Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 18 Number 2 (May 2019) pp. 8-14
ISSN 1119-7455

DIVERSITY AND ABUNDANCE OF DIURNAL INSECTS ASSOCIATED WITH DRY SEASON *Amaranthus hybridus* L. IN THE UNIVERSITY OF ILORIN, NIGERIA

Ojumoola A.O., Raimi K.M. and Adesiyun A.A.

Department of Crop Protection, University of Ilorin, Ilorin, Nigeria

Corresponding author's email: ojumoolaolusegun@gmail.com

ABSTRACT
Amaranthus hybridus L. is an important leafy vegetable in sub Saharan Africa whose production is mainly limited by field insect pests. Integrated Pest Management (IPM) offers a sustainable approach for the management of these pests because it ensures effective insect pest control while also promoting the conservation of beneficial insect species in agro-ecosystems. Consequently, this study investigated the diversity and abundance of diurnal insects of dry season A. hybridus at the University of Ilorin to provide information for successful IPM programs in A. hybridus systems. Insect sampling from irrigated A. hybridus beds was done for 8 consecutive weeks from the second week after sowing. At each week, sampling was done in the morning (7:00 – 10:00A.M.), early afternoon (12:00 – 3:00P.M.) and late afternoon (4:00 – 7:00P.M.) with sweep net, aspirator and by handpicking. Seventy-eight insect specimens consisting of 24 species, 16 families, and 5 orders were collected. Herbivores in the family Acrididae, Alydidae, Chrysomelidae, and Pyrgomorphidae made up 78.3% of morning collections. Insect predators like Oecophylla sp. and Dorylus sp. in the family Formicidaewere most abundant in the early afternoon. Parasitoids in family Sphecidae and leaf feeders like Acridabicolor (Acrididae) made up 53.48% and 32.56% respectively of the total late afternoon collections. According to Shannon's and Simpson's diversity t- tests, insect taxa in the late afternoon were significantly (P < 0.05) less diverse than in the morning or early afternoon. In contrast, species richness in the morning and early afternoon did not differ significantly at P = 0.05.

Key words: *Amaranthus hybridus*, IPM, predators, parasitoids, biodiversity

INTRODUCTION
Amaranthus species or Amaranths are dicotyledonous annual plants belonging to the family Amaranthaceae (Maundu, 2004). They are relatively drought tolerant crops and may be cultivated in the dry season with less than 300 mm of water needed (Olufolaji *et al.,* 2010; Ribeiro *et al.,* 2017).They are widely cultivated and consumed in several African countries (Aderolu *et al.,* 2013) due to their early maturity, high nutritive values (Banjo, 2007) and ease of cultivation especially during the dry season. Both the leaves and seeds of amaranths may be consumed as vegetable amaranth and grain amaranth respectively (Saunders and Becker, 1984; Aderolu *et al.,* 2013). The smooth amaranth or smooth pigweed, *Amaranthus hybridus* L., is an important species of amaranths whose leaves serve as a rich source of dietary vitamins including Vitamins A, B1, B2, B3, C and E (Akubugwo *et al.,* 2007). In Nigeria and some other parts of Africa, the leaves are mixed with condiments and prepared as soup or consumed as green vegetables (Oke, 1983; Dhellot *et al.,* 2006; Akubugwo *et al.,* 2007). The interaction of insect species with crop plants is known to hold a number of negative economic consequences like crop damage, yield reduction or losses (Oerke, 2006; Oliveira *et al.,* 2014) as well as positive ecological outcomes such as pest management and crop pollination by insect parasitoids and pollinators respectively (Losey and Vaughan, 2006; Michener, 2007; Frund *et al.,* 2010). Since both pestiferous and beneficial insects interact with crops in agroecosystems, it has become mandatory to employ pest management approaches that rely on reduced pesticide use and conservation of natural enemy guilds for more sustainable agricultural production systems (Altieri and Nicholls, 2004; Étilé, 2012). Integrated Pest Management (IPM) is a sustainable approach that provides an alternative to the sole use of pesticides for pest management. IPM aims to promote sustainability in agriculture by employing pest management options that reduce crop losses and increase productivity without the negative environmental and health impacts associated with exclusive pesticide application (Van Huis and Meerman, 1997; Ojumoola *et al.,* 2016; Alalade *et*

Please cite as: Ojumoola A.O., Raimi K.M. and Adesiyun A.A. (2019). Diversity and abundance of diurnal insects associated with dry season *Amaranthus hybridus* L. in the University of Ilorin, Nigeria. Agro-*Science,* **18 (2),** 8–14. **DOI:** https://dx.doi.org/10.4314/as.v18i2.2

al., 2017). Amongst other requirements, good understanding of the diversity and role of insects within cropping systems will be needed for a successful IPM programme (Nwilene *et al.,* 2008). In other words, growers will be in a better position to make informed pest management decisions if they knew the identity and the beneficial or non-beneficial status of the insects they find on their crops. This study was thus carried out to investigate the diversity and abundance of diurnal insect species associated with dry season *A. hybridus* in the University of Ilorin, Nigeria.

MATERIALS AND METHODS

Study Site

The study was conducted on the Farm Practical Training (FPT) plots of the Faculty of Agriculture, University of Ilorin (8°29'20.9'' N and 4°33'11.1'' E) in the late dry season from February to April, 2017. The study site has been characterized under the southern guinea savanna agro-ecological zone of Nigeria (Olanrewaju, 2009). The dry season in the zone lasts for about 6-7 months, i.e., from October/November to March/April while the remaining months is usually wet and termed the rainy season (Ayanlade, 2009).

Field Cultivation of Amaranthushybridus

One hundred and fifty (150) beds were made with African hoes on a land area of approximately 1,421 m^2 (42.3 m x 33.6 m). Each bed had a dimension of 4.5 m x 1.5 m with a spacing of 0.5 m between beds. Beds were incorporated with dried poultry manure and after a week, seeds of *A. hybridus* were sown in drills made along the length of each bed (to a depth of about 1 cm) with an inter-row spacing of 30 cm. At one week after sowing, plants were thinned to 45 stands per row with a within row spacing of 10 cm giving approximately 225 plants per bed. Other standard practices for amaranth cultivation such as regular weeding and irrigation of beds were carried out throughout the study. The only other crop planted within the study site boundary was water melon, (*Citrullus lanatus* Thumb). It was also planted on irrigated beds at a distance of not less than 50 metres from the *A. hybridus* beds. Other plant species outside the study site boundary were a variety of weeds and shrubs common in the southern guinea savanna agro-ecological zone of Nigeria.

Insect Sampling, Preservation and Identification Procedures

Insects were sampled weekly from 15 randomly selected beds over a period of 8 consecutive weeks i.e. from the second week after sowing (2 WAS) to the ninth week after sowing (9 WAS). At seedling stage, sampling was carried out mainly with an insect aspirator and by hand picking. As plants matured and rows became closely packed, a standard sweep net was used with aspirator and hand picking used only when necessary. In addition, sampling was done 3 times a week i.e. morning (7:00 – 10:00 A.M.), early afternoon (12:00– 3:00P.M.) and late afternoon (4:00 – 7:00 P.M.). Each time of sampling was randomly allocated to a fixed day of the week. Consequently, in this study, sampling was done in the morning on Thursdays, in the early afternoon on Fridays and in the late afternoon on Sundays. Adult insects caught were immediately killed using a killing jar containing cotton wool soaked with ethyl acetate. However, attempts were made at rearing the few insect larvae collected by hand to adult for proper identification. All insect specimens collected from the field were taken to the laboratory, sorted and, where appropriate, preserved in labeled plastics (300 mL capacity) containing 10 mL of 75% ethanol. After the 8^{th} week of insect sampling, preserved adult specimens were taken for identification and taxonomic classification at the Insect Reference Collection Center, Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria.

Statistical Analysis

The diversity indices of insect taxa associated with *A. hybridus* during the day were determined using the Paleontological Statistics (PAST) software version 3.18 (Hammer *et al.,* 2001). The species richness or number of taxa (S) and the abundance of individuals (N) for each time of collection was calculated. Other diversity indices calculated include Simpson's index, Shannon's diversity index and Pielou's species evenness index. Simpson's index or Dominance (D) ranges from 0, where all taxa are equally distributed, to 1 where only one taxon dominates the community completely. It is given by $D = \Sigma\ (n_i/N)^2$ where n_i is the number of individuals of taxon *i*. Shannon's diversity index (H) varies from 0 for communities with only a taxon to high values for communities with many taxa each with few individuals. It is given by $H = -\Sigma[n_i/N \times \ln(n_i/N)]$. Pielou's species evenness index (J) is Shannon's diversity index (H) multiplied by the reciprocal of the natural logarithm of species richness or number of taxa (S) i.e. $J = H/\ln S$. It also ranges from 0 (no species evenness) to 1 (complete species evenness). Two diversity t-tests namely Shannon's t-test (Hutcheson, 1970) and Simpson's t-tests (Brower *et al.,* 1998) were used to compare the diversity of insect taxa collected at different times of the day.

RESULTS

The diversity and abundance of diurnal insects associated with dry season *A. hybridus* in the University of Ilorin, Nigeria is presented in Table 1. A total of 78 insect specimens belonging to 5 insect orders and 16 insect families were collected during the day over a period of 8 weeks from *A. hybridus* plants cultivated on irrigated beds. The order Hymenoptera had the highest percentage relative abundance (38.46%) of the total insect specimens collected. It was followed by the order Orthoptera with 28.20% of the total. The order Diptera was the least represented with only 3.85% of the total insect specimens collected. The orders Coleoptera and Hemiptera had intermediate percentage relative abundance values of 17.95% and 11.54% respectively. Insect species belonging to the wasp family Sphecidae (Hymenoptera) and grasshopper family Acrididae (Orthoptera) were the most represented with a percentage relative abundance of 29.49% and 23.07% respectively. Intermediate numbers of insect species in the family Formicidae: Hymenoptera (7.68%), Alydidae: Hemiptera (6.41%), Chrysomelidae: Coleoptera (6.41%) and Pyrgomorphidae: Orthoptera (5.13%) was also recorded.

Furthermore, insects traditionally known to play pestiferous roles in cropping systems constituted 55.11% of the total specimens collected and include those in the Bostrichidae (auger beetles), Chrysomelidae (leaf beetles), Scarabaeidae (scarab beetles), Tenebroinidae (darkling beetles), Acrididae (short-horned grasshoppers), Pyrgomorphidae (gaudy grasshoppers), Plataspidae (shield bugs), Alydidae (seed feeders), Lygaeidae (seed bugs) and Cercopidae (xylem feeders) families. On the other hand, beneficial insects made up 44.85% of the total specimens. They include predators in the Coccinellidae (lady beetles), Asilidae (robber flies) and Formicidae (ants) families as well aswasp parasitoids in the Sphecidae and Vespidae families. In addition, hoverflies (Syrphidae) whose larvae and adults are known mostly as excellent predators and pollinators respectively were collected.Shannon's diversity index value was 2.219 reflecting a high occurrence of insect taxa associated with *A. hybridus*. In addition, Pielou's evenness index was computed as 0.8002 showing a high spread of species in the study area. Simpson's Dominance index value (0.1624) showed that no single taxa dominated the community instead all taxa were almost evenly distributed. Figures 1 to 4 show the abundance and distribution of insect taxa according to the time of collection. A total number of 22 insect species in 7 insect families were collected in the morning. These accounted for only 28.2% of total insect specimens collected in the study and were distributed amongst the five insect orders collected. Majority (90.90%) of the insect species were herbivores while predators (family Asilidae) and parasitoids (family Vespidae) accounted for just 4.5% each of total morning collections. In the early afternoon, 13 insect species belonging to 7 insect families were collected. These were however limited to just 3 insect orders namely Coleoptera, Diptera and Hemiptera. Higher numbers of insect species (53.8%) in traditionally beneficial insect families such as Coccinellidae, Formicidae and Syrphidae were collected in the early afternoon than in the morning. The highest number (43) of insect specimens were collected in the late afternoon accounting for 55.1% of total diurnal collection and representing five insect families and four insect orders. Shannon's diversity index values of insect taxa associated with *A. hybridus* increased slightly from 1.8193in the morning to 1.8849 in the early afternoon and thereafter decreased to 1.1160 in the late afternoon (Table 2). Species evenness in the morning (0.9349) and early afternoon(0.9687) was observed to be close to unity and thus very high according to Pielou's evenness index (Table 2). In contrast, species evenness in the late afternoon (0.6934) was at a moderate level. Simpson's Dominance index (D) value was highest (0.3997) in the late afternoon than at any other time of the day reflecting the tendency of the family Sphecidae and family Acrididae to dominate the community. The relatively lower index values of (D) in the morning and early afternoon suggest that all taxa were almost equally distributed at both periods. According to Shannon's and Simpson's diversity t-tests (Table 2), there was a significant difference ($P<0.05$) in the diversity of insect taxa associated with *A. hybridus* in the morning and late afternoon. Similarly, a significant difference ($P<0.05$) was observed in the diversity of insect taxa associated with *A. hybridus* in the early afternoon and late afternoon. However, no significant difference ($P > 0.05$) was observed in the diversity of insect taxa associated with green amaranths in the morning and early afternoon according to both diversity t-tests.

DISCUSSION

Insect species belonging to different taxonomic groups were found associating with *A. hybridus* during the day in this study. The vegetative parts of *A. hybridus* are known to be rich reservoirs of nutrients that are often targeted by leaf feeders, seed feeders and sap feeding insect herbivores (DAFF, 2010). It therefore holds no surprise that more diurnal insect pests were found associating with the crop than traditionally beneficial insects during the study. Several insect pests which inadvertently cause varying degrees of damage and yield losses have been reported on *A. hybridus* (DAFF, 2010; Ebert *et al.,* 2011; Aderolu *et al.,* 2013). On the other hand, parasitoids and predators are natural regulators of insect pest populations and are thus considered as beneficial organisms in cropping systems (Waage, 2007). The high numbers of wasp parasitoids as well as the presence of hymenoptera and coleopteran predators in the present study provide evidence on the availability of natural enemy guilds for the biological control of insect pests in *A. hybridus* cropping systems. It is common knowledge that the presence of insect herbivores within a given cropping system often leads to the immigration of natural enemies – mainly insect parasitoids and insect predators. It should however be noted that attraction of natural enemies to agroecosystems is not limited to the availability of insect preys within such systems. Several authors including Wäckers *et al.* (2008), Lundgren *et al.* (2009) and Étilé (2012) have reported that many predators and parasitoids consume non-prey vegetable materials like pollen, floral nectar, seeds and sap as secondary food sources. Other requirements such as shelter and oviposition sites could also attract natural enemies to agricultural systems.

Table 1: Diversity and abundance of diurnal insects associated with dry season *Amaranthushybridus* in the University of Ilorin, Nigeria

S/N	Insect order	Insect family	Insect species	Number of specimen collected	Percentage relative abundance
1	Coleoptera	Bostrichidae	Heterobostrychussp.	2	2.56
2		Coccinellidae	Exochomussp.	2	2.56
3		Chrysomelidae	Lemasp.	4	5.13
4		Chrysomelidae	Criocerissp.	1	1.28
5		Scarabaeidae	-	2	2.56
6		Tenebroinidae	-	3	3.85
7	Diptera	Asilidae	-	1	1.28
8		Syrphidae	-	2	2.56
9	Hemiptera	Plataspidae	Coptosomasp.	1	1.28
10		Alydidae	-	5	6.41
11		Lygaeidae	Aspilocoryphussp.	2	2.56
12		Cercopidae	Locrissp.	1	1.28
13	Hymenoptera	Formicidae	-	2	2.56
14		Formicidae	Oecophyllasp.	1	1.28
15		Formicidae	Dorylussp.	2	2.56
16		Formicidae	Crematogastersp.	1	1.28
17		Sphecidae	-	23	29.49
18		Vespidae	-	1	1.28
19	Orthoptera	Acrididae	Acridabicolor	2	2.56
20		Acrididae	Acrotylussp.	1	1.28
21		Acrididae	-	13	16.67
22		Acrididae	Trilophidiasp.	1	1.28
23		Acrididae	-	1	1.28
24		Pyrgomorphidae	Zonocerusvariegatus	4	5.13
		Abundance (N)		78	
		Number of taxa (S)		16	
		Shannon's diversity index (H)		2.2190	
		Pielou's evenness index (J)		0.8002	
		Simpson's Dominance (D)		0.1624	

- Some insect specimens could not be identified to species level. Diversity indices were thus computed with sixteen insect families

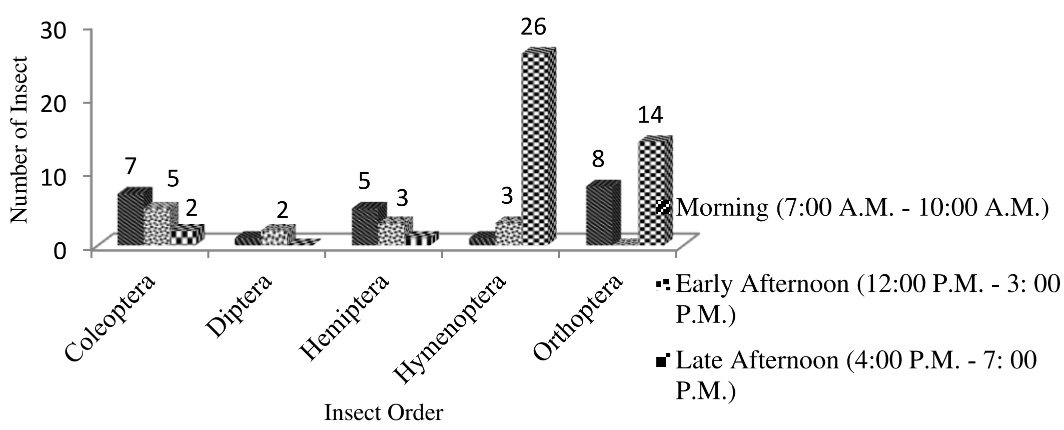

Figure 1: Abundance and distribution of insect orders according to the time of collection

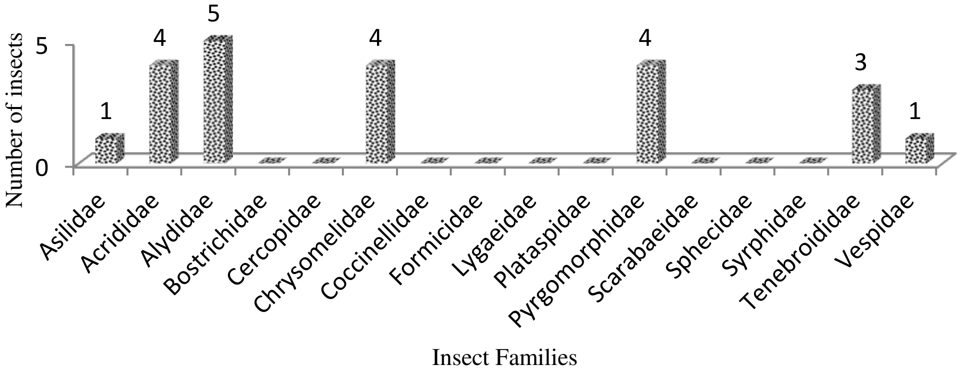

Figure 2: Abundance and distribution of insect taxa collected in the morning between 7:00 A.M. and 10:00 A.M. on *A. hybridus*

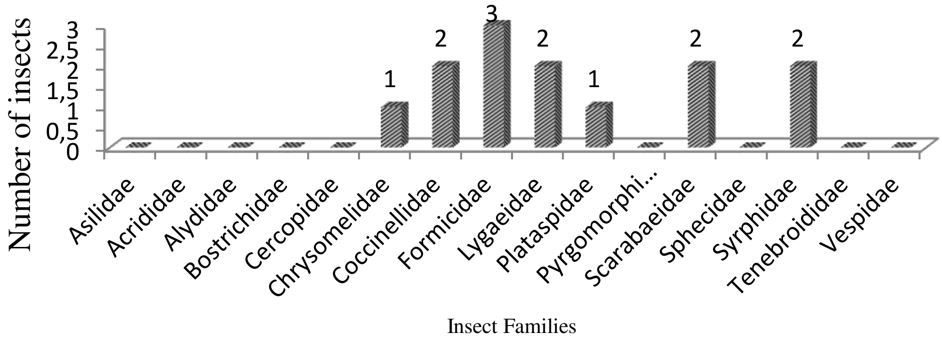

Figure 3: Abundance and distribution of insect taxa collected in the early afternoon between 12:00 P.M. and 3:00 P.M. on *A. hybridus*

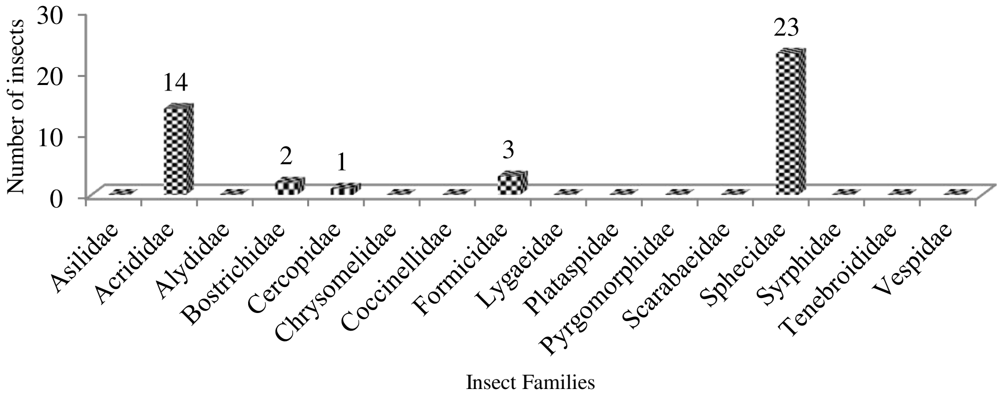

Figure 4: Abundance and distribution of insect taxa collected in the late afternoon between 4:00 P.M. and 7:00 P.M. on A. hybridus

Behaviors such as locomotion, feeding, mating and egg-laying are known to occur only at certain fixed times of the day in most insects (Moore *et al.,* 1989). Thus, the relatively lower diversity of insect taxa as observed during this study in the late afternoon might be due to the 'winding down' of activities amongst diurnal insects at that time of the day with most of them already seeking safe shelter for the night. The quality and quantity of crop yields in agricultural systems is usually influenced by insect pollinators especially bee (Hymenoptera: Apoideae) and syrphid fly (Diptera: Syrphidae) species (Klein *et al.,* 2007; Saunders, 2018).

Table 2: Abundance and diversity of diurnal insects associated with *A. hybridus*at different periods of the day

Time of collection	Abundance (N)	Species richness (S)	Shannon's diversity index (H)	Pielou's evenness index (J)	Simpson's Dominance (D)
Morning 7:00A.M.– 10:00 A.M.)	22	7	1.8193[a]	0.9349	0.1736[a]
Early afternoon (12:00P.M. – 3:00 P.M.)	13	7	1.8849[a]	0.9687	0.1598[a]
Late afternoon (4:00P.M.– 7:00 P.M.)	43	5	1.1160[b]	0.6934	0.3997[b]

Values of H' and D followed by different letters are significantly different (P<0.05) according to diversity t-test

In this study, no bees were found on *A. hybridus* and only a few syrphid fly specimens were collected over the entire period of insect sampling. Both groups of insects, as a matter of necessity, visit flowers for nectar and pollen with the latter being a more critical food resource for both species (Saunders, 2018). In addition, they do not restrict themselves to entomophilous plants and may be found visiting anemophilous plants (Saunders, 2018) like A. *hybridus* that produce lots of pollens (CABI, 2018) but no nectar (Anonymous, 2018). Insects, including bees, would however prefer to pollinate plants rich in nectar (Haaland *et al.,* 2011) and pollen than on those which give only pollen rewards. The absence of bee and butterfly species amongst insects collected on A. *hybridus*in the present study maybe due to the availability and proximity of such entomophilous nectar-pollen rich plant species like *C. lanatus* (Delaplane and Mayer, 2000). In contrast, the few syrphid flies pollinators found associating with the crop in this study may have been attracted by herbivorous insect pests on which their predaceous larvae could feed after hatching rather than by the possibility of pollen rewards (Inouye, 2012). According to Aderolu *et al.* (2013) and Ezeh *et al.* (2015) the beet webworm moth, *Hymenia recurvalis*, is the most abundant lepidopteran pest on amaranth in Ibadan and Benin respectively. Other lepidopteran insect pests reported on amaranths include *Psarabipunctalis, Sylepta derogate*, *Helicoverpaarmigera* and *Spodopteralitura (Okunlola et al., 2008; Ebert et al., 2011).*No adult lepidopetran insect pests were however recorded on *A. hybridus*in this study though a couple of lepidopteran larvae were collected but failed to develop into adults. Both Ibadan and Benin have bimodal rainfall patterns and are located in the derived guinea savanna and rainforest agro-ecological zones of Nigeria respectively (Aderolu *et al.*, 2013; Ezeh *et al.*, 2015). The difference in the study area's agro-ecology and the dry season during which the study was conducted may be responsible for the absence of these economically important lepidopteran insect pests on *A. hybridus*.

CONCLUSION

A diverse species of insect pests and beneficial insects were found associating with *A. hybridus* at different times of the day during the study. Diversity of insect species was observed to increase from morning to early afternoon with a decline in the late afternoon time. Information provided in this study may be used by agricultural extension officers and entomologists to educate farmers on the ecosystem services of beneficial insects especially as it relates to sustainable pest management in *A. hybridus* cropping systems.

REFERENCES

Aderolu A.I., Omoloye A.A. and Okelana, A.F. (2013). Occurrence, abundance and control of the major insect pests associated with amaranth in Ibadan,Nigeria. *Ento.Ornit., and Herp.,***2**, 97-112. Doi:10.4172/2161-0983.1000112.

Akubugwo, I.E., Obasi, N.A., Chinyere G.C. and Ugbogu, A.E. (2007).Academic journals on nutritional and chemical value of *Amaranthushybridus*L. leaves from Afikpo, Nigeria. *Afr. J. Biotech.*,**6 (24),** 2833-2839.

Alalade O.A., Matanmi B.M., Olaoye I.J., Adegoke B.J. and Olaitan T.R. (2017). Assessment of pests control methods and its perceived effect on agricultural production among farmers in Kwara State, Nigeria. *Agro-Science*, **16 (1),** 42-47. DOI:https://dx.doi.org/10.4314/as.v16i1.8

Altieri M. and Nicholls C. (2004). Biodiversity and pest management in agroecosystems, CRC Press, Boca Raton, pp. 252.

Anonymous (2018). Amaranth Family (Amaranthaceae).[Online]. [Available at:http://science.jrank.org/pages/278/Amaranth-Family-Amaranthaceae.html]. [Accessed 28 October 2018].

Ayanlade A. (2009). Seasonal rainfall variability in Guinea Savanna part of Nigeria: a GIS approach. *Int. J. Clim. Chan. Strat. Manag.,***1 (3),** 282-296. [Online] [Available at: http://dx.doi.org/10.1108/17568690910977492]

Banjo A.D. (2007).Bio-ecology and life history of *Gasteroclisusrhomboidalis* Boh. (Coleoptera: Curculionidae) a pest of *Amaranthus cruentus* (L.) Sauer.*J.Ent.,***4**, 308-316.

Brower J.E., Zar J.H. and Von Ende C.N. (1998). Field and laboratory methods for general ecology, McGraw-Hill, Boston, pp. 273.

CABI. (2018). Invasive Species Compendium.[Online] [Available at: https://www.cabi.org/isc/datasheet/4643] [Accessed: 28 October 2018]

DAFF. (2010). Amaranthus – Production guidelines. A publication of the Department of Agriculture, Forestry and Fisheries, Republic of South Africa, pp.16.

Delaplane K.S. and Mayer D.F. (2000).Crop pollination by bees. CABI Publishing, New York, NY, pp. 344.

Dhellot J.R., Matouba E., Maloumbi M.G., Nzikou J.M., Safou-Ngoma D.G., Linder M., Desobry S. and Parmentier M. (2006). Extraction, chemical composition and nutritional characterization of vegetable oils: Case of *Amaranthushybridus*(Var 1 and 2) of Congo Brazzaville. *Afr. J. Biotech,* **5 (11),** 1095-1101.

Ebert A.W.Wu.T. and Wang S. (2011)**.**Vegetable amaranth (*Amaranthus* L.) International Cooperator's guide. AVRDC – The World Vegetable Center, 11-754

Étilé E. (2012). Agricultural practices that promote crop pest suppression by natural predators. A publication of the Ministry of Agriculture and Agri-Food, Canada, pp. 36.

Ezeh A.E., Ogedegbe A.B.O. and Ogedegbe S.A. (2015). Insect pest occurrence on cultivated *Amaranthus* spp in Benin City, Edo State, Nigeria.*J. Appl. Sci. and Env. Mgt.,* **19 (2),** 335 - 339.

Frund J., Linsenmair K.E. and Bluthgen N. (2010). Pollinator diversity and specialization in relation to flower diversity. *Oikos*, **119**, 1581-1590.

Haaland C., Naisbit R.E. and Bersier L.F. (2011) Sown wildflower strips for insect conservation: A review. *InsectConsv.Diver.*, **4**, 60 - 80.

Hammer Ø., Harper D.A.T. and Ryan P.D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontol. Electronica*, **4 (1),** 9 p.

Hutcheson K. (1970). A test for comparing diversities based on the Shannon formula. *J. Theor. Biol.,* **29**, 151-154.

Inouye D.W. (2012). Review: Syrphid flies: pollinators, predators, mimics, biocontrol agents, and decomposers. *Ecology*, **93 (5),** 1243-1244.

Klein A.M., Vaissi-ere B.E., Cane J.H., Steffan-Dewenter I., Cunningham S.A., Kremen C. and Tscharntke T. (2007). Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B, **274,** 303–313.

Losey J.E. and Vaughan M. (2006). The economic value of ecological services provided by insects. *Bioscience,* **56**, 311-323.

Lundgren J.G., Wyckhuys K.A.G. and Desneux N. (2009). Population responses by O*rius insidiosus*to vegetational diversity. *BioControl,* **54,** 135-142.

Maundu P.M. (2004). Traditional African leafy vegetables: from despised to prized, in Geneflow, a publication about the Earth's genetic resources, Rome, IPGRI.

Nwilene F.E., Nwanze K.F. and Youdeowei A. (2008). Impact of integrated pest management on food and horticultural crops in Africa. *Ent. Exp. et Appl.,* **128**, 355-363

Oerke E.C. (2006). Crop losses to pests.*J. Agric. Sc.*, **144**, 31-43.

Okunlola A.I., Ofuya T.I. and Aladesanwa R.D. (2008). Efficacy of plant extracts on major insect pests of selected leaf vegetables of Southwestern. Nigeria. *Agric. J.,* **3**, 181-184.

Olanrewaju R.M. (2009). Climate and the growth cycle of yam plants in the Guinea Savannah ecological zone of Kwara State, Nigeria. *J. Met.Clim. Sc.,***7**, 43-48.

Oliveira C.M., Auad A.M., Mendes S.M. and Frizzas M.R. (2014). Crop losses and the economic impact of insect pests on Brazilian Agriculture. *Crop Prot.*, **56**, 50-54.

Olufolaji A.O., Odeleye F.O. and Ojo O.D. (2010). Effect of soil moisture stress on the emergence, establishment and productivity of Amaranthus (*Amaranthuscruentus* L.). *Agric. Biol. J. N. Amer.*, , 1169-1181.

Ojumoola O.A., Adesiyun A.A. and Usman L.A. (2016). Susceptibility of the life stages *Callosobruchus maculates* (Fabr.) in stored cowpea grains to fumigation with essential oil vapour of *Ocimumbasilicum L.* leaves. *Trop. Agric.* **93 (3),** 178-184

Oke O.L. (1983) Amaranth in Nigeria. In: H.T. Chan Jr. (Ed.),*Handbook of Tropical Foods*, (p. 1) Marcel-Dekker Inc., New York, USA.

Michener C.D. (2007). The bees of the world. Johns Hopkins University Press, Baltimore. i-xiv, 1-972.

Moore D., Siegfried D., Wilson R. and Rankin M.A. (1989).The influence of time of day on the foraging behavior of the honeybee, *Apismellifera*. *J. Bio. Rhyt.*,**4 (3),** 305-325. DOI: 10.1177/074873048900400301

Ribeiro J.E.M.M., Pieterse P.J. and Famba S.I. (2017).Vegetative growth of *Amaranthus hybridus* and *Amaranthus tricolor* under different watering regimes in different seasons in southern Mozambique.*South Afr. J. Plt. Soil*, **34 (3)** 201-210,DOT:10.1080/02571862.2016. 1266045

Saunders R.M. and Becker R. (1984) *Amaranthus*: A potential food and feed source, In: Y. Pomeranz (ed.). *Adv. in Cereal Sc. Tech.*, **6**, 57-396.

Saunders M.E. (2018). Insect pollinators collect pollen from wind-pollinated plants: implications for pollination ecology and sustainable agriculture.*Insect Consv.Diver.*,**11**, 13–31.

Van Huis A. and Meerman F. (1997).Can we make IPM work for resource-poor farmers insub-Saharan Africa? *Int. J. Pest Manage.*,**43 (4)** 313 – 320.

Waage J. (2007). The sustainable management of biodiversity for biological control in food and agriculture: Status and Needs. Published by the Commission on Genetic Resources for Food and Agriculture, Food and Agriculture Organization of the United Nations, pp. 58.

Wäckers F.L., Van Rijn P.C.J. and Heimpel G.E. (2008). Honeydew as a food source for natural enemies: making the best of a bad meal? *Biol. Control,* **45**, 176-184.