanzania and Ethiopia in East and Central Africa; South Africa, Zambia and Zimbabwe in Southern Africa [9-13]. Smith and Eyzaguirre [12] noted that different vegetable parts are useful for several purposes. Amaranth is one of those rare plants whose leaves are eaten as vegetables and seeds as cereal [14-16]. These are otherwise referred to as vegetable and grain amaranths, respectively.

Vegetable amaranth is cultivated and consumed in many parts of the world, with *A. cruentus, A. dubius, A. blitum* and *A. tricolor* being the documented cultivated species in East Africa. In West Africa, especially Nigeria where it is a common vegetable, the edible species include *A. cruentus, A. dubius, A. caudatus* and *A. hypochondriacus* [17]. Kamalanathan et al. [18], Oke [19], Banjo [20] stated that popularity of vegetable amaranth is due to its earliness to maturity, palatability and high nutritious value. Its protein content is well balanced in amino acids such as lysine and rich in minerals (Fe, I and Ca) and vitamins A and C [16,21,22]. Therefore, regular consumption reduces blood pressure, cholesterol levels and improves the body's antioxidant status and immunity [23].

However, one of the greatest limiting factors in increasing the productivity of amaranth is the range of insect pests with which they are associated and the level of losses suffered in unimproved and improved agriculture [20]. Akinlosotu [24] implicated insects of various orders namely; Coleoptera, Hemiptera, Lepidoptera and Orthoptera. Lepidopterous insect pests of *Amaranthus* include *Psara bipunctalis, Sylepta derogata* [25] as well as *Hymenia recurvalis, Helicoverpa armigera and Spodoptera litura* [26]. Furthermore, the publication by Tamil Nadu Agricultural University, Coimbatore, India on ‘Insect Pests of Amaranthus’ recorded that Leaf caterpillar, *Hymenia recurvalis* and *Psara basalis* are the most important pests of *Amaranthus* species.

The Beetworm Moth, *Hymenia recurvalis* Fab. (Lepidoptera: Pyralidae) causes severe losses to *Amaranthus* species. The caterpillar rolls the leaf into distinctive leaf shelter and voraciously feed on the green matter. Severe attack results in complete skeletonisation and drying up of the leaves within a short time [27,28]. This has necessitated the need to control the insect pest and other pests of *Amaranthus* species.

The management of these insect pests has been through the use of insecticides. Dales [29] noted that the use of synthetic insecticides pose health risk and result in environmental pollution. Also, Schmutzler [30] reported that the World Health Organization (WHO) had reported the poisoning of at least 3 million agricultural workers from which 20,000 deaths are recorded annually due to pesticide usage. Awasthi [31] also noted that consumers of vegetables may be at risk from pesticide residues. Thus, research has been geared towards identifying non-chemical methods of pest control, which are safe, cheap, easy to...
apply and accessible to farmers [32]. In this regard botanicals from neem have shown considerable potential [25,33].

The leaf and seed extracts of the neem tree *Azadirachta indica* A. Juss have been shown to affect over 200 insect species including some species of aphids, beetles, caterpillars, leafminers, mealybugs, scales, thrips, true bugs and whiteflies; it is also the most popular botanical pesticide against foliage feeding pests. The aqueous extract of *A. indica* bark has been shown to be as effective as a synthetic insecticide (Cymbush) in controlling foliage feeders of vegetables [25]. Meanwhile, Copping [34] has earlier reported no known incompatibilities of neem extracts with other crops protection agents. There is evidence available for the synergistic action of neem with microbial pesticides such as NPVs of tomato fruit worm [35] and common armyworm [36], and entomopathogenic fungi (*Beauveria bassiana*) against common army worm [37]. Asian Vegetable Research and Development Centre (AVRDC) has developed IPM strategies for tomato and vegetable soybean involving neem as an integral component with microbial pesticides such as *Bacillus thuringiensis* and NPVs in managing phytophagous insects [38]. Such IPM strategy would only be possible through a thorough knowledge of the pest under consideration.

Therefore, in view of the need to control the beet webworm moth, potential locked up in *A. indica* and the need to develop non-toxic, safe and effective biodegradable alternative to synthetic insecticides which could be deployed in a site specific IPM approach which in turn depends on adequate information on the pest as well as appropriate pest population estimates. Consequently, this study evaluates the biology and management of the leaf caterpillar, *H. recurvalis* (Lepidoptera: Pyralidae) on Amaranths in Ibadan, Nigeria.

Materials and Methods

The study site

This research was carried out at the valley bottom site of the Practical Year Farm Training Plot of the Faculty of Agriculture and Forestry, University of Ibadan and in the Entomology Research Laboratory of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria. Ibadan is the capital of Oyo State, Nigeria.

The study area lies approximately between longitude N07°26′850" to N07°27′087" and latitude E003°53′899" to 003°53′552" with elevation ranging from 205 m-227 m above sea level [39]. The climate of the area is divided into wet season (April-October) and dry season (November-March) with bimodal rainfall which peaks in June and September. The bimodal rainfall pattern with onset at around March/April corresponds to the period when *Hymenia recurvalis* moths were abundant due to availability of wild *Amaranthus species*, *Amaranthus spinosus* and other hosts range supported by persistent rainfall. Except where otherwise stated, all laboratories and screen houses experiments were conducted under ambient conditions of 27 ± 3°C temperature and 75 ± 3% RH.

Field survey for abundance and diversity of insects associated with *Amaranthus* spp.

The survey aimed at identifying insect pests that attack *Amaranthus* grown in two seasons in Ibadan Southwest Nigeria. In this study, three methods of insects trapping were employed, namely hand capture for wingless insects, hand net for flying insects and improvised pitfall trap for soil dwelling insects. The first set of field trials were conducted to assess the abundance and diversity of insects associated with *Amaranthus species* during the rainy season in May and June followed by dry season planting in November and December 2009. The second trial was conducted during the rainy season in May and June followed by dry seasons in November and December 2010. The site was manually cleared and the debris packed along the borders to ensure clean seed-bed for sowing. The land area 13×11.5 m² was laid out into nine blocks of 11.5 m long each, with a spacing of 0.5 m between each block of 1 m wide. Each block contained four plots each measuring 2.5×1 m² with 0.5 m spacing between plots in each block (Table 1). The plots were assigned to the amaranth varieties studied in a randomized complete block design and replicated four times. Beds were constructed manually with hoe. Seeds of each variety were sown by drilling with inter row spacing of 30 cm apart. Plant were later thinned to 25 stands per row at an average spacing of 5 cm within each row (200,000 plant stands/ha) at two weeks after sowing (WAS) as shown in Plate 1 [40]. Weeds were manually removed from the plots at two weeks after planting. Standard management practices such as manure application, regular watering and thinning were employed for the duration of the growing seasons.

However, the abundance and diversity of insect population associated with the amaranth species were estimated by quadrat sampling. The quadrat of dimension 0.5×0.5 m² was laid randomly in each plot five times between 07.00 and 09.00 hrs (local time). The number of insects species per quadrat was taken at 14 DAS and thereafter weekly till 70 DAS. The quadrat samples were taken in five replicates. This was used to determine the frequency of occurrence of insect pest on the *Amaranthus* spp being evaluated at different season, which was in turn used in computing percentage occurrence of insect pests of the *Amaranthus* spp.

All samples collected were identified by comparing their morphological characteristics with insect paratypes at the Insect Reference Collection Centre of the Department of Crop Protection and

![Plate 1: Seedlings at 2 weeks after sowing: showing period of insect infestation.](image-url)
Environmental Biology, University of Ibadan using taxonomic keys, hand lens as well as light microscope for checking fine structures. Data was analysed using analysis of variance (ANOVA) with descriptive statistics and standard diversity indices at P=0.05.

Results

Occurrence and abundance of insect diversity associated with Amaranthus species in Ibadan

The overall mean of spectral analysis of species and abundance associated with Amaranthus sp. during the wet seasons of 2009 and 2010 and dry seasons of 2009 and 2010 are as shown in Figures 1-4 respectively. The peak frequency (0.3897) during wet season was not significantly (P>0.05) higher than peak frequency (0.3114) during dry season in the two years.

Abundance and diversity of insects associated with Amaranthus sp. in the wet season

The diurnal insects associated with Amaranthus sp. in Ibadan varied significantly in the wet seasons of 2009 and 2010 as presented in Table 2 total of 37,593.2 ± 16.38 individuals in 2009 and 36,464.0 ± 15.85 in 2010 comprising adults and immature stages of different insects from 29 families and 12 orders of insects were encountered during the field assessments. The six most abundant species were *Hymenia recurvalis* 2916.8 ± 138.83 (7.76%), *Hypolixus truncatulus* 2262.7 ± 94.10 (6.02%), *Lixus truncatulus* 2088.7 ± 36.37 (5.56%), *Gastroclisus rhomboidalis* 2011.4 ± 12.03 (5.35%), *Aspavia armigera* 1733 ± 49.41 (4.61%), and *Mirperus jaculus* 1454.3 ± 44.99 (3.87%). In 2010, the populations of *H. recurvalis* 2632.1 ± 111.18 (7.22%) and *L. truncatulus* 2076.6 ± 35.74 (5.69%) were not significantly (P>0.05) different from 2009 and no significant (p>0.05) difference were recorded in the population of *H. truncatulus* 2236.8 ± 96.36 (6.13%), *A. armigera* 1741.3 ± 43.59 (4.78%), *G. rhomboidalis* 2006.3 ± 13.59 (5.50%), and *M. jaculus* 1455.4 ± 54.86 (3.99%) from that of 2009. The most abundant species encountered during the study period was *H. recurvalis* with a total of 2916.8 ± 138.83 individuals in 2009 and 2632.1 ± 111.18 individuals in 2010. This was followed by *H. truncatulus* with a total of 2262.7 ± 94.10 in 2009 and 2236.8 ± 96.36 individuals in 2010. The species were highly diversified with Simpson diversity index of 0.964 in 2009 and this was not significantly (p>0.05) different with species diversity recorded in 2010. Similarly, the index of evenness was high being 0.651 and 0.650 for 2009 and 2010 respectively as presented in Table 3.
| Species (n=10) | Order | Family | 2009 (N=52) | 2010 (N=52) |
|---------------|-------|--------|-------------|-------------|
| Tetranychus cinnabarinus | Acarina | Tetranychidae | 35.7 ± 3.38 | 36.2 ± 3.24 |
| Tetranychus urticae | Acarina | Tetranychidae | 201.9 ± 6.11 | 198.7 ± 5.45 |
| Apate monachus | Coleop. | Bostrichidae | 623.3 ± 14.06 | 618.9 ± 12.29 |
| Stenaspis v. insignis | Coleop. | Cerambycidae | 15.5 ± 1.01 | 14.5 ± 1.12 |
| Cn Gloveriis asparagi | Coleop. | Chrysomelidae | 201.9 ± 6.11 | 198.7 ± 5.45 |
| Aphididae spp. | Hemip. | Aphididae | 1089.7 ± 32.34 | 1083.3 ± 31.00 |
| Riptortus dentipes | Hemip. | Alydidae | 1168.6 ± 34.74 | 1161 ± 27.21 |
| Empoasca spp. | Hemip. | Cicadellidae | 487.8 ± 26.35 | 481.9 ± 27.21 |
| Clavigralla tomentosicollis | Hemip. | Coreidae | 1601.7 ± 9.35 | 1595.0 ± 9.05 |
| Cladoncopha unifasciata | Hemip. | Coreidae | 1528.0 ± 45.12 | 1524.5 ± 45.91 |
| Podisus aculissimus | Hemip. | Pentatomidae | 1528 ± 60.49 | 1524.5 ± 62.15 |
| Aspavia armigera | Hemip. | Pentatomidae | 1733 ± 49.41 | 1741.3 ± 43.59 |
| Nezara viridula | Hemip. | Pentatomidae | 1517.2 ± 56.05 | 1502.8 ± 56.03 |
| Philaenus spumarius | Hemip. | Cercopidae | 31.3 ± 2.03 | 30.4 ± 2.37 |
| Apanteles hymenaea | Hymeno. | Braconidae | 161.7 ± 6.87 | 160.8 ± 6.73 |
| Pogonomyrmex barbatus | Hymeno. | Formicidae | 50.8 ± 9.0 | 49.3 ± 2.45 |
| Solenopsis geminate | Hymeno. | Formicidae | 45.7 ± 42.08 | 44 ± 2.13 |
| Armitermes evuncifer | Blattodea | Termitidae | 33.8 ± 2.48 | 33 ± 2.54 |
| Spilosoma oblique | Lepidop. | Arctiidae | 324.1 ± 17.93 | 317.9 ± 19.91 |
| Psara basalis | Lepidop. | Crambidae | 790.7 ± 32.34 | 790.7 ± 33.19 |
| Phyllotis Catullus | Lepidop. | Hesperiidae | 98.1 ± 4.25 | 96.1 ± 4.21 |
| Agrotis nigrum | Lepidop. | Noctuidae | 877.2 ± 28.50 | 877.2 ± 28.50 |
| Helicoverp armigera | Lepidop. | Noctuidae | 910.5 ± 16.22 | 905.2 ± 18.39 |
| Chrysodeixis eriosoma | Lepidop. | Noctuidae | 842.3 ± 18.20 | 835.2 ± 21.20 |
| Earias biplaga | Lepidop. | Noctuidae | 1157.8 ± 39.01 | 1170.3 ± 27.37 |
| Ottheis fulonica | Lepidop. | Noctuidae | 520.1 ± 8.69 | 510.3 ± 8.29 |
| Spodoptera exempta | Lepidop. | Noctuidae | 872.5 ± 21.48 | 868.2 ± 21.59 |
| Spodoptera litura | Lepidop. | Noctuidae | 931 ± 39.03 | 605.7 ± 5.79 |
| Junonia orithya | Lepidop. | Nymphalidae | 224.8 ± 8.05 | 218.8 ± 6.45 |
| Hymenia recurvalis | Lepidop. | Pyralidae | 2916.8 ± 138.82 | 2632.1 ± 111.2 |
| Hygmenia perspectalis | Lepidop. | Pyralidae | 807.8 ± 24.38 | 803.1 ± 23.28 |
| Manucata derolate | Lepidop. | Pyralidae | 1014.3 ± 9.41 | 1005.1 ± 13.78 |
| Sylepta derogate | Lepidop. | Pyralidae | 1081.5 ± 69.75 | 763.3 ± 22.71 |
| Plutella xylostella | Lepidop. | Plutellidae | 433.6 ± 7.73 | 428.7 ± 8.44 |
| Eretmocera impactella | Lepidop. | Scythrididae | 249.7 ± 12.37 | 240.9 ± 11.11 |
| Ophiogomphus susbechta | Odonata | Gomphidae | 94 ± 29.5 | 91.9 ± 5.57 |
| Gryllotalpa similis | Orthop. | Gryllotalpidae | 10.3 ± 0.90 | 10.1 ± 8.7496 |
| Frankliniella spp. | Thysanop. | Thripidae | 722.4 ± 9.12 | 715.3 ± 11.25 |
| Total | | | 1733 ± 49.41 | 3646.4 ± 15.85 |

Table 2: Occurrence of insects associated with Amaranthus sp. during wet season in Ibadan.

Abundance and diversity of insects associated with Amaranthus sp. in the dry season

The diurnal insects associated with Amaranthus sp. in Ibadan varied significantly (P<0.05) in the dry season of 2009 and 2010 as presented in Table 3. In total, there were 26296.5 ± 15.17 individuals in 2009 and 26151.6 ± 15.26 individuals in 2010 of 59 species from 29 families and 12 orders of insects. In 2009, the six most abundant
| Species                  | Order      | Family             | 2009 (N=59)          | 2010 (N=59)          |
|-------------------------|------------|--------------------|----------------------|----------------------|
| Tetranychus cinnabarinus | Acarina    | Tetranychidae      | 30.1 ± 1.44          | 30.9 ± 0.86          |
| Tetranychus urticae     | Acarina    | Tetranychidae      | 165.2 ± 4.05         | 188.9 ± 3.28         |
| Apatel monachus         | Coleop.    | Bostrichidae       | 401.2 ± 11.71        | 408.3 ± 8.10         |
| Stenaspis v. insignis   | Coleop.    | Cerambycidae       | 11.5 ± 1.02          | 12.3 ± 0.70          |
| Cricotopus asparagi     | Coleop.    | Chrysomelidae      | 126.4 ± 4.80         | 128.2 ± 4.11         |
| D. undecimpunctata      | Coleop.    | Chrysomelidae      | 211.3 ± 10.71        | 218.7 ± 5.24         |
| Oltheis vollonica       | Coleop.    | Chrysomelidae      | 303.3 ± 8.30         | 304.4 ± 7.25         |
| Ootheca mutabilis       | Coleop.    | Chrysomelidae      | 286.1 ± 3.87         | 286.8 ± 4.31         |
| Podagrica siostedli     | Coleop.    | Chrysomelidae      | 20.6 ± 1.00          | 21.7 ± 0.54          |
| Cheilomenes vicina      | Coleop.    | Coccinellidae       | 196.8 ± 9.37         | 204.9 ± 3.13         |
| Epilachna chrysolimina  | Coleop.    | Coccinellidae       | 308.4 ± 9.09         | 309.9 ± 8.87         |
| Gastroclisus rhomboidalis | Coleop.    | Curculionidae      | 1037.7 ± 22.03       | 1046.3 ± 17.37       |
| Lagria villoso          | Coleop.    | Lagriidae          | 201.2 ± 3.87         | 205.2 ± 3.77         |
| Linomyza brassicae      | Diptera    | Agromyzidae        | 594.6 ± 11.62        | 608.4 ± 8.13         |
| Diopsis longicornis     | Diptera    | Diopsidae          | 49.1 ± 2.31          | 51.3 ± 1.71          |
| Efferia pogonias        | Diptera    | Asilidae           | 23.1 ± 1.97          | 24.4 ± 1.19          |
| Macrospilus spp.        | Hemip.     | Aphididae          | 126.4 ± 4.80         | 128.2 ± 4.11         |
| Emopasca spp.           | Hemip.     | Aphididae          | 211.3 ± 10.71        | 218.7 ± 5.24         |
| Clavigralla fomentosicollis | Hemip.  | Coreidae            | 1456.3 ± 17.77       | 1472.8 ± 16.78       |
| Cleptomorpha unifasciata | Hemip.    | Coreidae           | 117.3 ± 4.59         | 120.1 ± 4.61         |
| Cletus ochraceus        | Hemip.     | Coreidae           | 1010.9 ± 28.08       | 1027.9 ± 22.03       |
| Mirpesaurus jaculus     | Hemip.     | Coreidae           | 990.9 ± 30.40        | 1004.7 ± 23.60       |
| Lygus lineolaris        | Hemip.     | Miridae            | 54.8 ± 1.99          | 57.2 ± 1.33          |
| Podilla aculissimus     | Hemip.     | Pentatomidae       | 699.2 ± 14.88        | 712 ± 9.11           |
| Rhyncocoris bicolor     | Hemip.     | Reduvidae          | 36.9 ± 1.75          | 39 ± 0.79            |
| Myza persicae           | Hemip.     | Aphididae          | 479.3 ± 11.36        | 454.4 ± 17.24        |
| Bemisia tabaci          | Hemip.     | Aleyrodidae        | 101.4 ± 1.86         | 102.6 ± 1.93         |
| Aspavia armigera        | Hemip.     | Pentatomidae       | 1107 ± 21.92         | 1057.1 ± 20.68       |
| Nezara viridula         | Hemip.     | Pentatomidae       | 995.2 ± 14.90        | 1003 ± 13.16         |
| Dysdercus superstitiosus | Hemip.    | Pyrrhocoridae     | 11.7 ± 0.86          | 12 ± 0.88            |
| Apaneles hyemanae       | Hymено.   | Braconidae          | 141 ± 4.66           | 147.7 ± 1.31         |
| Pogonomymyrmex barbatus | Hymено.   | Formicidae         | 33.9 ± 2.11          | 35.3 ± 1.98          |
| Solenopsis geminata     | Hymено.   | Formicidae         | 29.2 ± 1.70          | 30.4 ± 1.59          |
| Vespula vulgaris        | Hymено.   | Vespidae           | 18.6 ± 1.33          | 19.8 ± 0.88          |
| Armilermes evuncifer    | Blattodea  | Termitidae          | 28.9 ± 1.22          | 30.6 ± 0.88          |
| Spilokoma oblqua        | Lepidop.   | Arctidae           | 186.3 ± 5.23         | 188.1 ± 4.94         |
| Psara basalis           | Lepidop.   | Crambidae          | 596 ± 4.64           | 600.6 ± 5.30         |
| Phthosora calusus       | Lepidop.   | Hesperidae         | 96.5 ± 2.28          | 100.7 ± 2.37         |
| Agrillis nigrum         | Lepidop.   | Noctuidae          | 575.9 ± 11.83        | 582.1 ± 9.86         |
| Helicoverp armigeria    | Lepidop.   | Noctuidae          | 794.9 ± 16.45        | 722.1 ± 17.18        |
| Chrysoedaix eriosoma    | Lepidop.   | Noctuidae          | 306 ± 13.16          | 312.2 ± 11.78        |
| Earias biplaga          | Lepidop.   | Noctuidae          | 1012.5 ± 10.08       | 1021.4 ± 11.02       |
| Oltheis vollonica       | Lepidop.   | Noctuidae          | 278.3 ± 11.84        | 282 ± 11.17          |
| Spodoptera exempta     | Lepidop.   | Noctuidae          | 496.8 ± 10.28        | 506.6 ± 10.6         |
| Spodoptera litura       | Lepidop.   | Noctuidae          | 921.4 ± 41.80        | 856.5 ± 47.44        |
| Junonia orithya         | Lepidop.   | Nymphalidae        | 197.4 ± 5.54         | 195.3 ± 2.93         |
| Hymenia recurvata      | Lepidop.   | Pyralidae          | 2311.5 ± 32.46       | 2122.4 ± 16.33       |
| Hymenia perspectalis   | Lepidop.   | Pyralidae          | 591.4 ± 12.20        | 605.4 ± 8.96         |
| Maruca vitrata         | Lepidop.   | Pyralidae          | 679.8 ± 15.37        | 687.4 ± 13.34        |
| Sylepta derogata        | Lepidop.   | Pyralidae          | 1071.1 ± 63.51       | 1029.8 ± 53.00       |
| Plutella xylostella     | Lepidop.   | Plutellidae        | 292.9 ± 10.37        | 297 ± 11.15          |
| Eretmocera implicata    | Lepidop.   | Scythrididae       | 160.7 ± 3.89         | 166 ± 1.71           |
| Ophiogomphus susbechha  | Odonata    | Gomphidae          | 79 ± 1.28            | 80.1 ± 0.95          |
| Gryllotalpa similis    | Orthop.    | Gryllotalpidae   | 11.4 ± 0.50          | 11.9 ± 0.43          |
| Zonocerus variegatus    | Orthop.    | Pyrgomorphidae    | 27.5 ± 1.014         | 28.4 ± 0.97          |
| Frankliniella spp.      | Thysano.   | Thripidae          | 531.5 ± 10.88        | 535.8 ± 1.00         |
| Total                   |            |                    | 26296 ± 15.17        | 26151.6 ± 15.26      |

Table 3: Occurrence of insects associated with Amaranthus sp. during dry season in Ibadan.
species were *Hymenia recurvalis* 2311.5 ± 32.46 (8.79%), *Clavigralla tomentosicollis* 1456.3 ± 17.77 (5.54%), *Lixus truncatulus* 1142.3 ± 25.58 (4.34%), *Hypolixus truncatulus* 1135.9 ± 31.72 (4.32%), *Aspavia armigera* 1107 ± 21.92 (4.21%) and *Sylepta derogata* 1071.1 ± 63.51 (4.07%). In 2010, there were significant (P>0.05) increases in the populations of *C. tomentosicollis* 1472.8 ± 16.78 (5.63%), *L. truncatulus* 1153.1 ± 26.01 (4.41%), *H. truncatulus* 1171 ± 25.42 (4.48%). Also, in 2010, there was a significant decrease (p<0.05) in the populations of *H. recurvalis* 2122.4 ± 16.33 (8.12%) and *S. derogata* 1029.8 ± 53.00 (3.94%) while no significant (P>0.05) difference was recorded in the population of *A. armigera* 1057.1 ± 20.68 (4.04%). However, the most abundant species encountered during the study period in dry season was *H. recurvalis* with a total of 2311.5 ± 32.46 and 2122.4 ± 16.33 individuals in 2009 and 2010 respectively. This was followed by *H. truncatulus* with a total of 1135.9 ± 31.72 and 1171 ± 25.42 individuals in 2009 and 2010 respectively. Similarly, the trend of species diversity of insect associated with *Amaranthus* species in the dry season follow the pattern of wet season except that the number of species increases from 52 to 59 which include: *Liriomyza brassicae*, *Diopsis longicornis*, *Myzus persicae*, *Bemisia tabaci*, *Dysdercus superstitiosus* and *Vespula vulgaris*.

Plate 2 above showed adult stage, newly laid eggs (in batch) and 3rd larva instar of the *H. recurvalis*.

The summary of species diversity obtained from PAST software [41] revealed that the species were highly diversified with Simpson diversity index of 0.964 in both 2009 and 2010. Likewise, the index of evenness was high being 0.651 and 0.650 for 2009 and 2010 respectively as presented in Table 4.

**Table 4: Summary of the diversity of insects associated with *Amaranthus* species in wet-season in Ibadan, Southwest Nigeria.**

| Diversity indices | 2009  | 2010  | Remarks                                      |
|-------------------|-------|-------|----------------------------------------------|
| Taxa_S            | 52a   | 52a   | Insect species in the study area             |
| Individuals       | 37593.2a | 36464b | Total number of insects in the study area    |
| Dominance         | 0.03602a | 0.036a  | No species dominate the ecosystem in both year |
| Simpson Index     | 0.964a | 0.964a | Species are evenly distributed in the study site |
| Shannon Index     | 3.522a | 3.521a | Species diversity is high in both year       |
| Evenness_e^H/S    | 0.6509a | 0.6504a | Even distribution within each family in both years |
| Brillouin         | 3.517a | 3.516a | Species diversity is high in both year       |
| Menhinick         | 0.2682a | 0.2723a | Species richness/plot is low                 |
| Margalef          | 4.81b  | 4.855b | Overall species richness is moderate         |
| Equitability_J    | 0.8913a | 0.8911a | Even distribution within each family in both years |
| Fisher_alpha      | 5.941b  | 5.964a  | Species diversity is high in both year       |
| Berger-Parker     | 0.07759a | 0.07218a | No species dominate the ecosystem in both year |

**Comparative efficacy of selected botanical extracts against field infestation of *H. recurvalis* on *Amaranthus* spp.**

Generally, the neem leaf had better values of % N and P than neem bark ash (NBA). Neem bark as extract had higher values of % K, Ca and Mg than neem leaf. The *λ*-Cyhalothrin 2.5EC did not have any insecticidal properties of neem leaf extract are Azadirachtin and calcium carbonate in neem bark extract respectively while that in *λ*-Cyhalothrin 2.5EC is *Lambdacyhalothrin*.

Effect of insect infestation on the susceptible amaranthus plant under different control treatment solutions is as presented in Table 6. There were significant decreases (P<0.05) in the *Hymenia recurvalis* population per plant and number of damaged leaves per plant under the neem leaf, wood ash, modified neem leaf extracts and *λ*-Cyhalothrin compared to the control treatment. Modified neem...
leaf extracts decreased the insect population and number of damaged leaves per plant in amaranthus by 30% and 41% respectively compared to the neem leaf extract. λ-Cyhalothrin also decreased significantly the number of damaged leaves per plant by 37% compared to the neem leaf extract. Among the treatment extracts, modified neem leaf extract had the best values of amaranthus leaf yield followed by λ-Cyhalothrin while the neem bark ash and neem leaf extract did not differ significantly in amaranthus yield.

Discussion

Insect pest infestations are perhaps the most important constraint to production of amaranths in Nigeria and one of the primary causes of low quality and yields. From the result of the survey conducted, it

| Diversity indices | 2009        | 2010        | Remarks |
|-------------------|-------------|-------------|---------|
| Taxa_S            | 59a         | 59a         | Insect species in the study area |
| Individuals       | 26296.5b    | 28060.6a    | Total number of insects in the study area |
| Dominance_D       | 0.03474a    | 0.04432a    | No species dominate the ecosystem in both year |
| Simpson Index     | 0.9653a     | 0.9575a     | Species are evenly distributed in the study site |
| Shannon Index     | 3.591a      | 3.509a      | Species diversity is high in both year |
| Evenness_e^H/S    | 0.6149a     | 0.5663b     | Even distribution within each family in both years |
| Brillouin         | 3.583a      | 3.502b      | Species diversity is high in both year |
| Menhinick         | 0.3638a     | 0.3522b     | Species richness/plot is low |
| Margalef          | 5.699a      | 5.663b      | Overall species richness is moderate |
| Equitability_J    | 0.8807a     | 0.8609b     | Even distribution within each family in both years |
| Fisher_alpha      | 7.191a      | 7.127b      | Species diversity is high in both year |
| Berger-Parker     | 0.0879b     | 0.1437a     | No species dominate the ecosystem in both year |

Table 5: Summary of the diversity indices of the insects associated with Amaranthus species in Dry-Season in Ibadan, Southwest Nigeria.

| Treatments          | Weight of amaranthus leaves (t/ha) |
|---------------------|-----------------------------------|
| Control             | 10.028d                           |
| Neem leaf extract   | 18.680c                           |
| Wood ash extract    | 19.880c                           |
| Modified neem leaf extract | 21.880a                       |
| Karate 720EC        | 20.480b                           |

Means followed by the same letters are not significantly different from each other using Duncan Multiple Range Test (DMRT) at 5% level.

Table 7: Effect of insect infestation on the susceptible amaranthus plant under different pest control treatments.
was established that species diversity and abundance of insect pests associated with *Amaranthus species* in Ibadan varied from season to season in the study site, but *Hymenia recurvalis*, beetworm moth was the most abundant Lepidoptera pest, while *Hypolius truncatus* was the most abundant coleoptera pest causing considerable damage to the crop. This was not in support of earlier study by Akínlosotú [24] that reported *Sylepta derogata* and *Gastroclis rhomboidalis* as the major pest of *Amaranthus cruentus* in Nigeria. This alteration in pest incidence and abundance may be due to rivalry for food and space between insect's pests of different species on *Amaranthus* leaf in the field. Also, there had been changes in climatic factors, like temperature and humidity overtime. As regards *G. rhomboidalis*, the ranking of *Amaranthus* leaf as the desired product, rather, the indirect damage caused by *G. rhomboidalis* on *Amaranthus* stem. This assertion was supported by Rüsinks and Kogan [42] as quoted by Banjo [20], who referred to *G. rhomboidalis* as an indirect pest of *Amaranthus*, damaging parts that may not affect yield. However, increase in temperature overtime might be a reason why moths (especially *H. recurvalis*) were able to uphold their status as a major pest of *Amaranthus*. Even though, the influence of these climatic factors were not studied in this work, earlier report by Shirai [43] showed that *H. recurvalis* are ectotherms and the adult fly and survive longest at temperature range between 17°C and 23°C on honey-based diets. This suggested that adaptability of *H. recurvalis* to a wide range of temperature and relative humidity was high within different locations and could migrate from cooler regions, especially during winter, to regions with relatively higher temperature.

Other Lepidoptera pest of economic importance encountered were *Erias biphaga*, *Sylepta derogata*, *Psara basalis*, *Maruca vitrata*, *Spodoptera sp.*., *Helioverpa armigera*, *Agrotis nigrum*, *Chrysodeixis eriosoma* and *Otheis fullonica* which were observed at varying levels on all the *Amaranthus* accessions being assessed. This implies that any of these lepidotera pests have potentials of becoming the major insect pest of *Amaranthus* in Nigeria as they could out-compete *H. recurvalis* if not well-managed and this was corroborated by Ebert et al. [26], who listed *Spodoptera litura*, *H. armigera* and *Psara basalis* as important but often ignored Lepidoptera pests of *Amaranthus*. This is also in consonance with earlier study reported by Silesli et al. [44], Cherian and Brahmacari [45], Thompson and Simmonds [46] (listed in prey-host record) that *Sylepta derogata*, *H. armigera* and *Psara basalis* respectively under favorable conditions can exceed *H. recurvalis* in competition for food and space especially on a laboratory diet. This study showed that an array of insect pests’ complex infests *Amaranthus* leaves on the field at ambient temperature and relative humidity in association with one another in a competitive manner. This trend of insect species confirms the presence of the insect species previously reported as pests of amaranth [47,48] and this requires multifaceted and integrated management approach.

Three neem extracts: 0.125 g Aqueous Neem Leaf (ANL) w/v; 0.125 g Aqueous Neem Bark Ash (ANBA) w/v and Aqueous Modified ANL+ANBA (AMAN) (1:1) all at 31/25 m2 were bioassayed as ecologically friendly field protectant against BM using λ-cyhalothrin only 5% to λ-cyhalothrin; implying suitability as environmentally safe compared to the untreated control; but comparatively less effective by association with one another in a competitive manner. This trend of insect species confirms the presence of the insect species previously reported as pests of amaranth [47,48] and this requires multifaceted and integrated management approach.

Conclusion

This study revealed that there are significant differences (p ≤ 0.05) in the seasonal abundance and diversity of insect pests of amaranth in Ibadan Southwest Nigeria. Loss of foliage was highly dependent on the infesting insect pest especially defoliators.

Sixty insect species associated with amaranth crop were determined; of these, the species with the major presence level on the foliage were *H. recurvalis* and *Sylepta derogata* with 8.8% and 4.1% of occurrence, respectively. The borers group, curculionids, caused infestations of 12.6%, while the white grubs group infests 7.3% of the plants. The most voracious and damaging stage of *H. recurvalis* is the third instar larva which prefers tender leaf. Hence, availability of amaranths is very peculiar and germane to the seasonal abundance and population dynamic of *H. recurvalis* on the field.

There was considerable variation in the effectiveness of the extracts at the minimum inhibitory concentration of the neem and ash extracts used in the control of *H. recurvalis*. Modified neem extracts at 1200 l/ha was the most effective among the screened neem and ash extracts and has synergistic effect in the control of *H. recurvalis*. Beetworm Moth was the most important defoliator of *Amaranthus species*. The resistant donor cultivar *Amaranthus hybridus* along with aqueous modified neem leaf with bark ash extracts could be used in integrated management of the insect pest. Therefore, it is recommended as environmental safe alternative, practicable, available and sustainable form of control compared to synthetic pesticides.

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