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Influence of Agro-Ecological Zones on African Indigenous Vegetables Insect Pests Diversity and Density in Western Kenya

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Abstract

The influence of agro-ecological zones on African indigenous vegetables (AIVs) insect pest diversity in western Kenya has been scarcely documented. It was therefore important to discover the effect of Agro-ecological zones on the AIVs insect pest population and diversity. This study inventoried insects found on amaranth (Amaranthus sp), spider plant (Cleome gynandra) and nightshade (Solanum nigrum) in western Kenya. A field survey was conducted in Homa Bay, Siaya, Kisumu, Busia, Kakamega, Uasin Gishu and Kisii counties where amaranth, spider plant and nightshade are commonly produced and consumed. The counties were then sub-divided into agro-ecological zones (AEZs). Data was subjected to both numerical descriptive analysis and one-way ANOVA. From the survey 66 (84.6%) out of the 78 total insect species collected were insect pests. Hemipterans were the most numerous, while coleopterans were the most diverse. Insect species diversity on the surveyed AIVs was as follows: spider plant> amaranth> nightshade. Aphids were the most important common pests with Aphis fabae and Myzus persicae found on all three AIVs among the six aphid species identified. The influence of Agro-ecological zones on each AIVs insect density was strong ($p=<0.05$). The highest insect population and diversity was found in locations characterized by highland equatorial climate while the lowest population and diversity was found in locations with hot and dry climate. The study therefore concluded that indeed agro-ecological zones influence insect pest population and diversity. Therefore, farmers should always consider their agro-ecological zones before deciding on which AIVs to produce in order to maximize production while minimizing input expenditures.

Keywords: African Indigenous Vegetables, Agro-Ecological Zones, Insect Pests

INTRODUCTION

African indigenous vegetables (AIVs) have a long history of cultivation, production and utilization in Africa. (Abukutsa-Onyango, 2010). While some researchers believe consumption of AIVs has declined because of a perception that AIVs are inferior in taste and nutritional value compared to exotic vegetables like spinach and cabbage (Mwaura *et al.*, 2013), others report a steady growth of AIV consumption with increasing appearance and availability in formal markets in the recent years (Mwaura *et al.*, 2013). This is due to the recent awakening to the benefits of these 'super vegetables' which has significantly increased their demand (Shiundu & Oniang'o, 2007). This consumer demand has created an opportunity to produce AIVs all year round, but practices that intensify production have increased pest problems. In western Kenya, insect pests have proven to be a big menace. They are reported as one of the major challenges in AIVs production. Through their mode of feeding (chewing, sucking or burrowing), they affect both quality and quantity of AIVs by reducing yield and market value leading to economic loss and loss of crop diversity since farmers will not plant what is highly susceptible (Omasaja, 2016; Unger, 2014). Researchers and practitioners have classified AIVs as "hard core survivor plants" and often recommended them for marginalized areas. This is because they are perceived to adapt well to harsh environments and various stresses, which contributed to the scarcity of evidence on how climate change, water stress, pests, weeds and agro-ecological zones (AEZs) affects small holder production of AIVs (Chepkoech *et al.*, 2018; Hutchinson *et al.*, 2011). Insect pests vary from season to season, climate, agro-ecological zones, diversity, abundance, population dynamics, distribution and damage (Fajinmi *et al.*, 2011; Omasaja, 2016; Owusu *et al.*, 2014). Nevertheless, there is insufficient information recorded about the influence of agro-ecological zones on AIVs insect pests' diversity and population density in western Kenya (Hutchinson *et al.*, 2011). It is, therefore, in view of these gaps, that this study aimed to develop an inventory of the common AIVs insect pests found in the different agro-ecological zones of western Kenya, what insect species attack which specific AIVs and finally see if Agro-ecological zones had any significant impact on AIVs insect pest densities.

MATERIALS AND METHODS

Counties Sampled

The survey of common insects including pests of AIVs was done in western Kenya in two parts between November and December 2016. The first part was done in Uasin Gishu, Busia and Kakamega counties on 3rd, 4th and 7th November 2016 while the second part was in Siaya, Homa Bay, Kisumu and Kisii counties on 28th, 29th and 30th November 2016. Stratified random sampling was used where strata were the AIVs farmers in the AEZs visited. The surveyed sites were randomly selected farmer fields and research station fields growing amaranth, nightshade and spider plant along a predetermined destination travel route set for each day. An average of 8 farms were sampled in each AEZ. Collection and preservation of insect specimens was done according to (Craemer *et al.*, 2000).

Agro-Ecological Zones Descriptions for the Surveyed Areas in each County

Busia County

a) Kalro Alupe and Bugengi - Lower Midland 1 Sugar Cane Zone (LM1-SCZ) (MoALF, 2016).

Kakamega County

a) Eshitsiru- Upper Midland (UM).
b) Mwamba-Upper Midland (UM) (MoALF, 2018).

Siaya County

a) Usula-Lower Midland 4 (LM4) and Lower Midland 5(LM5).
b) Usula-Ludha – Lower midland 1 (LM1).
c) Luanda - Lower Midland 3 (LM3) (MoALF, 2016).

Homa Bay County

a) Adongo- Lower midland 2 (LM2).
b) Maguti- Lower Midland 4 (LM4).
c) Miyal west -Lower Midlands 5 (LM5) (MoALF, 2016).

Kisumu County

a) Marera (Maseno) -Upper Midland 1 (UM1) (MoALF, 2018)

Kisii County

a) Bogeka and Kisii town outskirts Lower Highland (LH) (CIDP, 2018-2022).

Uasin Gishu County

a) Chepkoilel -Lower Highland 3 (LH3).
b) Race course – Lower Highland 3 (LH3) (MoALF, 2018).

Sample Collection and Preservation

Common insects found on AIVs were collected and recorded separately from every sampled amaranth, spider plant and nightshade field and location. Collection was done using two methods:

i. Hand picking using a No.2 soft brush for non-flying soft bodied (both larvae and adult) insects,

ii. Sweep net for flying and jumping insects.

Collected insects were labeled and preserved as either dry specimens for direct pinning or as wet specimens for subsequent species determination, while aphid specimens were also preserved for DNA bar-coding. Dry preserved specimens were sorted into recognizable taxa, according to orders, pinned or pointed and labeled. Pinned specimens were stored in carton boxes from BioQuip. The wet insects specimens preserved in 70% ethanol were also sorted according to their taxonomic orders. Some insects preserved in alcohol vials were later removed and pinned or pointed. Adult Lepidoptera samples were put in vellum envelopes to protect the wings and stored in a container for subsequent identification.

Identification

Morphological taxonomic determinations

Pinned and alcohol-preserved insect specimens were identified using family dichotomous keys at the National Museums of Kenya-Nairobi. All insects were then identified according to either taxonomic family, genus or species. Aphid specimens were identified using a combination of morphological characteristics (colour, appearance, cornicles sizes, cauda prominence and number of segments on antennae among others) and known host ranges of common aphids species in western Kenya.

Molecular taxonomic determinations

Species identification of aphids was done at Purdue University. Voucher samples of adult aphids stored in 95% alcohol were used for this procedure. A selection of aphid specimens was collected from nightshade, amaranth and spider plant in western Kenya were preserved in 95% ethanol and shipped to Purdue University for DNA extraction and barcording. DNA was extracted from specimens individually using a Quiagen DNeasy® Blood and Tissue Kit. Once extracted, the DNA was stored in a freezer at -20°C while awaiting amplification. Fragments of the aphid COI gene were targeted for PCR amplification using selected aphid primers. The DNA was amplified using PCR, verified using agarose gels to visualize the PCR products, quantified using a nanodrop protocol and prepared for sager sequencing using a 'cleanup kit' (ExoSAP-IT PCR Product Cleanup Reagent ThermoFisher Scientific). Purified DNA samples were bidirectionally sequenced using an ABI 3730xl DNA sequencer (Applied Biosystems, Foster City, California) at the Purdue Genomics Core Facility, Purdue University Sequences were assembled, aligned and edited then the COI sequences were queried for species determination via the basic local alignment search tool (BLAST) at the GenBank database hosted by NCBI (http://www.ncbi.nlm.nih.gov).

Data was subjected to numerical descriptive analysis.

RESULTS

An array of insects was observed on the AIVs sampled in western Kenya. All insects identified on the 3 AIVs fell in the following taxa: 6 orders, 28 families, 63 genera and 78 species. However not all insects were pests, some were non-pests and beneficial insects (predators and parasitoids). The largest insect species identified were pests at 84.6%. Beneficial insect species accounted for only 13.63% (predators 12.8% and parasitoids 2.6%) in all the combined agroecological zones (Table 1).

Table 1: Overall Insect Observations

Overall	**Pests**	**Predators***	**Total**
Orders	5	4	6
Families	25	4	28
Genera	54	9	63
Species	66 (84.6 %)	12 (12.8 %)	78

* Includes two parasitoids (2.6 %)

Herbivorous insect pest species were identified under five orders Coleoptera-33 species (i.e. *Phyllotreta cheiranthi*), Hemiptera- 22 herbivorous species i.e (*Aphis fabae*), Lepidoptera-8 species (i.e *Helicoverpa armigera*), Hymenoptera- 2 species (i.e *Athalia sp*) and Orthoptera- 1 specie (i.e. Unknown *Acrididae sp*). Predators were from 3 different orders and families.

Some insect species were only hosted by specific AIV varieties. Amaranth hosted 3 lone families, 13 lone genera and 13 lone species. 3 families, 11 genus and 14 lone insect species were hosted on nightshade. Spider plant had the highest number of unique insect taxa with 8 families, 16 genus and 19 lone insect species that were not found on any other AIVs.

Using the agro-ecological zones angle, LH hosted the highest total insect taxa at 23 with 11 lone insect taxa, while LM1-SCZ and LM4 had the least total insect taxas with no lone insect taxas in them. When broken down further, separating the AIVs, showed that spider plant in agro-ecological zone LH had the highest number of insect taxa (16) followed by the same in agro-ecological zone LM1(15). Spider plant in LM4, and LM1-SCZ and nightshade in LM1-SCZ had the least insect taxas (1). Overall, therefore, spider plant had the highest insect taxa in all combined agro ecological zones while nightshade had the least.

Aphid barcode results confirmed 7 aphid species (*Aphis craccivora*, *Aphis fabae*, *Aphis gossypii*, *Brevicoryne brassicae*, *Hysteroneura setariae*, *Myzus persicae*, *Rhopalosiphum padi*) on nightshade, amaranth and spider plant. Some aphid species (*Aphis fabae*) were common in as many as 8 agroecological zones (Table 2).

Table 2: Inventory of Insect Species Found on AIVs in each Agro-ecological Zone of Western Kenya

Agro-ecological zone	Amaranth	Spider plant	Nightshade
LH	*Aphis craccivora*		*Aphis craccivora*
	Aphis fabae	*Aphis fabae*	*Aphis fabae*
		Aphis gossypii	
	Cletus ochraceus		
	Deraeocoris ostentans	*Deraeocoris ostentans*	
	Dysdercus nigrofasciatus		
	Epilachna sp.		
	Hippodamia variegate	*Hippodamia variegate*	*Hippodamia variegate*
	Jamesonia sp.	*Jamesonia sp.*	*Jamesonia sp.*
			Lagria cyanicollis
			Luperodes exclamationis
		Lycus turneri	
		Macrosteles sp.	
	Myzus persicae	*Myzus persicae*	*Myzus persicae*
		Phyllotreta cheiranthi	
	Platynaspis capicola		
		Sameodes cancellalis	
	Scymnus trepidulus	*Scymnus trepidulus*	*Scymnus trepidulus*
		Silidius apicalis	
		Silidius breviapicalis	
LH3	*Agonoscelis versicolor*		
		Aphidius colemani	*Aphidius colemani*
	Aphis craccivora		*Aphis craccivora*
	Aphis fabae	*Aphis fabae*	*Aphis fabae*
		Bagrada hilaris	*Brevicoryne brassicae*
	Cletus ochraceus		
	Deraeocoris ostentans	*Deraeocoris ostentans*	
	Dysdercus nigrofasciatus		
	Monolepta leuce		
		Phyllotreta cheiranthi	
		Phyllotreta cheiranthi	
LM1		*Aphidius colemani*	*Aphidius colemani*
	Aphis fabae	*Aphis fabae*	*Aphis fabae*
		Apion sp.	
	Apthona sp.	*Apthona sp.*	
			Cassida dorsovittata
	Cheilomenes sulpherea	*Cheilomenes sulpherea*	*Cheilomenes sulpherea*
			Chilocous sp.
		Coryna apicicornis	
		Drepanocerus kirbyi	
			Epitrix sp.
		Epitrix torvi	
		Exitianus sp.	
	Haltica pyricosa		
	Hippodamia variegate	*Hippodamia variegate*	*Hippodamia variegate*

	Jamesonia sp.	*Jamesonia sp.*	*Jamesonia sp.*
	Lema viridivittata		
	Lixus rhomboidalis		
	Myzus persicae	*Myzus persicae*	*Myzus persicae*
	Poephila sp.	*Poephila sp.*	*Poephila sp.*
	Scymnus trepidulus	*Scymnus trepidulus*	*Scymnus trepidulus*
	Unknown Tingidae sp.		Unknown Tingidae sp.
LM2		*Aphidius colemani*	*Aphidius colemani*
	Aphis fabae	*Aphis fabae*	*Aphis fabae*
		Apthona sp.	*Apthona sp.*
	Callosobruchus maculatus		
	Cheilomenes sulpherea	*Cheilomenes sulpherea*	*Cheilomenes sulpherea*
	Jamesonia sp.	*Jamesonia sp.*	*Jamesonia sp.*
	Myzus persicae	*Myzus persicae*	*Myzus persicae*
	Poephila sp.	*Poephila sp.*	*Poephila sp.*
		Rhopalosiphum padi	
	Scymnus sp.		*Scymnus sp.*
	Scymnus trepidulus	*Scymnus trepidulus*	*Scymnus trepidulus*
	Unknown Cercopidae sp	Unknown Cercopidae sp	
	Unknown Tingidae sp.		Unknown Tingidae sp.
LM3	*Jamesonia sp.*	*Jamesonia sp.*	*Jamesonia sp.*
	Myzus persicae	*Myzus persicae*	*Myzus persicae*
LM4	*Aphis fabae*	*Aphis fabae*	*Aphis fabae*
	Scymnus sp.		*Scymnus sp.*
LM5		*Aphidius colemani*	*Aphidius colemani*
	Hippodamia variegate	*Hippodamia variegate*	*Hippodamia variegate*
	Jamesonia sp.	*Jamesonia sp.*	*Jamesonia sp.*
	Lixus rhomboidalis		
			Lycaena sp.
	Micraspis sp.		
	Micraspis striata		
	Myzus persicae	*Myzus persicae*	*Myzus persicae*
		Podagrica weisi	
	Poephila sp.	*Poephila sp.*	*Poephila sp.*
	Scymnus trepidulus	*Scymnus trepidulus*	*Scymnus trepidulus*
		Unknown Lycaenidae sp.	
LM1-SCZ	*Scymnus sp.*		*Scymnus sp.*
	Unknown Cercopidae sp	Unknown Cercopidae sp	
UM	*Aphis craccivora*		*Aphis craccivora*
	Aphis fabae	*Aphis fabae*	*Aphis fabae*
		Brevicoryne brassicae	
	Cletus ochraceus fuscescens		
	Deraeocoris ostentans	*Deraeocoris ostentans*	

			Hysteroneura setariae
			Junonia Sophia
			Lagria cyanicollis
			Leptotes sp.
			Lysiphlebus fabarum
	Myzus persicae	*Myzus persicae*	*Myzus persicae*
		Nezara viridula	
		Phyllotreta cheiranthi	
	Poephila sp.	*Poephila sp.*	*Poephila sp.*
	Rhynocoris vulneratus	*Rhynocoris vulneratus*	*Rhynocoris vulneratus*
	Scymnus trepidulus	*Scymnus trepidulus*	*Scymnus trepidulus*
		Unknown Acrididae sp.	
			Unknown Lycaenidae sp.
UM1	*Callosobruchus maculatus*		
	Jamesonia sp.	*Jamesonia sp.*	*Jamesonia sp.*
	Macrosteles strifrons		
	Myzus persicae	*Myzus persicae*	*Myzus persicae*
	Platynaspis sexguttata		
	Scymnus sp.		*Scymnus sp.*
	Scymnus trepidulus	*Scymnus trepidulus*	*Scymnus trepidulus*

Generally, the AIVs insect pest populations were highly influenced by the different Agro-ecological zones as seen in Table 3 (p=<0.005).

Table 3: One-Way ANOVA Table Showing Influence of Agro-Ecological Zones on AIVs Insect Pest Densities

		Sum of Squares	df	Mean Square	F	Sig.
Amaranth	Between Groups	1235.685	9	137.298	20.092	.000
	Within Groups	116.167	17	6.833		
	Total	1351.852	26			
Nightshade	Between Groups	308.758	8	38.595	5.845	.003
	Within Groups	85.833	13	6.603		
	Total	394.591	21			
Spider plant	Between Groups	668.013	9	74.224	4.831	.003
	Within Groups	245.833	16	15.365		
	Total	913.846	25			

DISCUSSION

Results from the survey in all the agro-ecological zones visited show Coleoptera, Hemiptera, Lepidoptera, Hymenoptera, Dermaptera and Orthoptera insect orders found on AIVs. These included several natural enemies, but a majority were pest species. A study by (Omasaja, 2016) found insect pests of AIVs to include hemipterans, coleopterans, dipterans and lepidopterans. A study done on amaranth in Ibadan, Nigeria reported an array of hemipterans, coleopterans, lepidopterans and thysanopterans (Aderolu *et al.*, 2013). The common species between studies were primarily herbivores in the order Hemiptera, Coleoptera and Lepidoptera. Variations in study results can be attributed to differences in study regions, seasons, years and study focus.

Mureithi *et al*. (2015) found that hemipterans, specifically aphids, were most populated (major) insect pests of Amaranth and spider mites on nightshade in Kenya. This study recorded aphids as the highly populated insect pests across all three AIVs in western Kenya even though coleopterans were the most diverse insect pest species. This difference could be attributed to study focus, difference in time of study and climatic changes.

Insects found on AIVs differed between crops. Spider plant had the highest diversity with thirty-six total insect species (32 pest species) compared to amaranth with twenty-eight total insect species and nightshade with twenty-six total insect species (18 pest species). Spider plant had the most diverse assemblage of insect most unique taxa at all levels. Nightshade, on the other hand, had the greatest number of natural enemy species. The difference in plant preferences could be explained by some unique differences between crops, while similar feeding habits and dietary requirements could explain the common insect species on a crop.

Despite generally having high insect species diversity, spider plant had fewer aphid species than nightshade and amaranth. This might be due to better plant defenses provided by the high amount trichome structures on spider plant (Edeoga *et al.*, 2009). Leaf trichomes probably hinder aphid movement and feeding and act as mechanical barriers, particularly for immature aphids, that would make spider plant less attractive as seen with aphid plant interactions on wild hairy tomato (*Lycopersicon hirsutum* f. glabratum) (Musetti & Neal, 2003).

Agro-ecological zones characterized by highland equatorial climate had the highest diversity of both general and unique insect taxa. Low insect diversity was recorded in areas experiencing both hot and dry climate or are heavy cash crop producers (sugar cane). Whether it is due to the environmental factors, food abundance levels, agronomic practices or any other factor in these Agro-ecological zones that influenced and led to the difference in the AIVs insect pest density differences is a subject to further research.

Two aphid species (*Aphis fabae*, *Myzus persicae*) were common in all three AIVs. This could be because they are polyphagous in nature. There was however different aphid species noted on nightshade, e.g., *Hysteroneura setariae* and *Brevicornye brassicae*. *Hysteroneura setariae* host plant preference is majorly Poaceae family and *Brevicornye brassicae* host preference is the family Brassicaceae. This species has not been reported on AIVs before in western Kenya. *Aphis gossypii* which prefer Curcurbitaceae, Rutaceae and Malvaceae and *Rhopalosiphum padi* which prefer host in the family Poaceae were also identified as new aphid species on spider plants in this study. Since AIVs were not the only crops in the farm, this difference in insect-plant interaction could be attributed to several factors including agronomic practices which puts pressure on selection of quality host plants by having to learn new associations. Also this being a phytochemical driven process, it could also be attributed to insects receiving blends of plant volatiles from different crops nearby thereby making the new plant hosts more attractive compared to the individual volatiles from these new hosts which would turn out as repellant as seen in a study done on *Aphis fabae* (Bruce, 2015).

Aphids are also found on several terrestrial habitats and can adapt to long term changes in climate given time (van Baaren *et al.*, 2010). This could explain the reason as to why they were in as many as 8 Agro-ecological zones.

CONCLUSION AND RECOMMENDATION

The diversity and population density of AIVs insect pests is influenced by agro-ecological zones, therefore farmers should consider their agro-ecological zones before planting AIVs to reduce insect pest incidences, management costs and improve yields.

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