ASSESSMENT OF NATURAL ENEMY RICHNESS, DOMINANCE, DENSITY AND FUNCTION IN LEPIDOPTEROUS LARVAL PESTS ATTACKING *Amaranthus hybridus* L. IN ZARIA, NIGERIA

Mailafiya, D. M.[*1, 2], Mani, U.[1], Utono, I. M.[1], Kwanashie, A. J.[1], Usman, M. S.[1] and Banwo, O. O.[1]

[1]Department of Crop Protection, Faculty of Agriculture/Institute of Agricultural Research, Ahmadu Bello University, P.M.B. 1044, Zaria, Nigeria [2]Department of Crop Protection, Faculty of Agriculture, University of Maiduguri, P.M.B. 1069, Maiduguri, Nigeria

[*]Corresponding author's e-mail: dmailafiya@gmail.com

SUMMARY

This study evaluated the richness and dominance of larval pests and natural enemies, plant infestation, pest and parasitoid density and larval parasitism in *Amaranthus hybridus* L., as cultivated and volunteer hosts, in Zaria, Nigeria. Field inspections were carried out between June and September, 2018 in seven to 15 farmers' fields and their fringes. Recovered larvae were maintained in the laboratory till adult insect emergence. Of the three lepidopterous larval pests found, the Beet web worm, *Hymenia recurvalis* (Fabricius) was the major pests (dominance (79%/92%) and frequency (69%/81%)), while the Leaf webber, *Psara basalis* Walker and the Leaf roller, *Sylepta derogata* (Fabricius) were minor pests (dominance (3%-12%) and frequency (25%-31%)). In all, five parasitoids (*Apanteles* sp., *Bracon* sp., *Braunsia* sp., *Tetrastichus stictococci* Silv. and Scelioninae) and one predator species (*Scymnus loewii* Mulsant) were recovered. In particular, *Apanteles* sp., *Bracon* sp. and *S. loewii* were common in both cultivated and volunteer hosts. *Apanteles* sp. was the most active parasitoid in both host types (dominance (61%-84%) and frequency (57%-78%)). Plant infestation rate was generally moderate to high (25%-43%) in *A. hybridus*. Although larval pest (16-23) and parasitoid abundance (4-8) per farmers' field/fringe varied significantly between host types, their densities (3-4 and ≤1, respectively) per plant were significantly similar. Larval parasitism of *Apanteles* sp. (7%-12%) and the total seasonal rate (11%-18%) were low

in *A. hybridus*. In conclusion, *H. recurvalis* is clearly the major lepidopterous larval pest of *A. hybridus* in this locality. Lepidopterous pests habour a few natural enemies in both cultivated and volunteer hosts. *Apanteles* sp. is the most dominant parasitoid species, but total parasitism per species or the seasonal rate is low and insufficient.

Keywords: *Amaranthus hybridus*, infestation, lepidopterous pests, *Hymenia recurvalis*, *Apanteles* sp., parasitism

Agro-biodiversity critically supports delivery of various essential functions to the well-being of man. Nutrient cycling or manure decomposition and predation or parasitism are examples of key functions that render beneficial services in the provision of fertile soils and regulation of climate or abundance of crop pests via the antagonistic actions of natural enemies. Particularly, natural enemies of crop pests utilize requisites, nectar/shelter and favorable microclimate, in natural and semi-natural habitats to perpetuate and function (i.e., predation, parasitism and disease infection). Since pest regulation depends on processes that facilitate energy transfer along food webs, persistence of the same for sustained agricultural productivity hinges upon the maintenance of biological diversity in agro-ecosystems (28, 33). Research increasingly posits that ecosystems are most resistant and resilient to change where species diversity and key functional species groups are maintained (14, 35). Insect pest population fluctuations or outbreaks tend to be much more effectively regulated in communities with more diverse natural enemies (6, 8, 9, 38). Sustainability of agro-biodiversity and related agro-ecosystem services are however increasingly threatened by increasing agricultural land expansion, intensification of harmful agro-pastoral practices and land degradation in the face of global warming and climate change (11, 13, 34, 36). For instance, unfavorably high temperatures can disrupt the synchrony of antagonistic predator/parasitoid and prey/host relationships, thereby freeing some herbivore pests from natural population regulation (10, 39). Such developments might encourage massive pesticides intervention against agricultural insect pests. Inappropriate use of pesticides may in turn: i) kill natural enemies, ii) disturb the equilibrium between crop pests and their natural enemies, and iii) lead to the development of resistant insect biotypes (16, 29, 37). It is all the more paramount to establish the richness/diversity, function and habitat preference of natural enemies of crop pests at local and landscape levels, and also have thorough understanding of the complex multitrophic interactions of biotic and abiotic components of agro-ecosystems along with the anthropogenic influences on these interactions.

Amaranthus hybridus L. is commonly cultivated throughout Nigeria under both rainfed and irrigated systems. The relative ease of amaranth cultivation year-round, its vigorous growth, early maturity with little moisture requirement, resistance to heat or drought, low labour requirement and high adaptability to a wide range of soils make it a valuable source of nutrients, dietary fiber and income to small-scale farmers (22). The tender leaves, shoots and stems of amaranth are subject to infestation by a myriad of insect pests. At least 40 lepidopterous larval pest species are reported to attack amaranth in the country (1, 2, 12, 17, 21, 26). The Beet web worm, *Hymenia recurvalis* Fabricius (Lepidoptera: Crambidae: Pyraustinae: Spilomelini) is the most abundant larval pest of amaranth during the cropping and/or off-seasons in most regions of the country (1, 12, 17, 21, 24). The richness of parasitoids attacking these larval pests in a single locality within the country can be high (≥17 species) (21). Effective parasitoids play an important role in regulating their larval host/pest populations. For instance, parasitism of *Busseola fusca* (Fuller) by indigenous parasitoids is high, ≥ 70%, in parts of Kenya (15) and South Africa (18). Altogether, these make *A. hybridus* an important vegetable for cataloguing the diversity of associated pests and their natural enemies in all the agroecological zones of the country. Presently, the faunal assemblage of this cherished green leafy vegetable in the Guinea Savannah region is poorly known. This study, determined the richness, dominance and frequency of larval pests and natural enemies associated with two host types of *A. hybridus*, cultivated and volunteer hosts, as well as the rates of plant infestation and larval parasitism along with pest and parasitoid abundance and density in these hosts in Zaria, Nigeria.

MATERIALS AND METHODS

Field inspection of *A. hybridus*, as cultivated and volunteer hosts, was carried out between June and September, 2018 in seven to 15 farmers' fields (intercropped mainly with cereals (maize/sorghum) and legumes (cowpea)) and their fringes in Zaria. Thirteen weekly visits were made to each of the farmers' field or fringes, where 20 or ten to 15 plants were randomly inspected, respectively. Each lepidopterous larva recovered was placed in a ventilated plastic jar for feeding as described by Le Ru *et al*. (19) and for daily observations till pupation, under ambient conditions in an Entomology laboratory, Department of Crop Protection, Ahmadu Bello University (ABU), Zaria. All pupae and cocoons obtained were kept separately in smaller vials until adult emergence of moths or parasitoids. Larval parasitism was calculated as the percentage of susceptible larvae parasitized (42). Plant infestation, larval and parasitoid abundance or density and larval parasitism were compared between host types using Kruskal-Wallis one-way ANOVA ($\alpha = 0.05$) with the STATISTIX statistical software, version 10.0. Insect species dominance was determined as the percentage of individuals of a given taxon compared to the individuals of all taxa found, with species classification as Dominant (>5%), Influent (2-5%) or Recedent (<2%) (7). The frequency of a species is the percentage of samples in which the particular taxon was detected, with species classification as Constant (>50%), Accessory (25-50%), or Accidental (<25%). Margalef's richness index (*Dmg*) was estimated using the formula (20):

$Dmg = (S - 1) / ln(n)$

Where S is the number of taxa and n is the number of individuals.

RESULTS

In all, 5425 *A. hybridus* plants were inspected. Of which, 1525 were volunteer hosts, while 3900 were cultivated hosts. Six insect pests were found attacking *A. hybridus* in this locality (Table 1 and Plate 1).

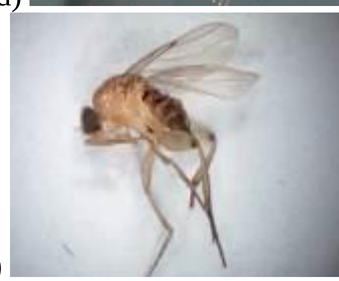
Table 1: The taxa and host distribution of larval pests and natural enemies in two host types of *A. hybridus* during 2018 cropping season in Zaria, Nigeria

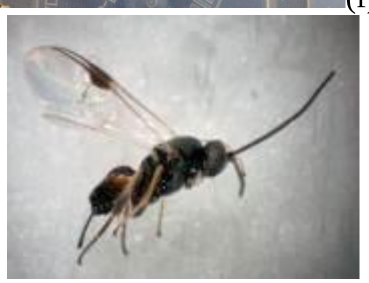
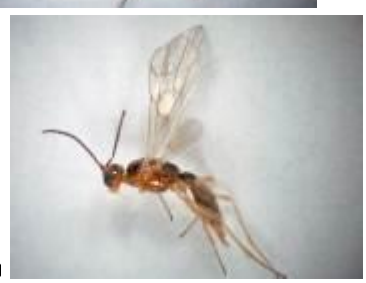
Order	Family	Subfamily	Tribe	Genus species	*A. hybridus* Cultivated host	*A. hybridus* Volunteer host
Pests:						
Lepidoptera	Crambidae	Spilomelinae	Spilomelini	*Hymenia recurvalis* (Fabricius)	+	+
				Psara basalis Walker	+	+
				Sylepta derogata (Fabricius)	+	+
Diptera	Drosophilidae	Drosophilinae	Colocasiomyini	*Zaprionus ghesquierei* Collart	+	+
	Scatopsidae	Scatopsinae	Rhegmoclematini	*Scatopse* sp.	+	+
	Sciaridae			*Lycoriella* sp	+	-
Natural enemies:						
A) Parasitoids						
Hymenoptera	Braconidae	Microgastrinae	Microgastrini	*Apanteles* sp.	+	+
				Bracon sp.	+	+
	Braconidae	Agathidinae	Agathidini	*Braunsia* sp.	+	-
	Eulophidae	Tetrastichinae	Tetrastichini	*Tetrastichus stictococci* Silv.	+	-
	Scelionidae	*Scelioninae*		Scelioninae	+	-
B) Predator						
Coleoptera	Coccinellidae	Scymninae	Scymnini	*Scymnus loewii* Mulsant	+	+

+, present; -, absent

(a)  (b) 

(c)  (d) 

(e)  (f) 

(g)  (h) 

(i)  (j) 

(k)  (l) 

Plate 1: Showing (a) lepidopterous larvae in cultivated *A. hybridus* (b) larval feeding damage in volunteer hosts; some insect pests recovered: (c) *H. recurvalis*, (d) *P. basalis*, (e) *S. derogata* and (f) *Z. ghesquierei*; all parasitoids and predator recovered: (g) *Apanteles* sp., (h) *Bracon* sp., (i) *Braunsia* sp., (j) *T. stictococci*, (k) Scelioninae and (l) *S. loewii*

Three lepidopterous species including *H. recurvalis*, the Leaf webber, *Psara basalis* Walker and the Leaf roller, *Sylepta derogata* (Fabricius) were recovered in both cultivated and volunteer hosts. Three dipteran species including *Lycoriella* sp., *Scatopse* sp. and *Zaprionus ghesquierei* Collart were recovered in cultivated hosts, whereas only the latter two species were recovered in volunteer hosts. Six species of natural enemies including five parasitoids species (*Apanteles* sp., *Bracon* sp., *Braunsia* sp., *Tetrastichus stictococci* Silv. and Scelioninae) and one predator species (*Scymnus loewii* Mulsant) were recovered in cultivated hosts, whereas only half of the species (*Apanteles* sp., *Bracon* sp. and *S. loewii*) were recovered in volunteer hosts. *Hymenia recurvalis* and *P. basalis* or *S. derogata* were respectively dominant and influent pest species in cultivated hosts, but were strictly dominant species in volunteer hosts (Table 2). *Hymenia recurvalis* constantly occurred in cultivated and volunteer hosts, while *P. basalis* and *S. derogata* were accessory species in these hosts. The richness of natural enemies, parasitoids and predator, ranged from 0.56 in volunteer hosts to 0.92 in cultivated hosts. *Apanteles* sp., *Bracon* sp./*S. loewii* and *Braunsia* sp./*T. stictococci*/Scelioninae were respectively dominant and influent species in cultivated hosts. Also, *Apanteles* sp./*Bracon* sp., *Braunsia* sp./*T. stictococci*/Scelioninae and *S. loewii* were respectively constant, accidental and accessory species in cultivated hosts. In volunteer hosts, *Apanteles* sp./*Bracon* sp. and *S. loewii* were respectively dominant and influent species. Also, *Apanteles* sp. and *Bracon* sp./*S. loewii* were respectively constant and accessory species in volunteer hosts.

Percentage plant infestation, number of larvae, number of parasitoids and larval parasitism per farmer's field/fringe were significantly higher in cultivated than in volunteer hosts (*H* = 49.7; df = 320; *P* = 0.0001, *H* = 144; df = 320; *P* = 0.0001, *H* = 20.7; df = 320; *P* = 0.0001 and *H* = 47.3; df = 320; *P* = 0.0324, respectively) (Table 3). Larval and parasitoid density per plant did not vary significantly between cultivated and volunteer hosts (*H* = 0.44; df = 320; *P* = 0.2117 and *H* = 0.56; df = 320; *P* = 0.5124, respectively). The abundance of *Apanteles* sp. or *Bracon* sp. was significantly higher in cultivated than in volunteer hosts (*H* = 11.6; df = 320; *P* = 0.0010 or *H* = 9.47; df = 320; *P* = 0.0028, respectively) (Table 4). However, the abundance of *S. loewii* did not vary significantly between cultivated and volunteer hosts (*H* = 0.79; df = 320; *P* = 0.3758). The larval parasitism rate of *Apanteles* sp. was significantly higher in cultivated than in volunteer hosts (*H* = 2.05; df = 320; *P* = 0.0230) (Table 5), while that of *Bracon* sp. did not vary significantly between cultivated and volunteer hosts (*H* = 1.33; df = 320; *P* = 0.1848).

Table 2: The richness, dominance and frequency of lepidopterous larval pests and natural enemies in two host types of *A. hybridus* during 2018 cropping season in Zaria

Lepidopterous pest species	Quantitative categorisation (%, category)				Natural enemy Species	Margalef's richness (*Dmg*)		Quantitative categorisation (%, category)			
	Dominance		Frequency					Dominance		Frequency	
	Ch	Vh	Ch	Vh		Ch	Vh	Ch	Vh	Ch	Vh
H. recurvalis	92, D	79, D	69, Cn	81, Cn	*Apanteles* sp.	0.92	0.56	61, D	84, D	78, Cn	57, Cn
P. basalis	5, I	12, D	30, Ac	31, Ac	*Bracon* sp.			31, D	11, D	53, Cn	25, Ac
S. derogata	3, I	9, D	25, Ac	27, Ac	*Braunsia* sp.			5, I	-	20, Ad	-
					T. stictococci			5, I	-	22, Ad	-
					Scelioninae			5, I	-	9, Ad	-
					S. loewii			8, D	5, I	31, Ac	39, Ac

Ch, cultivated hosts; Vh, volunteer hosts
D, Dominant; I, Influent;
Cn, Constant; Ac, Accessory; Ad, Accidental

Table 3: Plant infestation/larval parasitism rate and larval pest/parasitoid abundance and density in two host types of *A. hybridus* during 2018 cropping season in Zaria (mean ± SE)

A. hybridus	Plant infestation (%) per farmer's field/fringe	No. larvae per farmer's field/fringe	Larval density per plant	No. parasitoids per farmer's field/fringe	Parasitoid density per plant	Larval parasitism (%) per farmer's field/fringe
Cultivated host	42.75±3.6a	23.04±1.9a	4.15±2.2	8.15±0.8a	0.79±0.5	18.11±2.7a
Volunteer host	24.95±2.7b	15.61±0.6b	2.86±0.61	3.49±0.1b	0.15±0.1	10.79±2.1b

Table 4: Parasitoid/predator abundance per species in two host types of *A. hybridus* during 2018 cropping season in Zaria (mean ± SE)

A. hybridus	No. (per farmer's field/fringe)					
	Apanteles sp.	*Bracon* sp.	*T. stictococci*	*Braunsia* sp.	Scelioninae	*S. loewii*
Cultivated host	2.11±0.3a	0.75±0.1	0.20±0.0a	0.15±0.0a	0.61±0.1a	1.11±0.3
Volunteer host	0.43±0.0b	0.18±0.0	-	-	-	0.25±0.0

Table 5: Percentage parasitism of larval pests in two host types of *A. hybridus* during 2018 cropping season in Zaria (mean ± SE)

A. hybridus	Larval parasitism (%, per farmer's field/fringe)				
	Apanteles sp.	*Bracon* sp.	*T. stictococci*	*Braunsia* sp.	Scelioninae
Cultivated host	12.09±1.2a	3.29±0.4	0.46±0.1	0.76±0.1	1.53±0.3
Volunteer host	6.67±1.8b	3.31±0.3	-	-	-

DISCUSSION

Although a few lepidopterous pest species (≤ six) were recorded in *A. hybridus* in this locality and in Benin, south southern Nigeria (12), amaranth reportedly habours a high richness (≥17 species/8 families) of these pests in southwestern (1) and northeastern parts of the country (21). The low richness of lepidopterous pests recovered in this study was to an extent attributed to wide spectrum or protective pesticidal applications in farmers' fields and the surrounding non-cropped patches, as was observed severally whilst sampling. This might further explain the none recovery of other lepidopterous larval pests commonly reported in amaranth (1, 21), such as the Cotton boll worm, *Helicoverpa armigera* (Hübner), the Cotton leaf worm, *Spodoptera litura* (Fabricius) or the *African armyworm*, *Spodoptera exempta* (Walker). The high dominance (79% / 92%) and constant occurrence (69% / 81%) of *H. recurvalis* in both cultivated and volunteer hosts, indicates that it is a major pest of this leafy vegetable in this locality. *Hymenia recurvalis* is also the major lepidopterous pest of amaranth in all the earlier mentioned regions or agro-ecological zones of Nigeria, accounting for 21% to 93% of the larvae recovered and ≤ 69% foliage loss (1, 12, 17, 24, 25). The marginal dominance (9% / 12%) of *P. basalis* and *S. derogata* in volunteer hosts, coupled with their very low dominance (3% / 5%) in cultivated hosts and moderate occurrence (25% to 31%) in both host types signifies that they are minor or occasional larval pests of *A. hybridus* in this area. *Psara* sp. and *S. derogata* have also been observed to be minor pests of amaranth in most of the earlier mentioned regions of the country, accounting for 7% to 10% of all larval collections (1, 12, 17, 22, 24). *Sylepta derogata* is an economic pest of cotton, okra, hibiscus and other leafy/fruit vegetables in different parts of Nigeria (3, 4, 23, 40). In cotton, *S. derogata* is responsible for plant infestation of between 15% and 42% at 50 days after sowing (40). In okra, *S. derogata* accounts for 92% abscission of pods and seeds during the rainy seasons, leading to 65% non-germination of mature seeds (23). The three dipteran species found, *Lycoriella* sp., *Scatopse* sp. and *Zaprionus ghesquierei* Collart. are non-economic cosmopolitan insect species, which often have their larval stages present in decaying plant or animal materials (5, 41).

The high dominance (61% / 84%) and constant occurrence (57% / 78%) of *Apanteles* sp. in cultivated and volunteer hosts indicates that it is the most active of the five parasitoid species recovered in this locality. *Apanteles* spp. might be common parasitoids of larval pests of amaranth in some parts of the country. In Ibadan, *Apanteles hymenaea* was the sole larval parasitoid found, following two years data collection in amaranth (1). Although, this larval endoparasitoid was surprisingly recovered in pupal hosts, it accounted for 63% of the hymenopterans collected (28). The somewhat moderate dominance (31%) and constant occurrence (53%) of *Bracon* sp. in cultivated hosts, along with its marginal dominance (11%) and moderate occurrence (25%) in volunteer hosts suggests that it is partly active against lepidopterous larval pests in *A. hybridus*.

To our knowledge, this is the first report of *Braunsia* sp., *T. stictococci*, *Scelioninae* and *S. loewii* recovery in lepidopterous larval pests of amaranth in Nigeria. However, the former three parasitoid species were restricted to larval pests in cultivated hosts. Their dominance level and recovery/occurrence frequency were respectively observed to be low (5%) and accidental (9% to 22%). These suggest that they are minor or opportunistic parasitoids of larval pests feeding in *A. hybridus* within this locality. *Braunsia biluntata*, is a related species recovered in northeastern Nigeria by Okrikata *et al*. (27), whilst assessing the diversity and abundance of insects in different habitats within Wukari, Taraba State. Though the associated hosts (plant and herbivoure) remain unknown, at 0.8% abundance, the dominance level of the parasitoid is likewise very low. Most members of the family Scelionidae are egg parasitoids of lepidopterous and hemipterous hosts (30, 31, 32). The scelionid species recorded in this study may therefore be an egg-to-larval parasitoid, since it emerged from larval hosts. The low (5%) or marginal (8%) dominance of *S. loewii* and its moderate occurrence (31% to 39%) in both cultivated and volunteer hosts indicates that the cosmopolitan species is not active against larval pest of *A. hybridus* in this area. The generalist predator might have favourably concentrated on other abundant prey(s) in agroecosystems within this locality. Further studies may establish the predatory response pattern and impact of this beneficial species on crop pest population regulation in different agroecosystems in this region.

Irrespective of the variation recorded between host types, the infestation rate of *A. hybridus* seems to be moderate to high (25% to 43%) during the rainy season. Evidently, larval parasitism according to each parasitoid species and the total seasonal rate in both cultivated (≤ 12% / 18%) and volunteer (≤ 7% / 11%) hosts are low and hardly exceeds 18%. Much higher parasitism rates (21% to 49%) of *Cotesia* sp. has been recorded against larval pests of *A. hybridus* cultivated in Maiduguri, northeastern Nigeria (21). The results of larval pest attack in different host types confirms that the parasitism rates of braconid parasitoids in amaranth rarely surpasses 8%, and is thus negligible. Nevertheless, similar to the earlier suggestion with regards larval pest densities, low parasitoid densities in *A. hybridus* within this area may not be unconnected with pesticidal applications in farmers' fields and the surroundings to protect against crop infestation.

CONCLUSION

Our results indicate that *H. recurvalis* and *P. basalis* or *S. derogata* are respectively major and minor lepidopterous larval pests of *A. hybridus* in this locality. Plant infestation rate by these larval pests appear to be moderate to high (25% to 43%) in both cultivated and volunteer hosts. The richness of parasitoids found in different host types was low (≤ 5 species). Larval pest (≤ 4) and parasitoid (≤ 1) densities per plant tends to be generally low in these hosts. Likewise, larval parasitism of *Apanteles* sp. or the total seasonal rate is low (≤ 18), and almost insignificant.

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