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Preliminary Studies of Insect Diversity and Abundance on Twelve Accessions of Tomato, *Solanum lycopersicon* L. Grown in a Coastal Savannah Agro Ecological Zone

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Abstract

The relative abundance and diversity of insect species were studied for three months, between the months of June and August 2013 on twelve different accessions of tomato (*Solanum lycopersicon* L.) at the Ghana Atomic Energy Commission's Biotechnology and Nuclear Agriculture Research Institute (BNARI) farm. The main objectives of the study were to determine the insect diversity and the relative abundance of the insect species on twelve tomato accessions. The field was divided into four replicates each containing twelve different accessions of tomato coded V_1, through to V_{12}. In general, there was lower abundance of insect species across tomato accessions. The study revealed higher abundance of *Bemisia tabaci* (Gennadius) (Hemiptera, Aleyroidae) on accession V_{11} followed by V_1 with V_6 having the least number. *Bemisia tabaci* accounted for 95.5% of the insect counts. Low diversity of insect species was observed across the field of study. *B. tabaci*, *Omocestus viridulus*, (Linnaeus) (Orthoptera, Acrididae) and *Psylla mali* (Schmidb) (Hemiptera, Psyllidae) were observed to occur on all the accessions. Accessions V_6 and V_{11} have the highest diversity of insects while accession V_3 has the least diversity. The other major insect pests such as *Aphis craccivora* (Koch) (Hemiptera, Aphididae), *Phenacoccus* sp., *Podagrica* sp. and *Zonocerus variegatus* (Linnaeus) (Orthoptera, Pyrgomorphidae) recorded very low percentages. The highest record of insect pests was recorded at the fruiting stage of the plant's development. Fourteen different insect species were recorded giving an indication of the species diversity of the farm.

Keywords: abundance, accession, diversity, tomato, insect

1. Introduction

Tomato, *Solanum lycopersicon* L. (syn. *Lycopersicon esculentum* Mill.) is one of the most consumed vegetables in the world and global production is estimated at around 136 Billion metric tons per year (FAOSTAT, 2008). Tomato is the third most economically important vegetable crop after potato and onion. Major production countries in descending order include China, USA, India, Turkey and Egypt respectively. Africa contributes 15% of the world's tomato production (FAOSTAT, 2008). Globally, tomato is the most important greenhouse vegetable crop with a production of 720 MT and a total value of $170 Million per year (FAOSTAT, 2008).

Tomato is a dietary source of vitamins especially A and C, minerals and fiber, which are important for human nutrition and health. In addition, tomato is the richest source of lycopene, a phytochemical that protects cells from oxidants that have been linked to human cancer (Giovannucci, 1999).

In Ghana, tomato is a popular vegetable with high per capita consumption as it is used in almost all Ghanaian homes. Tomato production is a source of employment and income to both rural and urban dwellers. It contributes significantly to the economic growth of Ghana and source of foreign exchange. Tomato is the most important crop in recently established dry season gardens in Northern and Upper Regions and in southern Volta Region of Ghana (Obeng-Ofori et al., 2007).

Total production cost for an acre of fresh market tomato is approximately $6,000 to $7,000, with nearly 25 percent of costs related to pest management (Olson et al., 2005). This cost is mainly borne by farmers and this ultimately increases the cost of production of the tomato and farmers find it difficult to break even all due to the damage posed by arthropod pests.

Tomato production in Ghana has been facing many biotic and environmental constraints. Prominent among such constraints are pests and diseases which reduce yields and the quality of marketable fruits. In the tropics, particularly in Ghana, many insect pests are associated directly with tomato damage and yield losses while some others are most important as vectors of diseases (Messiaen, 1992; Tindall, 1983).

The cultivated tomato, *S. lycopersicon*, is susceptible to a wide array of arthropod pests (Kennedy, 2003; Haji et al., 2002; Franca et al., 2000). These include species that feed almost exclusively on foliage, and species that feed on both foliage and fruit (Lange & Bronson, 1981). Several pests inflict yield reductions indirectly by foliar feeding. These include the agromyzid leafminers, *Liriomyza salivae* Blanchard and *Liriomyza trifolii* Burgess, greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) and the sweet potato whitefly, *Bemisia tabaci* (Gennadius) (Costa & Brown, 1991).

In the field, leafminers, stink bugs and fruitworms cause maximum damage to the tomato fruit. However, severe damage may result either from their feeding on the fruit or by spreading diseases. These insect pests attack tomato from the time plants first emerge in the seed bed until harvest (Webb et al., 2001). At least 27 arthropod pests have the potential of seriously reducing both yields and the market value of tomato fruit (Bloem & Mizell, 2004). According to Horna et al. (2008) and Gianessi (2009), fresh tomato yield losses in Ghana can be as high as 64%.

In Ghana, several insect species are associated with tomato. These include *Liriomyza* sp., *Bemisia tabaci* (Gennadius)., *Aphis gosypii* Glover, *Nesidiocoris tenuis* (Reuter), *Nezara viridula* (L), *Achaea lienardi* (Boisd), *Anomis flava* Fabricius, *Helicoverpa armigera* (Hubner), *Spodoptera littoralis* (Boisd), *Gryllotalpa africana* Palisot de Beauvois and *Zonocerus variegatus* (L.) (Enomoto, 2008; Obeng-Ofori et al., 2007).

Even though farmers complain incessantly, there are no estimates of abundance and diversity of insects on tomato production in Ghana. This knowledge gap makes it impossible to plan and implement any strategies to control insect pests affecting tomato production in the country. Therefore, quantitative studies on the abundance and diversity of insects in any growing area vis-a-vis reduction in crop yield must be carried out in order to establish economic thresholds necessary for instituting control measures. This information will guide stakeholders and farmers in making informed decisions as to when to institute control measures. It is in this vein that this study was carried out to determine the abundance and diversity of insect species on twelve different accessions of tomato. This would assist us develop an Integrated Pest Management (IPM) strategies for tomato cultivation and ultimately boosting the production of this important commodity.

2. Materials and Methods

2.1 Study Site

The experiment was conducted at one of the experimental plots at the Ghana Atomic Energy Commission’s Biotechnology and Nuclear Agriculture Research Institute farm from June to August, 2013. This period was the major planting season for growing tomato in Ghana. The study site was located about 20 km north of Accra (5º40′36.6″ N and 0º11′52.5″ W), with an elevation of 76 m above sea level. The vegetation is Coastal Savannah, and the area is characterized by a bimodal rainfall pattern with the major rain season falling between March and June, and a minor rainy season around October. The mean annual rainfall is 810 mm distributed over less than 80 days, and temperatures are moderate with maxima rarely exceeding 32 ºC while the minimum does not fall below 17 ºC.

2.2 Land Preparation and Experimental Design

An acre area that has been left fallow for over two years was used. No tomato has ever been planted on any part of the research field. Border effects were considered in setting up the research field to cancel out the activities of suspected insects hibernating in neighboring alternative host plants. Stumps were removed from the field before being ploughed. Disc harrowing was done a week after ploughing. No fertilizer or manure was applied to the experimental plots. Seeds were nursed on 14th May, 2013 and transplanted on 6th June, 2013 onto an experimental plot measuring 28 m × 24 m in the center of the one acre area so that the experimental plot was surrounded by a homogeneously managed terrain. Each replicate was allotted a plot size of 143 m^2. Twelve tomato accessions (treatments) were tested and coded from V_1 to V_{12}. The parent plant, Wosowoso, Roma, Wild and New Wild were obtained from a seed shop at Tudu market, Accra, Ghana and Cherry yellow tomato fruits were obtained from Shoprite, Accra Mall, Ghana and seeds extracted. The parent plants were crossed and selection made based on desirable traits to obtain hybrids from which these accessions (V_1-V_{12}) were obtained.

The experimental plot was subdivided in four sub-plots. Each sub-plot hosted one replicate of all the accessions under observation. Each replicate consisted of 20 plants of the same accession, transplanted with a space of about 0.45 m, along rows that had a distance of 1.5 meters to each other. The experimental treatments were deployed in a Randomized Complete Block Design (RCBD), replicated four times. Blocking was done to cater for any variability in the tomato accession. Plots were separated by 2 meters. Weeding was done by hoe and neither irrigation nor pesticides were used during these experiments. Observations were recorded starting from one month of planting when foliage starts to appear till when harvesting time was due.

2.3 Sampling of Entomofauna on Tomato Plants

Weekly scouting for insects was made by visual observations of insect occurring throughout all above ground plant parts of 5 randomly selected plants per accession per replicate (i.e. 5 × 12 × 4 = 240 plants selected). Visual surveys have been shown to be an effective and efficient method for censuring insect species richness and abundance on a variety of host plants including soybean (Mayse et al., 1978a, 1978b). The leaves in each selected plant were observed (naked eye) from the base of the stem to the crown. Plots were visited from 5:00 am to 9:00 am since this is the time most insects were less active. Counting was done on the insect species that were found and recorded on a data sheet. Thirty minutes was spent on each replication to thoroughly take an inventory and observe behavior of the insect species. Only adult insects were collected, recorded and kept in 70% alcohol. Identification to family, genus and species level and curation of the insects were done in the laboratory using insect voucher specimens, CAB International manual keys and descriptions. The data were analyzed by performing an analysis of variance (ANOVA) at 95% level of significance, using the statistical package for agricultural sciences Genstat Software version 12 release 12.1 (Genstat, 2009). The least significant difference (LSD) was used to separate the means of treatments that showed significant "F"values. The diversity of the experimental area was calculated using Simpson index, $Ds = 1-\Sigma (n_i (n_i-1))/(N(N-1))$ where Ds = Simpson's index of diversity; N = total number of individuals of all species; n_i = total number of individuals of the species i.

Figure 1. Fruit worm and its damage on tomato

Figure 2. *Zonocerus variegatus* on tomato fruit

Figure 3. *Phenacoccus* sp. on tomato plant

Figure 4. *Dysdercus* sp. on tomato plant

Figure 5. *Cheilomenes lunata* on tomato

Figure 6. Chlorosis and leaf curl of tomato plant

3. Results

Table 1. Insect species recovered from three developmental stages of tomato in Kwabenya, Ghana

Crop developmental stage	Name of Insect	Scientific name	Damaging stage of the insect	Plant parts damaged
Vegetative stage	Aphids	*Aphis craccivora*	Adult	Leaves
	Apple sucker	*Psylla mali*	Adult	Leaves
	Cotton stainer	*Dysdercus* sp.	Adult	Leaves and fruit
	Field cricket	*Gryllus campestris*	Adult	Leaves
	Flea beetles	*Podagrica* sp.	Adults	Leaves
	Green Grasshopper	*Omocestus viridulus*	Adult	Leaves
	Mealy bugs	*Phenacoccus* sp.	Adult	Leaves
	Phylloxera	*Phylloxera* sp.	Adult	Leaves
	White flies	*Bemisia tabaci*	Adults	Leaves
		Predators		
	Carpenter ant	*Camponotus* sp.	None	None
	Lady bird beetle	*Cheilomenes lunata*	None	None
	Praying mantid	*Mantis religiosa*	None	None
Flowering Stage	Aphids	*Aphis craccivora*	Adults	Leaves
	Apple sucker	*Psylla mali*	Adults	Leaves
	Field cricket	*Gryllus campestris*	Adults	Leaves
	Flea beetles	*Podagrica* sp.	Adults	Leaves
	Green Grasshopper	*Omocestus viridulus*	Adults	Leaves
	Mealy bugs	*Phenacoccus* sp.	Adults	Leaves
	White flies	*Bemisia tabaci*	Adults	Leaves
		Predators		
	Carpenter ant	*Camponotus* sp.	None	None
	Lady bird beetle	*Cheilomenes lunata*	None	None
	Praying mantid	*Mantis religiosa*	None	None
Fruiting stage	Aphids	*Aphis craccivora*	Adult	Leaves
	Apple sucker	*Psylla mali*	Adult	Leaves
	Cotton stainer	*Dysdercus* sp.	Adult	Leaves and fruit
	Field cricket	*Gryllus campestris*	Adult	Leaves
	Flea beetles	*Podagrica* sp.	Adult	Leaves
	Green Grasshopper	*Omocestus viridulus*	Adult	Leaves
	Green Sting bug	*Nezara viridula*	Adult	Leaves and fruit
	Mealy bugs	*Phenacoccus* sp.	Adult	Leaves
	Phylloxera	*Phylloxera* sp.	Adult	Leaves
	Variegated grasshoppers	*Zonocerus variegatus*	Adult	Leaves
	White flies	*Bemisia tabaci*	Adult	Leaves
		Predators		
	Carpenter ant	*Camponotus* sp.	None	None
	Lady bird beetle	*Cheilomenes lunata*	None	None
	Praying mantid	*Mantis religiosa*	Adult	Leaves

Table 2. List of insect species and their abundance on twelve accessions of tomato in Kwabenya, Ghana

		Name of Tomatoes Accessions												
Family	**Name of Insect**	**V_1**	**V_2**	**V_3**	**V_4**	**V_5**	**V_6**	**V_7**	**V_8**	**V_9**	**V_{10}**	**V_{11}**	**V_{12}**	**Total**
Acrididae	*Omocestus viridulus*	5	2	2	3	15	12	4	1	5	2	3	2	**56**
Aleyrodidae	*Bemisia tabaci*	976	968	854	620	682	602	831	942	805	771	1082	954	**10,087**
Aphididae	*Aphis craccivora*	3	6	19	21	0	0	0	0	1	0	1	12	**58**
Chrysomelidae	*Podagrica* sp.	6	5	0	5	2	2	3	0	2	3	6	14	**48**
Coccinellidae	*Cheilomenes lunata*	0	2	0	0	1	2	0	1	0	0	2	0	**8**
Formicidae	*Camponotus* sp.	1	22	7	0	8	2	8	0	15	17	6	3	**89**
Gryllidae	*Gryllus campestris*	2	0	0	0	2	0	0	0	0	0	1	0	**5**
Mantidae	*Mantis religiosa*	0	0	0	0	0	3	1	0	0	0	0	0	**4**
Pentatomidae	*Nezara viridula*	0	0	0	0	0	2	0	1	0	0	0	0	**3**
Phylloxeridae	*Phylloxera* sp.	0	6	0	3	4	2	0	0	1	0	5	8	**29**
Pseudococcidae	*Phenacoccus* sp.	5	14	0	4	4	4	4	0	4	5	0	4	**49**
Psyllidae	*Psylla mali*	7	11	14	6	13	14	19	6	11	12	8	2	**123**
Pyrgomorphidae	*Zonocerus variegatus*	0	0	0	0	0	0	0	1	0	0	1	0	**2**
Pyrrhocoridae	*Dysdercus* sp.	0	0	0	0	0	0	0	0	0	1	0	0	**1**
	Total	**1005**	**1036**	**897**	**662**	**730**	**645**	**870**	**952**	**845**	**811**	**1115**	**994**	**10,562**

V_1 = Wild, V_2 = New Wild, V_3 = Cherry Yellow Control, V_4 = Wosowoso control, V_5 = Cherry yellow, V_6 = Wosowoso big fruits, V_7 = Wosowoso prolific, V_8 = Roma pure red, V_9 = Wosowoso oblong fruits/long shelf life, V_{10} = Wosowoso hardened, V_{11} = Wosowoso big fruits, V_{12} = Roma oblong.

Table 3. Mean numbers of dominant insect pests counted on twelve accessions of tomato

	Accessions											
Pests	**V_1**	**V_2**	**V_3**	**V_4**	**V_5**	**V_6**	**V_7**	**V_8**	**V_9**	**V_{10}**	**V_{11}**	**V_{12}**
Podagrica sp.	2.0^{a}	2.0^{a}	0.0^{a}	1.2^{a}	0.5^{a}	3.5^{a}	1.0^{a}	0.0^{a}	0.5^{a}	0.8^{a}	2.0^{a}	3.0^{a}
Bemisia tabaci	244.0^{b}	242.0^{b}	213.5^{b}	155.0^{b}	188.0^{b}	178.8^{b}	208.0^{b}	236.0^{b}	231.2^{b}	178.0^{b}	254.0^{b}	238.0^{b}
Psylla mali	2.0^{a}	3.0^{a}	3.2^{a}	1.8^{a}	3.0^{a}	3.5^{a}	7.0^{a}	2.0a	2.8^{a}	5.2^{a}	3.0^{a}	0.0^{a}
Aphis craccivora	1.0^{a}	2.0^{a}	2.2^{a}	5.2^{a}	0.0^{a}	1.8^{a}	0.0^{a}	0.0^{a}	0.2^{a}	0.0^{a}	0.0^{a}	2.0^{a}
Omocestus viridulus	1.0^{a}	1.0^{a}	0.2^{a}	0.8^{a}	3.8^{a}	3.0^{a}	1.0^{a}	0.0^{a}	1.2^{a}	0.5^{a}	0.0^{a}	0.0^{a}
Phenacoccus sp.	1.0^{a}	3.0^{a}	0.0^{a}	1.5^{a}	1.0^{a}	1.0^{a}	1.0^{a}	0.0^{a}	1.2^{a}	1.2^{a}	0.0^{a}	1.0^{a}
S.E.D	43.7	41.5	21.64	23.54	29.73	26.10	24.4	36.0	27.12	34.50	39.4	40.6

Means followed by the same letters within the column are not significant ($P < 0.05$).

Analysis of variance showed that there was significant difference in the mean number of insect species collected from the twelve different accessions of tomato ($P < 0.05$). There was no significant difference between the different insect species among the twelve different accessions of tomato except *B. tabaci* (Table 3).

Table 4. Species abundance and diversity recorded during the study period at Kwabenya, Ghana

Name of Insect	**No. of Individuals(n_i)**	**%Abundance**	**$n(n_i$-1)**
Omocestus viridulus	56	0.53	3080
Bemisia tabaci	10,087	95.50	101,737,482
Aphis craccivora	58	0.55	3306
Podagrica sp.	48	0.45	2256
Cheilomenes lunata	8	0.08	56
Camponotus sp.	89	0.84	7832
Gryllus campestris	5	0.05	20
Mantis religiosa	4	0.04	12
Nezara viridula	3	0.03	6
Phylloxera sp.	29	0.27	812
Phenacoccus sp.	49	0.46	2,352
Psylla mali	123	1.16	15006
Zonocerus variegatus	2	0.02	2
Dysdercus sp.	1	0.01	0
Total	**10,562**	**100**	**101,772,222**

Simpson's index of diversity, Ds = 0.0876.

3.1 Economic Status of the Identified Insect Species

During this study, 14 types of insects and predators were recovered from tomato field. Insects which may cause damage to tomato include *Aphis craccivora* (Koch) (Hemiptera, Aphididae), *Nezara viridula* (Linnaeus) (Heteroptera, Pentatomidae) *and Zonocerus variegatus* (Linnaeus) (Orthoptera, Pyrgomorphidae) (Figure 2), *Podagrica* sp., *Bemisia tabaci* (Gennadius) (Hemiptera, Aleyrodidae), *Psylla mali*, (Schmidb) (Hemiptera, Psyllidae), *Omocestus viridulus* (Linnaeus) (Orthoptera, Acrididae), *Phenacoccus* sp. (Figure 3), *Gryllus campestris* (Linnaeus) (Orthoptera, Gryllidae), *Dysdercus* sp. (Figure 4), Phylloxera sp. (Fitch) (Hemiptera, Phylloxeridae) and *Nezara viridula* were found to pose major threats to the cultivation of tomato. The beneficial insects encountered in the study included *Cheilomenes lunata* (Fabricius) (Coleoptera, Coccinellidae) (Figure 5) *Mantis religiosa* (Linnaeus) (Dictyoptera, Mantidae) *and Camponotus* sp. (Hymenoptera, Formicidae). Some of the insects attacked the tomato at all the stages of development from nursery to the last day of harvest. All the insects were found mainly at the vegetative stage of the tomato except *Zonocerus variegatus* (Figure 2). *Dysdercus* sp. (Hemiptera, Pyrrhocoridae) (Figure 4), *Zonocerus variegatus*, *Phylloxera* sp. and *Nezara viridula* were the only insects absent on the flowering stage (Table 1). Finally, *Aphis craccivora* (Koch), *Nezara viridula* and *Zonocerus variegatus* (Linnaeus), *Podagrica* sp., *Bemisia tabaci* (Gennadius), *Psylla mali, Omocestus viridulus*, *Gryllus campestris*, *Phenacoccus* sp., *Dysdercus* sp., *Phylloxera* sp and *Nezara viridula* were found to be present on the fruiting stage (Table 1). *Podagrica* sp. attacks the foliage leaving small round holes in the leaves. Occurrence of *Podagrica* sp. in large numbers may destroy entire leaves.

3.2 Abundance of Insect Species on Twelve Different Accessions of Tomato

A total of 10,562 insects were collected belonging to fourteen different families (Table 2). *B. tabaci* population was 10,087 representing about 95.5% of the total population of insects species collected (Table 4). Other major insect pests namely; *A. craccivora* has a total population of 0.50% of relative abundance, *Phenacoccus* sp. (0.46%), *O. viridulus* (0.53%), *Podagrica* sp. (0.45%) and *P. mali* (1.16%) (Table 4). Accession V_{11} had the largest population of 1,115 specimens of insects. This is followed by accession V_2 with an insect count of 1,036 while least number of insects was found on V_6 (645). The rest of the accessions V_3, V_4, V_5, V_7, V_8, V_9, V_{10}, and V_{12} had insect counts between nine hundred (900) and seven hundred (700). The total population of insect species varied. No single accession was heavily populated by all insect families (Table 2).

3.3 Diversity of Insect Species on Twelve Different Accessions of Tomato

During the study period, different insect species were collected from the twelve different accessions of tomato by sampling (Table 2). Fourteen different insect species belonging to fourteen families were recorded. These include Formicidae (1 genus), Aphididae (1 genus), Cocinellidae (1 genus) and Chrysomelidae (1 genus), Pentatomidae (1 genus), Acrididae (1 genus), Mantidae (1 genus), Pyrgomorphidae (1 genus), Aleyrodidae (1 genus), Cicadellidae (1 genus), Pyrrhocoridae (1 genus), Gryllidae (1 genus), Psyllidae (1 genus) and Phylloxeridae (1 genus) (Table 2). Three genera of insects commonly occurred on all the twelve different accessions of tomato (Table 2). These include *B. tabaci*, *O. viridulus*, and *P. mali*. However, some groups were specific and found only on one accession of tomato. For example, *Dysdercus* sp. was found on accession V_1. The prevalent insects belong to eight families namely; *B. tabaci* (Aleyrodidae), *Phenococcus* sp., (Cicadellidae), *Camponotus* sp., (Formicidae), *A. craccivora*, (Aphididae), *Podagrica* sp., (Chrysomelidae), *O. viridulus* (Linnaeus), (Acrididae), Phylloxera sp., (Phylloxeridae), and *P. mali*, (Psyllidae) (Table 2).

4. Discussions

4.1 Economic Status of the Identified Insect Species on Twelve Different Accessions of Tomato

The major insect group in the study belongs to the Aleyrodidae family which was *B. tabaci*. This insect group in their numbers poses a great danger to the development and survival of the tomatoes with respect to the harm they cause to the plant. High numbers of *B. tabaci* could cause total crop loss due to the sucking behavior and indirect transmission of virus as well as the development of sooty mould on the plant. A large insect group was found to be associated with the tomato accessions (Table 2). These insects attack tomato plant at all stages of its development. *Aphis craccivora*, *Z. variegatus*, *Podagrica* sp., *B. tabaci*, *P. mali*, *O. viridulus*, *G. campestris*, *Phenacoccus* sp., *Dysdercus* sp., *Phylloxera* sp. and *N. viridula* were mainly pests. *A. craccivora*, *P. mali*, *Phenacoccus* sp., *Phylloxera* sp., *N. viridula*, *Dysdercus* sp., and *B. tabaci* are mainly insects that suck sap from the plant. *B. tabaci* can also transmit viruses resulting in Tomato Yellow Leaf Curl Virus disease (Figure 6). The sucking of sap from the tomato plant by these insects resulted in stunted growth, yellowing of the leaves, wilting, fruit drop, and premature fruit ripening. Defoliators such as *Z. variegatus*, *O. viridulus*, *and Podagrica* sp. were also observed to defoliate the leaves of the tomato plant. The small holes created in the leaves of tomato by *Podagrica* sp. could ultimately affect the total photosynthetic area of the leaf resulting in poor yield of tomato. Three beneficial insects (predators) were also recorded in this work namely; *Camponotus* sp., *M. religiosa* and *C. lunata* (Table 1).

4.2 Abundance of Insect Species on Twelve Different Accessions of Tomato

Accession V_{11} which has the highest abundance of insect species may be due to certain attributes of the plant which make it more susceptible to attack by most of the insects in Table 2. There was significant difference in the mean number of *B. tabaci* at $P < 0.05$ among the twelve different accessions of tomato (Table 3). The high numbers of *B. tabaci* is due to the short season after major raining season in the area (Morales & Jones, 2004). *B. tabaci* numbers increases mostly when there is little or no rainfall. The low percentages recorded by other major insect pests do not pose a major threat to the crop due to their lower abundance. The numbers are not large enough to cause economic injury and ultimately reducing the yield of the plant. In general it can be said that there was low abundance of insect species on the tomato plot, giving an indication that a lot less number of individual insect species is associated with the tomato plant. The low numbers of *A. craccivora* in this study could be attributed to the predatory behavior of *C. lunata*. *C. lunata* tend to feed on *A. craccivora* and therefore reducing the total population of aphids (Xue et al., 2009; Ofuya, 1989). The least abundance of insect group on accession V_6 may confer tolerant attributes to that accession and therefore enhances it resistance to insect attack.

4.3 Diversity of Insect Species on Twelve Different Accessions of Tomato

During the study period, a total of 14 insect species were identified on the tomato plants from transplanting to fruiting (Table 2). The Simpson's diversity index, Ds calculated showed that the experimental area is less diversified. This is due to the fact that species diversity (species heterogeneity) is an expression of community structure. A community is said to have high species diversity if many equally or nearly equal abundant species are present. Conversely, if a community is composed of a very few species or if only a few species are abundant, then species diversity is low. Identification of these 14 different insect species on the tomato accessions within this period of the year gives an indication of how less rich the insect population on tomato in this agro ecological area is. Six of these insect species namely; *Z. variegatus*, *A. craccivora*, *Podagrica* sp., *B. tabaci*, *Dysdercus* sp. (Figure 4), and *N. viridula*, have been documented to be serious pests of tomatoes worldwide (Lange & Bronson, 1981). Minor pests such as *O. viridulus*, *Phenacoccus* sp., and *G. campestris* have also been recorded on some accessions of tomato. The major pest, *B. tabaci* recorded in this study confirms a similar study by Arno et al. (2008). They found out that *B. tabaci* is capable of causing severe losses even at low densities due to the range of plant viruses it can transmit. Purcell et al. (1993) identified five different insect pests as major pests and nine beneficial insects on tomato which were mainly parasitoids. The beneficial insects in this study can be exploited and packaged in an IPM strategy to combat the major pests in the study. It can, however, be established that the non-prevalence of fruit worm (Figure 1) and borers could be due to early harvest and short duration of the tomato plant growth. The borers did not have enough time to colonize the tomato plant. Contrary to the results of Mailafiya et al. (2014), who found only three main insect pests namely *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae), *B. tabaci* (Gennadius) and *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae) to be present on tomato, *B. tabaci* seems to be common to this study and this could be due to the invasiveness of this insect. Umeh et al. (2000) described these species as very common on tomato crop in a survey carried out in Oyo State where they recorded seven insect species common on tomato. Three of these recorded insects are present in this study. These common insects shared by the two studies include variegated grasshopper, whitefly and aphids. In Ghana, Sam et al. (2014) recorded five different insect species on tomato namely; *B. tabaci*, *Thrips tabaci* Lindeman, *A. gossypii*, *Liriomyza* sp. and the tomato fruit worm, *H. armigera* as the most important insect pests collected on tomato in Kumasi, Ghana.

5. Conclusion

A large number of experiments carried out, under different conditions, indicated a reduction in pest activity with diverse vegetation if compared with monoculture. The present study showed low diversity of insect species on the tomato plant. Fourteen different insect species have been recorded belonging to fourteen different families. Additionally, low abundance of insect species was recorded on the tomatoes despite *B. tabaci* accounting for 95.5% of the insect population. By considering the impact of insect pests on tomato, we can accurately predict pest population dynamics. This should assist research and extension personnel in designing integrated pest management programmes for tomato.

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