Influence of Accession and Collection Method on the Diversity and Abundance of Insect Taxa on Muskmelon

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Summary

Muskmelon, *Cucumis melo* L. is an annual cucurbit cultivated for its nutritional and medicinal fruits and seeds. The use of conventional insecticides for insect pest control on *C. melo* is deleterious to health and environment thus necessitating an Integrated Pest Management (IPM) approach. Decision making in IPM programs would, however, benefit greatly from insect diversity information. Even so, such information may be influenced by crop type and insect collection method. Consequently, insect diversity and abundance as influenced by *C. melo* accessions (NHCmGm-1 and NHCmKn-1) and collection method (handpicking, sweep net and pitfall trap methods) were investigated. Seeds of both accessions were planted on raised beds following standard methods. Collection by handpicking was done from 3rd to 5th week after planting (WAP). In contrast, sweep net and pitfall trap methods were used from 6th to 10th WAP. The highest abundance of specimens on NHCmGm-1 and NHCmKn-1 respectively, belonged to order Hymenoptera (53.9% and 65.6%) and family Formicidae (40.2% and 29.1%). Insects in the order Hymenoptera also formed the majority of specimens collected using handpicking (53.6%), sweep net (64.6%) and pitfall trap (59.6%) methods. Shanon's diversity index (H) of specimen was significantly higher on NHCmGm-1 (1.9590) than on NHCmKn-1 (1.298). Specimens collected with pitfall traps had the highest abundance (721) but the lowest H index (1.255). In contrast, insect collections with sweep nets had the richest species diversity (1.962). These results show that insect diversity and abundance in *C. melo* systems was significantly influenced by accession type and collection method.

Key words

Cucumis melo L., IPM, Shanon's diversity index, sweep net, pitfall trap

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Introduction

Various activities of insects contribute immensely to proper ecosystem functioning (Samways, 1994). When insects forage, they inadvertently provide numerous ecosystem services including seed dispersal and pollination that respectively enhance plant multiplication and food production (Berenbaum et al., 2006; Adelusi et al., 2018). Also, insects like the honey bees and silk worms participate directly in the production of food and fibre for man's use (Chima et al., 2013; Naman et al., 2019). To make nests or other activities, insects burrow into the soil inadvertently integrating litters and other plant materials thus improving soil aeration, soil fertility and general soil structure (Kaspari, 2000; Berenbaum et al., 2006). Furthermore, insects play vital roles in the natural processes that recycle nutrients, gases and water (Chima et al., 2013; Naman et al., 2019). Insects are also a natural reservoir of biomass and an excellent source of protein for other animals including livestock and wildlife (Scanlon and Petit, 2008; Gold et al., 2018; Van Huis, 2020). Despite the aforementioned ecosystem services, the activities of some insect species are pests that cause damage and diseases to man, his crops, and livestock (Nwilene et al., 2008; Schowalter et al., 2011; Naman et al., 2019). Nevertheless, many insect species are known to attack and feed on insect pests thus performing biological control services in the ecosystem. Both pestiferous and beneficial insects occur in crop systems necessitating insect diversity studies that would inform appropriate and sustainable pest management approaches (Ojumoola et al., 2019).

Muskmelon (*Cucumis melo* L.), also known as cantaloupe, belongs to the family Cucurbitaceae together with cucumber, watermelon, squash, gourds, and pumpkin. *C. melo* production is constrained by insect pest infestation and damage, amongst other factors (Choudhary et al., 2012). Muskmelon is attacked by a wide range of insect pests, many of which are also known to attack and damage other cucurbits. Such insects, like the striped cucumber beetle, *Acalymma vittatum* (Fabricius); melon fly, *Zeugodacus cucurbitae* (Coquillett); oriental fruit fly, *Bactrocera dorsalis* (Hendel); spotted cucumber beetle, *Diabrotica undecimpunctata howardi* (Barber); cucumber moth, *Diaphania indica* (Saunders); western flower thrips, *Frankliniella occidentalis* (Pergande); lesser pumpkin fly, *Dacus ciliatus* (Loew), and cucurbit beetle, *Aulacophora indica* (Gmelin) have been reported on *C. melo* and other cucurbits (Choudhary et al., 2012; CABI, 2021). According to Dhillon et al. (2005), yield losses between the ranges of 30 – 100 percent may result from pest attack on cucurbitaceous vegetables depending on the species cultivated and the season of cultivation.

The extensive and sole use of synthetic chemicals for pest control is deleterious and ecologically unsound (Van Huis and Meerman, 1997). Integrated Pest Management (IPM) is, however, a sustainable and environmentally friendly alternative to the use of synthetic pesticides. As the name implies, IPM seeks to manage pests rather than eradicate them in crop systems. It achieves this by carefully and logically combining and applying appropriate control measures in ways that reduce pest populations below damaging thresholds while at the same time preventing the environmental and health problems associated with the use of conventional pesticide applications (Van Huis and Meerman, 1997; Gyawali, 2018). While IPM does not completely exclude synthetic pesticide application, it ensures that more innocuous prophylactic and therapeutic options like pest monitoring, cultural, mechanical and biological control measures are primarily explored and that chemical spraying, if done at all, is reduced to the barest minimum that poses the least risk to the environment (Van Huis and Meerman, 1997; Gillot, 2005).

Insect diversity studies provide information on species richness and diversity, ecological roles and abundance of insects in a given crop system. Such information would enhance decision-making and the general success of an IPM program (Ojumoola et al., 2019). Nevertheless, it may be influenced by several factors including crop diversity (Wenda-Piesik and Piesik, 2021) and insect collection methods (Rodriguez-Rojas and Rebollar-Tellez, 2017). Studies on the influence of crop type and collection method on the diversity of insect species in *C. melo* systems are however, very scanty. Consequently, insect diversity and abundance on *C. melo* as influenced by two accession types and three collection methods were investigated in the University of Ilorin, Ilorin, Nigeria.

Materials and Methods

Study Site, Source and Types of *C. melo* Seeds

The research study took place on experimental plots at the Department of Crop Protection, Faculty of Agriculture, University of Ilorin, Kwara State, Nigeria (8°29'20.9"N and 4°33'11.1"E) in the dry season (October – December, 2017). Two accessions of *C. melo* were used and both were sourced from the National Horticultural Research Institute (NIHORT), Ibadan, Oyo State. The accessions include NIHORT *Cucumis melo* Gombe – 1 (NHCmGm-1) and NIHORT *Cucumis melo* Kano – 1 (NHCmKn-1). The seeds are small, light brown and smooth between 0.4 and 1.1 cm long and 0.2 – 0.3 wide.

Field Layout and Seed Cultivation

Experiments were laid out in a Randomized Complete Block Design (RCBD) with three blocks. A block was made up of six raised beds each of 250 cm by 200 cm by 50 cm (L x B x H), respectively. A spacing of 1 m was maintained between plots and also between blocks. Beds were fertilized with dried poultry droppings two days before planting. Three beds within a block were randomly allocated to an accession of *C. melo* within a block. On a bed, seeds were planted on double rows at 0.5 m by 0.5 m spacing. Two seeds of each variety were planted per hole to a depth of 1 cm. Seedlings were thereafter thinned to a stand at two weeks after planting (2 WAP). Other standard management practices like watering and weeding were also carried out as required.

Insect Collection, Preservation and Identification

Insects were collected from experimental beds every week using two active methods –handpicking and sweep net and one passive method – pitfall traps. Insect sampling was done by handpicking for the first three weeks after planting (i.e. 3rd – 5th WAP) at the beginning of which plants had few leaves and no canopies. From 6th – 10th WAP, when plant vines and canopies had extended and expanded respectively, sampling was done with a sweep net. Sampling by handpicking and sweep net was done on two randomly selected days of the week. To account for insect visitation at different diurnal periods, insect were collected by handpicking and sweep net on selected days at different time of the day. Thus, sampling was done in the morning on Mondays between the hours of 7:00 AM and 9:00 AM and in the afternoon on Wednesdays between 12:00 PM and 3:00 PM. Like the days of sampling, the time of sampling remained the same throughout the study. Insects collected by handpicking and sweep nets were immediately transferred to a killing jar containing cotton wool soaked with 100 mL ethyl acetate for few minutes until they died. Pitfall traps were made with 450 mL transparent plastic cups fixed into holes, at the centre of each bed immediately after planting, with lip at soil level. A single cup was used per bed and each was filled with 50 mL detergent solution as killing agent. Insects caught in traps were collected once a week from the 6^{th} to 10^{th} WAP with killing agents changed at each collection day.

The insect specimens collected on the field were taken to the laboratory at the Department of Crop Protection, Faculty of Agriculture, University of Ilorin where they were preserved separately in properly labeled plastic containers (300 mL) containing 50 mL of 75% ethanol. Lepidopteran specimens were, however, exempt from alcohol preservation. Insect specimens were thereafter taken to the Insect Collection Reference Centre of the Department of Crop Protection and Environmental Biology, University of Ibadan, were they were identified by comparing their morphological characteristics with voucher specimens.

Statistical Analysis

All data on insect abundance were summarized with descriptive statistics using Microsoft Excel package version 2010. Species richness (S), abundance (N), Simpson's index, Shannon's diversity index and Pielou's species evenness index for each accession of *C. melo* and method of collection were also calculated. Two diversity t-tests, namely Shannon t-test (Hutcheson, 1970) and Simpson's t-test (Brower et al., 1998) were thereafter used to compare the diversity of insects taxa associated with each accession and method of collection. Insect family distributions by collection methods were graphically presented with triplot and scatter gram. All diversity indices, diversity t-tests and graphical distributions were done using the Paleontological Statistics (PAST) software version 3.18 (Hammer et al., 2001).

Results

A total of 1058 insect specimens belonging to seven insect orders and 19 insect families were collected over a period of 10 weeks from both accessions of *C. melo* (Table 1). While all 540 specimens collected on NHCmGm-1 accession were identified to their order taxon, 512 could be identified to the family taxon. Similarly, all 518 specimens collected on NHCmKn-1 accessions were identified to the order taxon but 514 were successfully identified to their family taxon. The order Hymenoptera had the highest percentage of relative abundance (53.9% and 65.6%) in both NHCmGm-1 and NHCmKn-1 accessions respectively (Table 1). These values were followed by the order Coleoptera with 28.9% and 23.2% in accessions NHCmGm-1 and NHCmKn-1 respectively. The order Mantodea was the least represented on both accessions with only 0.4% of the total insect specimens collected.

Table 1. Taxonomic order and abundance of insects associated with two accessions of *Cucumis melo* L. in the University of Ilorin, Ilorin, Nigeria

Accession of *C. melo*	Insect Order	Insect Abundance	Relative Abundance (%)
NHCmGm-1	Coleoptera	156	28.9
	Mantodea	2	0.4
	Diptera	18	3.3
	Hemiptera	11	2
	Hymenoptera	291	53.9
	Lepidoptera	28	5.2
	Orthoptera	34	6.3
	TOTAL	540	100
NHCmKn-1	Coleoptera	120	23.2
	Mantodea	2	0.4
	Diptera	14	2.7
	Hemiptera	11	2.1
	Hymenoptera	340	65.6
	Lepidoptera	6	1.2
	Orthoptera	25	4.8
	TOTAL	518	100

Note: NHCmGm-1: NIHORT *Cucumis melo* Gombe-1; NHCmKm-1: NIHORT *Cucumis melo* Kano-1

Insect species belonging to the ant family Formicidae (order Hymenoptera) were the most represented with percentage relative abundance values of 40.2% and 64.3% in accessions NHCmGm-1 and NHCmKn-1 respectively (Table 2 and 3). Insect species in the darkling beetle family, Tenebrionidae (order Coleoptera) ranked second with percentage relative abundance values of 14.4% and 18.7% in NHCmGm-1 and NHCmKn-1 respectively. With the exception of insect species in the wasp family Braconidae of which 11.7% was collected on NHCmGm-1, other insect families on both accessions of *C. melo* had a representation of less than five percent (Table 2 and 3).

Furthermore, insects traditionally known to play pestiferous roles in crop systems including those in the family Acrididae (grasshoppers), Alydidae (broad-headed bugs), Chrysomelidae (leaf beetles), Gryllidae (grasshoppers), Muscidae (flies), Pentatomidae (stink bugs), Sarcophagidae (flesh flies), Scutelleridae (jewel bugs), Tenebrionidae (darkling beetles) and Tettigoniidae (bush crickets) constituted 32.5% and 29.1% of the total specimens collected on NHCmGm-1 and NHCmKn-1 respectively (Table 2 and 3). Conversely, beneficial insect species such as predators in the family Formicidae (ants), Mantidae (mantids), Reduviidae (assassin bugs) and Coccinellidae (lady beetles); parasitoids in the family Tachinidae (fly parasitoids) and Vespidae (wasp parasitoids) as well as pollinators in the family

Pieridae (butterflies) and Apidae (bees) made up 62.7% and 70.5% of total specimens collected on NHCmGm-1 and NHCmKn-1 respectively (Table 2 and 3).

Table 2. Taxonomic family, abundance and primary ecosystem role of insects associated with NHCmGm-1 accession of *Cucumis melo* L. in the University of Ilorin, Ilorin, Nigeria

Insect Family	Insect Abundance	Relative Abundance (%)	Primary Ecosystem Role
Acrididae	23	4.3	Phytophagous pest
Alydidae	5	0.9	Phytophagous pest
Apidae	2	0.4	Pollinator
Braconidae	63	11.7	Parasitoid
Calliphoridae	1	0.2	Phytophagous pest
Chrysomelidae	39	7.2	Phytophagous pest
Coccinellidae	7	1.3	Predator
Erotylidae	23	4.3	Phytophagous pest
Formicidae	217	40.2	Predator
Gryllidae	10	1.9	Phytophagous pest
Mantidae	2	0.4	Predator
Reduviidae	3	0.6	Predator
Sarcophagidae	15	2.8	Phytophagous pest
Scarabaiedae	9	1.7	Phytophagous pest
Scutelleridae	3	0.6	Phytophagous pest
Tachnidae	2	0.4	Parasitoid
Tenebrionidae	78	14.4	Phytophagous pest
Tettigoniidae	1	0.2	Phytophagous pest
Vespidae	9	1.7	Parasitoid
‡Unidentified	28	5.2	
TOTAL	540	100	

Note: NHCmGm-1: NIHORT *Cucumis melo* Gombe-1; ‡Unidentified refers to specimens that could not be identified to family level

Table 3. Taxonomic family, abundance and primary ecosystem role of insects associated with NHCmKn-1 accession of *Cucumis melo* L. in the University of Ilorin, Ilorin, Nigeria

Insect Family	Insect Abundance	Relative Abundance (%)	Functional Ecosystem Role
Acrididae	19	3.7	Phytophagous pest
Alydidae	3	0.6	Phytophagous pest
Apidae	5	1	Pollinator
Chrysomelidae	12	2.3	Phytophagous pest
Coccinellidae	6	1.2	Predator
Erotylidae	5	1	Phytophagous pest
Formicidae	333	64.3	Predator
Gryllidae	6	1.2	Phytophagous pest
Mantidae	2	0.4	Predator
Muscidae	7	1.4	Phytophagous pest
Pentatomidae	4	0.8	Phytophagous pest
Pieridae	2	0.4	Pollinator
Reduviidae	2	0.4	Predator
Sarcophagidae	6	1.2	Phytophagous pest
Scutelleridae	2	0.4	Phytophagous pest
Tachnidae	1	0.2	Parasitoid
Tenebrionidae	97	18.7	Phytophagous pest
Vespidae	2	0.4	Parasitoid
‡Unidentified	4	0.8	
TOTAL	518	100	

Note: NHCmGm-1: NIHORT *Cucumis melo* Gombe-1; ‡Unidentified refers to specimens that could not be identified to family level

A total number of 138, 175 and 745 insect specimens were respectively collected with handpicking, sweep net and pitfall trap methods (Table 4). Insect specimens in the order Hymenoptera were the most represented accounting for 53.6%, 64.6% and 59.6% of total insects collected by handpicking, with sweep net and pitfall traps respectively.

Table 4. Taxonomic order and abundance of insects collected with different methods on *Cucumis melo* L. in the University of Ilorin, Ilorin, Nigeria

Insect Collection Method	Insect Order	Insect Abundance	Relative Abundance (%)
Handpicking	Coleoptera	28	20.3
	Mantodea	1	0.7
	Diptera	1	0.7
	Hemiptera	10	7.2
	Hymenoptera	74	53.6
	Lepidoptera	10	7.2
	Orthoptera	14	10.1
	TOTAL	138	100
Sweep net	Coleoptera	31	17.7
	Mantodea	2	1.1
	Diptera	3	1.7
	Hemiptera	9	5.1
	Hymenoptera	113	64.6
	Orthoptera	17	9.7
	TOTAL	175	100
Pitfall traps	Coleptera	217	29.1
	Mantodea	1	0.1
	Diptera	28	3.8
	Hemiptera	3	0.4
	Hymenoptera	444	59.6
	Lepidoptera	24	3.2
	Orthoptera	28	3.8
	TOTAL	745	100

In addition, 16 insect families were collected by handpicking with about 32.5% being traditionally pestiferous while 61.3% were beneficial insects in crop systems (Table 5). Additionally, of the 14 insect families collected with sweep net, 24.6% were traditionally pestiferous while 75.3% were beneficial (Table 6). Fourteen insect families were also collected with pit fall traps with pestiferous and beneficial insect making up 29.8% and 66.9% respectively of total specimens collected (Table 7). The variability level reflected in the total abundance of insect families captured with the different methods of insect collection is graphically illustrated with a triplot dristribution (Fig. 1). The distribution shows that pitfall traps recorded the highest number of family abundance, hence its wide variation from the other collection methods.

Table 5. Taxonomic family, abundance and primary ecosystem role of insects collected by handpicking on *Cucumis melo* L. in the University of Ilorin, Ilorin, Nigeria

Insect Family	Insect Abundance	Relative Abundance (%)	Functional Ecosystem Role
Acrididae	10	7.2	Phytophagous pest
Alydidae	3	2.2	Phytophagous pest
Apidae	1	0.7	Pollinator
Braconidae	2	1.4	Parasitoid
Chrysomelidae	22	15.9	Phytophagous pest
Coccinellidae	4	2.9	Predator
Erotylidae	2	1.4	Phytophagous pest
Formicidae	71	51.4	Predator
Gryllidae	3	2.2	Phytophagous pest
Mantidae	1	0.7	Predator
Muscidae	1	0.7	Phytophagous pest
Pentatomidae	4	2.9	Phytophagous pest
†Pieridae	2	1.4	Pollinator
Reduviidae	2	1.4	Predator
Scutelleridae	1	0.7	Phytophagous pest
Tettigoniidae	1	0.7	Phytophagous pest
‡Unidentified	8	5.8	
TOTAL	138	100	

Note: † Larvae were collected and reared to adult: ‡Unidentified refers to specimens that could not be identified to family level

Table 6. Taxonomic family, abundance and primary ecosystem role of insects collected with sweep net on *Cucumis melo* L. in the University of Ilorin, Ilorin, Nigeria

Insect Family	Insect Abundance	Relative Abundance (%)	Functional Ecosystem Role
Acrididae	15	8.6	Phytophagous pest
Alydidae	5	2.9	Phytophagous pest
Apidae	6	3.4	Pollinator
Braconidae	61	34.9	Parasitoid
Chrysomelidae	19	10.9	Phytophagous pest
Coccinellidae	9	5.1	Predator
Erotylidae	3	1.7	Detritivore
Formicidae	42	24.0	Predator
Gryllidae	2	1.1	Phytophagous pest
Mantidae	2	1.1	Predator
Reduviidae	2	1.1	Predator
Scutelleridae	2	1.1	Phytophagous pest
Tachnidae	3	1.7	Parasitoid
Vespidae	4	2.3	Parasitoid
TOTAL	175	100.0	

Family Braconidae had the highest abundance in the sweep net collections; Chrysomelidae, Acrididae, Coccinellidae in handpicking method and Sacrophigidae in pitfall trap. The families Tenebrionidae and Formicidae occurred as outliers because of their very high numbers.

The number of species i.e. species richness (S) was slightly higher on accession NHCmGm-1 than on NHCmKn-1 (Table 8). Diversity t-tests also showed that Shannon's diversity index (H) value was significantly higher ($P < 0.05$) for accession NHCmGm-1 (1.959) than for NHCmKn-1 (1.298) thus reflecting the occurrence of more insect taxa in the former (Table 8). In contrast, Simpson's t-test showed a significantly lower ($P < 0.05$) Simpson's dominance (D) value of 0.2301 for NHCmGm-1 compared to accession NHCmKn-1 with 0.4582 reflecting the tendency of individuals in few taxa (i.e. families Formicidae and Tenebrionidae) to dominate more of the insect community in accession NHCmKn-1 than in NHCmGm-1 (Table 8). Also, species evenness as reflected by Pielou's evenness index (J) values was higher in accession NHCmGm-1 (0.3733) than in accession NHCmKn-1 (0.2034).

Species richness was the highest (16 families) in insect collections done by handpicking (Table 9). Species richness was, however, of the same value (14 families) for insect collections made with sweep net and pitfall traps. Lower insect taxa were collected with pitfall traps (1.255) compared to handpicking (1.661) and sweep net (1.962) methods as shown by Shannon's diversity index (H) value. There was, however, a significant difference ($P < 0.05$) in the H indices of all three insect collection methods according to Shannon's diversity t-test (Table 9). On the other hand, Simpson's dominance index (D) value was the lowest (0.2045) in collections made with sweep nets and the highest (0.4295) in collections made with pitfall traps. There was also a significant difference ($P < 0.05$) in the value of D value amongst insect specimens collected using all three methods according to Simpson's t-test (Table 9).

Table 7. Taxonomic family, abundance and primary ecosystem role of insects collected with pitfall traps on *Cucumis melo* L. in the University of Ilorin, Ilorin, Nigeria

Insect Family	Insect Abundance	Relative Abundance (%)	Functional Ecosystem Role
Acrididae	17	2.3	Phytophagous pest
Calliphoridae	1	0.1	Phytophagous pest
Chrysomelidae	10	1.3	Phytophagous pest
Erotylidae	23	3.1	Detritivore
Formicidae	437	58.7	Predator
Gryllidae	11	1.5	Phytophagous pest
Mantidae	1	0.1	Predator
Muscidae	6	0.8	Phytophagous pest
Reduviidae	1	0.1	Predator
Sacrophagidae	21	2.8	Detritivore
Scarabaiedae	9	1.2	Detritivore
Scutelleridae	2	0.3	Phytophagous pest
Tenebrionidae	175	23.5	Phytophagous pest
Vespidae	7	0.9	Parasitioid
‡Unidentified	24	3.2	
TOTAL	745	100.0	

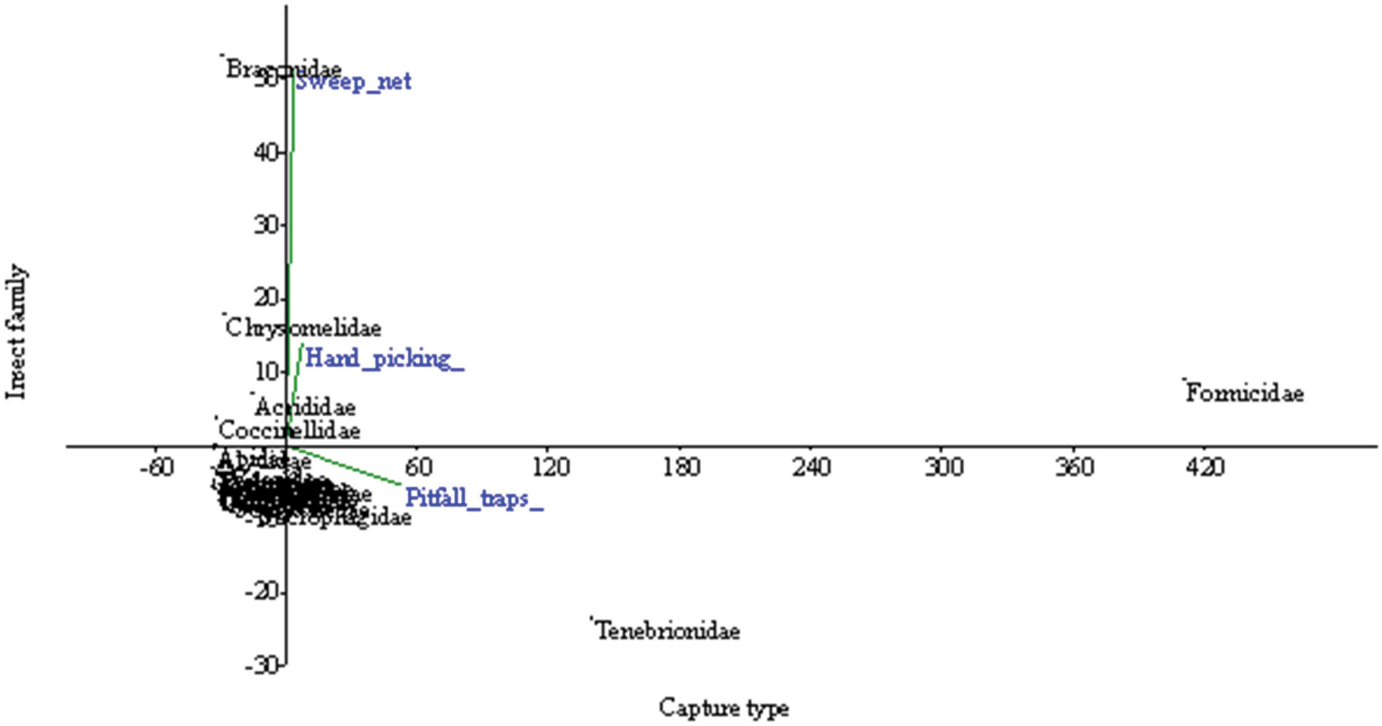

Figure 1. Triplot dristribution of the insect families as it relates to different capture types

Table 8. Diversity indices of insect families on two accessions of *Cucumis melo* L. in the University of Ilorin, Ilorin, Nigeria

Accession	Abundance (N)	Specie richness (S)	Shannon's diversity index (H)	Simpson's dominance (D)	Pielou's evenness index (J)
NHCmGm-1	512	19	1.959[a]	0.2301[b]	0.3733
NHCmKn-1	514	18	1.298[b]	0.4582[a]	0.2034

Note: H and D values in a column followed by the same letter are not significantly different at $P \leq 0.05$ level according to diversity t-tests

Table 9. Diversity indices of insect families on *Cucumis melo* L. by insect collection methods

Insect collection method	Abundance (N)	Specie richness (S)	Shannon's diversity index (H)	Simpson's dominance (D)	Pielou's evenness index (J)
Handpicking	130	16	1.661[b]	0.337[b]	0.3289
Sweep net	175	14	1.962[a]	0.2045[a]	0.5079
Pitfall traps	721	14	1.255[c]	0.4295[c]	0.2505

Note: H and D values in a column followed by the same letter are not significantly different at $P \leq 0.05$ level according to diversity t-tests

Pielou's evenness index (J) values followed a similar trend as Shannon's diversity indices with the lowest value (0.2505) and the highest value (0.5079) in observed in insect collections made with pitfall traps and sweep net respectively (Table 9).

Discussion

In this study, the highest proportion of insects collected on both accessions of *C. melo* were Hymenopterans. Naman et al. (2019) also reported higher abundance of Hymenopteran species in collections from different habitats in Kaduna, Nigeria. The order Hymenoptera consists of insects species like the bees, wasps and ants that are traditionally known to perform beneficial ecological roles including crop pollination and the parasitism or predation of insect pests. Some hymenopterans, however, have chewing mouth parts and can damage crops when they cut out foliage for nest materials (Unstad, 2012). In this study, ants in the family Formicidae were the most abundant Hymenopteran collected on *C. melo*. The family is reported to comprise 290 genera and almost thirteen thousand existing species (Bolton et al., 2007). Ants are also excellent soil modifiers and occupy a top predatory status amongst similar-sized animals (Trager, 1998). Also, in this study, insects in the wasp family Braconidae were collected in considerable numbers on NHCmGm-1. None were, however, found on accession NHCmKn-1. Like ants, braconid wasps are natural enemies of several phytophagous insect pests. Unlike ant predators, braconid wasps are parasitoids that parasitize soft-bodied insects, especially the slow moving grubs of scarabs in the family Scarabaeidae. The absence of these preferred insect hosts on NHCmKn-1 may explain why no braconid wasps were collected in collections made on this particular accession of *C. melo*.

Coleopterans were the second most abundant insect taxa collected on both accessions of *C. melo* in this study. The order Coleoptera or beetles constitute the largest insect order and the most ubiquitous, being found in all terrestrial parts of the globe. There are about three to four hundred thousand described species of beetles and these make up approximately twenty-five percent of all animals on earth. Most of the coleopterans collected in this study were, however, darkling beetles in thef family Tenebrionidae – one of the largest coleopteran family with about 190 genera and about 1200 described species (Erwin, 1997; Liebherr and McHugh, 2003). The darkling beetles are phytophagous insects with most being omnivores and scavengers that feed on plant materials and organic wastes on the surface and below surface ground levels. It is important to note that on both accessions, the abundance of predatory ants was approximately three times higher than that of phytophagous darkling beetles. This suggests a natural biological control process in which the population of the latter is being regulated by the former thus making the use of external pest control inputs less necessary in *C. melo* system at the study site.

Additionally, ants were found in collections made using all three insect collection methods, though the majority were caught with pitfall traps. Similarly, all insect specimen in the family Tenebrionidae were collected with pitfall traps alone. Unlike sweep nets and handpicking methods, pitfall traps are passive insect collection methods that enable the unbiased collection of diurnal and nocturnal insects over a 24-hour period (Unstad, 2012). It is regarded as the best method for conveniently sampling ants and other ground dwelling invertebrates with minimal costs (Esau and Peters, 1975; Unstad, 2012). In contrast, no braconid wasps were collected with pitfall traps, reflecting the unsuitability of the method for actively flying insects.

The use of sweep net is a selective active method that is best suited for collecting large flying insects or a variety of insects amongst vegetations (Gibb and Oseto, 2005). Similarly, handpicking involves the use of bare hands or forceps to selectively pick insects occuring on or around plant foliage. Muskmelon plants start flowering between 30 and 45 days after germination (Aluko et al., 2020) at which time leaves are lush, canopies are cosely packed and vines are fully extended. At this growth phase, it is usually more appropriate to use sweep nets rather than handpicking. Nevetheless, as earlier mentioned, no insects in the family Tenebrionidae were found in collections made with either methods in this study. Instead, leaf-feeders in the family Chrysomelidae were the most abundant coleopterans collected with sweep net and by handpicking. The foregoing observation suggests that Tenebrionidae in this study may have performed mainly detritivore roles down in the litters rather than as leaf feeders up in the canopies in the *C. melo* crop system studied.

Diversity and richness of insect species collected on the two accessions of *C. melo* were similar but not the same. Insect pests are known to show selective preference for host crops based on their perceived suitability as food or other requirements (Helenius, 1989; Wenda-Piesik and Piesik, 2021). Consequently, in polycropping scenarios where crop diversity was higher, insect pest populations were observed to be lower than in monocropping systems with a single crop type (Andrews and Kassam, 1976; Elmstrom et al., 1988). In the same vein, diversity of predators and parasitoids of insect pests and other natural enemies has been reported to increase as crop diversity increases (Pimentel, 1991; Wenda-Piesik and Piesik, 2021). Since both accessions were planted together in randomized blocks, sampled using the same type of insect collection methods, and generally subjected to the same agro-climatic conditions, the higher diversity of insect species collected on NHCmGm-1 may therefore be attributed to the presence or absence of certain morphological or biochemical factors in plants of accession NHCmKn-1. This, however, would require further studies to substantiate.

Trapping methods also influence the diversity of insects collected within a given geographical location (Rodriguez-Rojas and Rebollar-Tellez, 2017). Despite giving higher abundance of specimens, insect diversity was generally lower in pitfall trap collections in the present study than in the two active trapping methods. In contrast, collections with sweep nets gave the highest insect species diversity and evenness indices. This observation is in line with Adelusi et al. (2018), who reported that insect species diversity varied with different trapping methods with higher diversity observed with sweep net than with pitfall trap or by handpicking.

Conclusion

The foregoing shows that insect diversity and abundance in *C. melo* systems was significantly influenced by the type of accession sampled and the method of collection used. Findings in the study also suggest that the use of conventional insecticides for pest management may not be necessary as there may be an abundance of natural enemies that regulates the population of phytophagous insect pests in the *C. melo* system studied. Nevertheless, different collection methods should be employed to correctly ascertain the diversity and abundance of beneficial insect species so that good pest management decisions can be made.

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