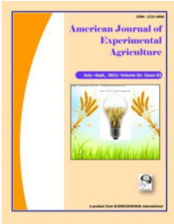

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Relative Abundance and Diversity of Insect Species on Nine Genotypes of Pepper (*Capsicum spp.*) Grown under Field Conditions in Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author ESKO performed the statistical analysis and wrote the first draft of the manuscript. Authors WN and EKQ designed the study. Authors MOA, HMA and ASA made significant contributions to the editing and proofreading of the final manuscript together with the above mentioned authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To identify the different types and relative abundance of insect species on the nine genotypes of pepper, as a guide to instituting control measures against unacceptable crop damage.
Study Design: The experimental treatments were deployed in a Randomized Complete Block Design (RCBD), replicated three times.
Place and Duration of Study: Nuclear Agriculture Research Center (NARC) farms and the laboratories of Radiation Entomology and Pest Management Center (REPMC) of Biotechnology and Nuclear Agriculture Research Institute (BNARI). The study was conducted during June-October, 2011.
Methodology: Seeds of the nine pepper genotypes (Anloga, Antillas, Archard, Big Sun, Bombardier, Forever F1, Legon 18, Poivron California Wonder (PCW) and Sunny F1) were sown in

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a nursery and transplanted 35 days after germination to an experimental plot measuring 40 m x 11.4 m in the centre of one acre area such that the experimental plot was surrounded by a homogeneously managed terrain. The experimental treatments were deployed in a Randomized Complete Block Design (RCBD), replicated three times. Each replicate was allotted a plot size of 12 m x 11.4 m. Each replicate was subdivided into nine sub-plots, with each sub-plot planted to one genotype consisting of 30 plants at a spacing of 0.8 m x 0.6m. Plots were separated by a distance of 2 m. Random sampling technique was used on weekly basis to study the relative abundance, diversity and behaviour of the insect species on the genotypes.

Results: Thirteen different insect species were identified from the vegetative through to the maturity stage with relative abundance ranging from 0.04– 54.29%. The highest number of insects were found on the genotypes Forever F1 (26.2%) and Anloga (25.9%). Legon 18 and Sunny F1 registered the highest diversity of insect species, while PCW, Big Sun and Forever F1 recorded the least diversity. *Aphis craccivora* (Koch) (*Hemiptera*, *Aphididae*) was the most dominant pests sampled on four genotypes (Anloga, Antillas, Forever F1 and Legon 18) of the nine pepper genotypes. Similarly, *Camponotus* sp. was the most dominant predator on the pepper genotype Archard. For the rest of the genotypes, there were no significant difference (P=.05) in mean number of insects sampled per genotype. Three mutualistic insects namely *Camponotus* sp., *Cheilomenes lunata* (*Fabricius*) (*Coleoptera, Coccinellidae*) and *A. craccivora* were sampled on the pepper genotypes. The degree of association between any of these is displayed in Table 4. Mean number of *C. lunata* was highly significantly correlated (P=.01) with that of *A. craccivora.*

Conclusion: The high abundance of insect pests in the study area coupled with the pest status of the majority (53.28%) necessitates control measures to prevent economic loss during commercial cultivation in the area. Further work needs to be done on designing a friendly IPM strategy for the major insects encountered in the study so that crop loss due to insect pest infestation can be minimized.

Keywords: Abundance; diversity; pepper; genotypes; pest; species; open field; Ghana.

1. INTRODUCTION

Pepper is cultivated world-wide and used primarily as spice or vegetable in various cuisines. It is also used extensively in both traditional and modern medicinal practice as topical medication for stimulating the circulatory system and as an analgesic in relieving pains [6]. Nutritionally, it is a good source of vitamins B and C as well as Calcium, Magnesium, Phosphorus and Potassium [1].

China, Mexico, Turkey, Indonesia, the USA and Spain are among the world's largest producers. In Africa, Egypt, Nigeria, Tunisia, Algeria, Morocco and Ghana, are highly ranked. Annual world production in 2012 stood at 302,388 metric tonnes [2].

In recent years pepper has attained the status of a high value crop in Ghana due to high demand from urban consumers. In addition there is a growing export trade in the commodity to European markets. Currently, Ghana is the fifth largest exporter of chili peppers to the European Union, where the demand for chili peppers has been growing annually by 17 percent on average since 2000 [3].

Key among the problems associated with the cultivation of pepper is the occurrence of pests which usually result in the outbreak of many diseases. Indeed, throughout the world, pepper production is affected by over 35 species of insects and mites [4]. In general, insect pests which attack the leaves, stem and fruits of pepper include *Tetranynchus urticae* Koch (*Acari: Tetranychidae*), *Aphis gossypii* (Glover) (*Hemiptera, Aphididae*), *Bemisia tabaci* (*Gennadius*) (*Hemiptera, Aleyrodidae*), *Epitrix cucumeris* (Harris) (*Coleoptera, Chrysomelidae*), *Thrips tabaci* Lindeman (*Thysanoptera, Thripidae*), *Pseudaletia unipuncta* (Haworth) (Lepidoptera, Noctuidae) and *Ostrinia nubilalis* (Hubner) (*Lepidoptera, Crambidae*) [5,6,7,8]. Damage from these attacks result in mild to severe stunting, defoliation, flower drop, fruit injury, fruit drop and fruit rot which contribute to reduced fruit yield and quality.

In Ghana, Obeng-Ofori et al. [9] observed five main insects as major pests of pepper. These include *Lena* sp., *Acanthocoris* sp., *Cletomorpha lancigera* Fabricius (*Heteroptera, Coreidae*), *Helopeltis bergrothi* Reuter (*Heteroptera, Miridae*) and *Odontotermes* sp. Norman (1992) [10] also mentioned crickets, cutworms, *Wyzus* sp., *Empoasca* sp. as pests of pepper. Mathew and Karikari [11] made mention of white fly as a pest of pepper.

Dinham [12] estimated that 87% of farmers in Ghana use chemical pesticides to control pests and diseases on vegetables, including pepper. They increase the frequency of insecticide application to minimize pest impact on yield and this is done without regard to pest status and critical time of infestation [13]. In general, farmers' limited knowledge on appropriateness of pesticides to use, timely application, and the quantity to apply have led to accumulation in water, sediment, crops and human fluids in areas of highly intensive vegetable production [14].The indiscriminate and widespread use of synthetic insecticides in pepper cultivation may also result in development of resistance in insect pests [15,16].

On the other hand, cultivation of pepper in Ghana without insect control leads to severe insect damage [17]. This damage drastically reduces market value of produce meant for export. In order for Ghana to fully exploit its competitive advantage over other African pepper producers there is a need to maintain high quality of produce. Even though farmers complain incessantly, there is no information on abundance and diversity of insects affecting pepper production in Ghana. This knowledge gap makes it impossible to plan and implement strategies for their effective control. Data on relative abundance and diversity of insects in an area will also serve as safeguard against overtreatment with pesticides.

The objectives of the study were twofold:

i. To determine relative abundance of these insects on the nine genotypes of pepper, as a guide to instituting control measures against unacceptable crop damage.
ii. To identify different species of insects on nine genotypes of pepper grown under field conditions in the Coastal Savannah agro-ecological zone of Ghana.

2. MATERIALS AND METHODS

2.1 Study Site and Experimental Layout

The study area has been described previously by Ofori et al. [18]. The field study took place from June to October, 2011. The study site is located about 20 km north of Accra (05º 40' 23.4" N and 0º 12' 55.4"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 season falling between the months of March and June, and a minor rainy season around September/October. The mean annual rainfall is 810 mm distributed over less than 80 days, and temperatures are moderate with maximum rarely exceeding 32ºC while the minimum does not fall below 17ºC [19].

The study was carried out under open field conditions. Seven exotic and two indigenous genotypes were used for the study. The choice of materials was based on their widespread cultivation and economic importance. This included one "Jalapeno-like" type (Archard), four cayenne types (Forever F1, Sunny F1, Anloga and Legon 18) and three "scotch bonnet-like" types (antillas, Big Sun and Bombadier). Forever F1 and Sunny are hybrids and three "scotch bonnet-like" types (Antillas, Big Sun and Bombardier). Exotic varieties (Archard, Forever F1, Sunny F1, Antillas, Big Sun, Poivron California Wonder (PCW) and Bombardier) were purchased from a commercial seed company (Agriseed®, distributors for Technisem®). Legon 18 (a popular variety released by the University of Ghana) was purchased from Agrimat® (an agricultural input shop) while the other local genotype, Anloga, was sourced from a farmer's field in Keta in the Volta Region of Ghana. The two local genotypes served as local checks. Border effects were considered in setting up the research field to cancel out the activities of suspected insects hibernating in neighbouring alternative host plants. The seeds were sown in a nursery and transplanted 35 days after germination to an experimental plot measuring 40 m x 11.4 m in the centre of one acre area such that the experimental plot was surrounded by a homogeneously managed terrain. The experimental treatments were deployed in a Randomized Complete Block Design (RCBD), replicated three times. Each replicate was allotted a plot size of 12 m x 11.4 m and was subdivided into nine sub-plots, with each sub-plot planted to one genotype consisting of 30 plants at a spacing of 0.8 m x 0.6 m. Plots were separated by a distance of 2 m. The nursery was watered thoroughly during pre-and post-seed germination to facilitate healthy seedling establishment. Poly feed (Green house grade, 19:19: 19 NPK) was applied at a rate of 40 g per 13 litres of water to the roots to enhance active root formation and shoot growth. Neither pesticide nor fertilizer was applied after transplanting. Observations were recorded once every week, starting from first day of transplanting till last day of harvest, on various insects that were found at different crop growth stages on the nine genotypes of pepper.

2.2 Sampling of Capsicum Entomofauna on Pepper

Sampling was done on the occurrence of various pests by observing ten randomly selected plants at vegetative (15 DAT, 30 DAT), reproductive (60 DAT, 90 DAT and 120 DAT) and maturity (150 DAT) stages of crop growth. Records were made on the different types and numbers of insect species found at various growth stages. The leaves on each selected plant were observed (using naked eye) from the base of the stem to the crown for an inventory of all insects present and their behaviour. The observation was conducted on weekly basis, sampling done from 6.00 am to 9.00am to coincide with the time of day when insects remain less active [18]. Adult insects encountered were carefully collected into labelled glass vials containing 70% alcohol. Sorting and identification to species level and curation of the insects were done in the laboratory using insect voucher specimens from the Entomological Museum of the Zoology Department, University of Ghana, CAB manual keys and descriptions, as well as literature [18].

2.3 Data Analysis

A total of 20 observations were recorded for evaluation and statistical analysis. Data were analysed by performing analysis of variance (ANOVA, P=.05), using the statistical package for agricultural sciences, Genstat Software version 12 release 12.1 [20]. The least significant difference (LSD) was used to separate means of treatments that showed significant “F”values. Correlation coefficient was used to determine the relationship between insects at P=.01. 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.

3. RESULTS

Table 1 lists the different types of adult insects (both pests and predators) found at different growth stages of the nine genotypes of pepper. Ten different insect species were recorded at the vegetative stage of the nine genotypes of pepper. These included pests such as *B. tabaci*, *Aphis craccivora* (Koch) (*Hemiptera, Aphididae*), *Podagrica* sp., *Nezara viridula* (Linnaeus) (*Heteroptera, Pentatomidae*) and *Zonocerus variegates* (Linnaeus) (*Orthoptera*, *Pyrgomorphidae*) and predators such as *Camponotus* sp., *Formica* sp., *Mantis religiosa* (Linnaeus) (*Mantodea, Mantidae*), *Cheilomenes lunata* (*Fabricius*) (*Coleoptera*, *Coccinellidae*) and *Solonopsis invicta* (Buren) (*Hymenoptera, Formicidae*). Similarly, five insect species were recorded at the reproductive stage. These included pests such as *A. craccivora*, *Podagrica* sp. and *N. viridula* and predators such as *Camponotus* sp. and *C. lunata*. At the matured stage, *A. craccivora, Podagrica* sp., *N. Viridula* and *Z. variegatus* were insect pests identified on the genotypes of pepper while *Camponotus* sp. and *C. lunata* were predators found.

A total of 2,332 insect species belonging to eleven families were collected throughout the sampling period on the nine pepper genotypes studied (Table 2). The highest collection of 611 insect species was made on Forever F1. This was followed by Anloga with 604 insect species. Big Sun attracted the least number of insect species (42). *Aphis craccivora* constituted the dominant group on Anloga with an abundance of 451 followed by Forever F1 which had an abundance of 305 of the same species. *A. craccivora* was found on all the genotypes of pepper except Archard (Table 2). Seven insects were predominant on the nine genotypes of pepper. These included *A. craccivora* (1,266), *Formica* sp., (412), *Camponotus* sp., (377), *C. lunata* (95), *N. viridula* (74), *Podagrica* sp., (38) and *S. Invicta* (36). Other insect species collected namely *C. aurata*, *Phenacoccus* sp., *Omocestus virudulus* (Linnaeus) (*Orthoptera, Acrididae*), *B. tabaci* and *Z. variegatus* had relatively lower abundances, between 1 and 15.

Thirteen (13) different insect species of the families; Formicidae (2 genera), Aphididae (1 genus), Coccinellidae (1 genus) and Chrysomelidae (1 genus), Pentatomidae (1 genus), Acrididae (1 genus), Mantidae (1 genus), Pyrgomorphidae (1 genus), Aleyrodidae (1 genus), Pseudococcidae (1 genus) and Scarabaeidae (1 genus) were recorded. Three genera of insects commonly occurred on all the nine different genotypes of pepper (Table 2). There were, however, some groups which were specific and found only on one genotype of pepper. For example *Phenacoccus* sp. was found on Legon 18 while *Cetonia aurata* (Linnaeus) (*Coleoptera, Scarabaeidae*) was found only on Forever F1.

The prevalent insects were *Camponotus* sp., *C. lunata*, *A. craccivora*, *Formica* sp., *Podagrica* sp., *S. invicta N. viridula* and *Z. variegatus*. Three species namely, *Camponotus* sp., *C. lunata* and *Podagrica* sp. were found on all the nine genotypes of pepper (Table 2). *Aphis craccivora* was found on all the other genotypes except Archard (Table 2).

Mean number of the six most dominant insects are displayed in Table 3. *A. craccivora* was the most dominant pests sampled on four genotypes (Anloga, Antillas, Forever F1 and Legon 18) of the nine pepper genotypes. Similarly, *Camponotus* sp. was the most dominant predator on the pepper genotype Archard. For the rest of the genotypes, there were no significant difference (P=.05) in mean number of insects sampled per genotype.

Three mutualistic insects namely *Camponotus* sp., *C. lunata* and *A. craccivora* were sampled on the pepper genotypes. The degree of association between any of these is displayed in Table 4. Mean number of *C. lunata* was highly significantly correlated (P=.01) with that of *A. craccivora.*

Thirteen different insect species were found to be associated with the nine genotypes of pepper the majority (53.8%) of which are pests (Table 5). The estimated Simpson's diversity index (Ds=0.645) shows that the experimental area is highly diversified. *A. craccivora* recorded the highest percentage abundance (54.29%) while *C. aurata* had the least (0.04%).

Fig. 1 shows the comparative abundance of three insects, which are inter- related with respect to feeding behaviour on the genotypes of pepper throughout the study period namely, *Camponotus* sp., *C. lunata* and *A. craccivora*. In general, the abundance of all three insects was high at 15 DAT but dropped sharply by 30 DAT. This was followed by a gradual rise in abundance for *A. craccivora* and *C. lunata* for the rest of the study period. However, for *Camponotus* sp., the decline in abundance continued till 60 DAT before rising to 1.5 at 120 DAT, followed by another decrease by 150 DAT.

4. DISCUSSION

4.1 Abundance of Insect Species on Nine Genotypes of Pepper

A total of 2,332 insects were identified in this study, comprising species belonging to eleven families. In a similar study, Khadijah et al. [21] recorded a total 774 insect species from 79 families. Also in a similar work done by Ofori et al. [18] on tomato within the same geographical area but in a different season recorded 10, 562 insects belonging to fourteen different families. The high abundance recorded on the tomato study was largely due to the high percentage of white flies collected (95.5%). But in this present study white fly accounted for 0.34% of the total insect collected. Xavier and Merlindayana [22] also conducted a similar study and recorded 2660 insects belonging to 44 species and 10 orders. 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 *Heliconia* spp. [23,24].

The study indicated a high abundance of insect species on the nine different genotypes of pepper. Some 53.8% of these insects are major insect pests of pepper. These insects are mainly defoliators and sucking insects, capable of inflicting damage to the pepper crop due to their numbers. Riley and Sparks [25] reported a high abundance of insect species on pepper. The severity of damage to pepper by insect pests is largely due to abundance of the pests, which is related to environmental conditions. In this study, however, beneficial insects such as *C. lunata* and *M. religiosa* were also recorded. Black ants such as *Camponotus* sp. and *Formica* sp. and red ants *S. invicta* were found where aphids were concentrated. Both *Camponotus* sp. and *A. Craccivora* exhibited the same trend in distribution and number through the different growth stages. Begon et al. [26] and Detran et al. [27] observed a positive correlation between ants and aphids. Aphids produce a sugar-rich substance known as honeydew, the waste product of their sap diet. Ants derive all or a large part of their nutrients from this honeydew as a source of food.

Table 1. List of insect pests and predators observed at various growth stages of nine genotypes of pepper grown on the field

Crop growth stage	Nature of insect	Common name	Scientific name	Damaging stage of pest	Plant part(s) damaged
Vegetative stage (15 DAT)	Pests	Aphid	*Aphis craccivora*	Adult	Leaves
		Flea beetle	*Podagrica* sp.	Adult	Leaves
		White fly	*Bemisia tabaci*	Adult	Leaves
	Predators	Carpenter ant	*Camponotus* sp.	None	None
		Field ant	Formica sp.	None	None
		Lady bird beetle	*Cheilomenes lunata*	None	None
		Praying mantid	*Mantis religiosa*	None	None
		Red Imported Fire Ant (RIFA)	*Solenopsis invicta*	None	None
Vegetative stage (30 DAT)	Pests	Aphid	*Aphis craccivora*	Adult	Leaves
		Flea beetle	*Podagrica* sp.	Adult	Leaves, fruits
		Green stink bug	*Nezara viridula*	Adult	Fruit, fruit bud
		Variegated grasshopper	*Zonocerus variegatus*	Adult	Leaves
	Predators	Carpenter ant	*Camponotus* sp.	None	None
		Lady bird beetle	*Cheilomenes lunata*	None	None
Reproductive stage (60DAT)	Pests	Aphid	*Aphis craccivora*	Adult	Leaves
		Flea beetle	*Podagrica* sp.	Adult	Leaves
		Green stink bug	*Nezara viridula*	Adult	Fruit, fruit bud
	Predators	Carpenter ant	*Camponotus* sp.	None	None
		Lady bird beetle	*Cheilomenes lunata*	None	None
Reproductive stage (90DAT)	Pests	Aphid	*Aphis craccivora*	Adult	Leaves
		Green stink bug	*Nezara viridula*	Adult	Fruit, fruit bud
	Predators	Carpenter ant	*Camponotus* sp.	None	None
		Lady bird beetle	*Cheilomenes lunata*	None	None
Reproductive stage(120 DAT)	Pests	Aphid	*Aphis craccivora*	Adults	Leaves, fruit
	Predators	Carpenter ant	*Camponotus* sp.	None	None
		Lady bird beetle	*Cheilomenes lunata*	None	None
Maturity stage(150 DAT)	Pests	Aphid	*Aphis craccivora*	Adults	Leaves, fruits
		Flea beetle	*Podagrica* sp.	Adults	Leaves
		Green stink bug	*Nezara viridula*	Adults	Fruit, fruit bud
		Variegated grasshopper	*Zonocerus variegatus*	Adults	Leaves
	Predators	Carpenter ant	*Camponotus* sp.	None	None
		Lady bird beetle	*Cheilomenes lunata*	None	None

Table 2. Abundance of insect species found on nine genotypes of pepper

		Pepper genotypes									
Family	**Scientific name of insect**	**Archard**	**Legon 18**	**Bombardier**	**Sunny F1**	**Antillas**	**Anloga**	**PCW**	**Big Sun**	**Forever F1**	**Total**
Formicidae	*Camponotus* sp.	23	44	11	26	20	35	38	17	163	377
	Formica sp.	0	53	21	9	17	91	101	6	114	412
	Solenopsis invicta	1	29	1	1	4	0	2	0	0	38
Aphididae	*Aphis craccivora*	0	205	26	106	57	451	108	8	305	1266
Coccinellidae	*Cheilomenes lunata*	7	14	8	12	10	7	6	7	24	95
Pentatomidae	*Nezara viridula*	0	5	0	63	0	4	0	0	2	36
Acrididae	*Omocestus virudulus*	0	0	0	2	1	0	0	0	0	3
Mantidae	*Mantis religiosa*	2	1	2	0	0	0	0	0	0	0
Pyrgomorphidae	*Zonocerus variegatus*	0	1	0	6	2	6	0	0	0	15
Aleyrodidae	*Bemisia tabaci*	0	0	0	2	0	5	0	1	0	8
Pseudococcidae	*Phenacoccus* sp.	0	2	0	0	0	0	0	0	0	2
Scarabaeidae	*Cetonia aurata*	0	0	0	0	0	0	0	0	1	1
Total		46	357	74	229	113	604	256	42	611	2,332

Table 3. Mean numbers of dominant insect on the nine genotypes of pepper

Scientific name of insect	Genotypes								
	Anloga	**Antillas**	**Archard**	**Big Sun**	**Bombardier**	**Forever F1**	**Legon 18**	**PCW**	**Sunny F1**
Aphis craccivora	190.00b	35.30b	1.33a	9.30a	17.70a	86.70b	76.70b	37.70a	56.00a
Bemisia tabaci	1.00a	0.00a	0.00a	0.00a	0.00a	0.30a	0.00a	0.00a	0.70a
Camponotus sp.	20.00a	14.70a	11.00b	10.00a	6.30a	18.70a	22.70a	10.00a	14.00a
Cheilomenes lunata	4.00a	6.30a	3.67a	6.00a	3.30a	16.30a	6.30a	4.00a	6.30a
Nezara viridula	1.00a	0.30a	0.33a	1.00a	1.00a	0.30a	2.00a	0.00a	24.70a
Podagrica sp.	2.00a	0.00a	4.00a	0.00a	1.30a	0.70a	1.00a	0.30a	1.00a

S.E.D40.40 14.593.064.689.82 32.20 20.0220.6729.28

LSD 88.00 31.796.6610.20 21.40 70.1543.6345.0763.80

Means followed by the same letters within the column are not significant (P =.05)

Table 4. Correlation between *Camponotus sp., Cheilomenes lunata* and *Aphis craccivora* on nine genotypes of pepper

Insects	Degree of freedomN-1	r value	P value
Camponotus sp. x *A. craccivora*	5	0.736	0.095
Camponotus sp. x *C. lunata*	5	0.595	0.212
C. lunata x *A. craccivora*	5	0.931**	0.007

Table 5. Abundance and diversity of insect species recorded during the study period

Name of Insect	No. of individuals per 10 plants (n_i)	% Abundance	$n_i(n_i-1)$
Aphis craccivora	1266	54.29	1,601,490
Bemisia tabaci	8	0.34	56
Camponotus sp.	377	16.17	141,752
Cetonia aurata	1	0.04	0
Cheilomenes lunata	95	4.07	8,930
Formica sp.	412	17.67	169,332
Mantis religiosa	5	0.21	20
Nezara viridula	74	3.17	5,402
Omocestus virudulus	3	0.13	6
Phenacoccus sp.	2	0.09	2
Podagrica sp.	36	1.54	1,260
Solonopsis invicta	38	1.63	1,406
Zonocerus variegatus	15	0.64	210
Total	2,332	100	1,929,866

Simpson's index of diversity, Ds = 0.645

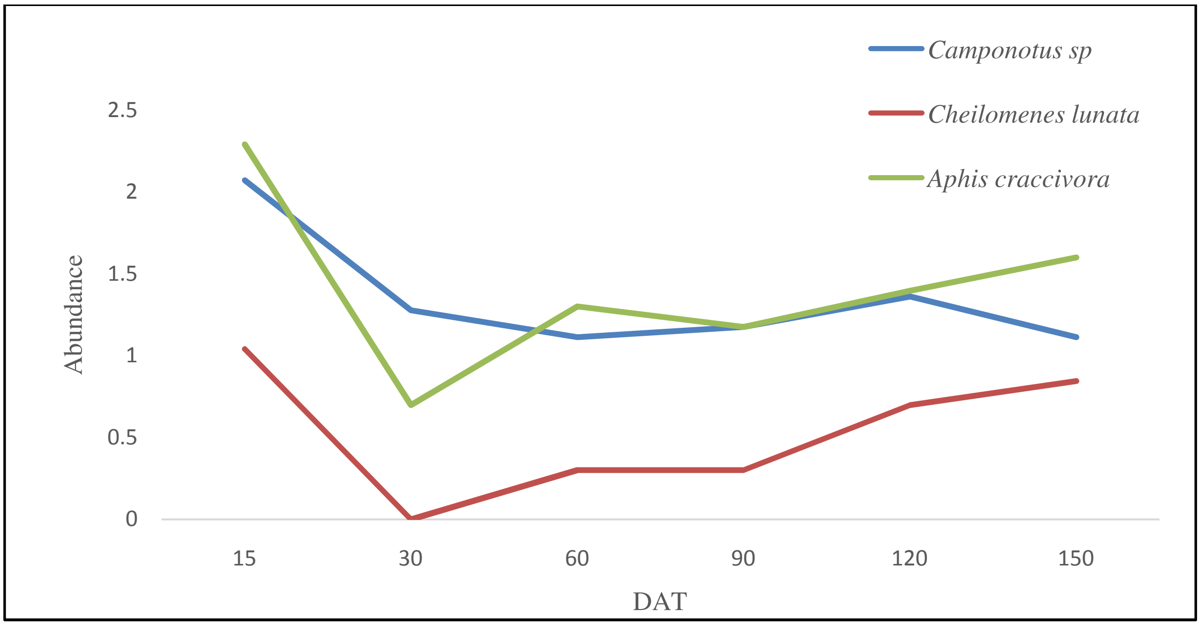

Fig. 1. Comparative abundance of *Camponotus* sp., *Cheilomenes lunata* and *Aphis craccivora* at various growth stages on nine genotypes of pepper

4.2 Diversity of Insect Species on Nine Genotypes of Pepper

The high diversity of insect species sampled in the study area is a reflection of species heterogeneity within the area. Ofori et al. [18] in a related study on tomato recorded a lower diversity index around the same geographical area but on a different experimental plot. The high diversity in this present study is due to the many equally or nearly equal abundant species recorded. Butani [28] reported over 20 insect species on chillies from India of which *A. gossypii* and *A. laburni* were among the most damaging pests. Dagnoko et al. [29], also recorded six different insect species which attack pepper. The high diversity of insects in the study area coupled with the pest status of the majority necessitates prompt institution of control measures to prevent economic loss.

Beneficial insects recorded in this study included *C. lunata*, *Camponotus* sp., *Cetonia aurata*, *Formica* sp., *S. invicta* and *M. Religiosa*, *C. lunata* has been documented to be predatory on aphids. Mochiah et al. [30] reported five major pests of pepper and one beneficial insect, *Cheilomenes* sp. on pepper. The major insect pests in their finding were *A. gossypii* mostly located on the under surface of leaves, either singly or in colonies, *T. tabaci* and *B. tabaci*, *Dysdercus superstitiosus* (Fabricius) (Heteroptera, Pyrrhocoridae) and *Z. variegatus.* They also observed in their study that, *Cheilomenes* sp. fed on *A. craccivora*. This supports the predatory behaviour of *Cheilomenes* sp. as observed in the present study. In related studies, other workers Picket et al. [31]and later Kontodimas and Stathas, [32] noted that ladybird beetles, or ladybugs are important predators of aphids and could be exploited more effectively as biological control agents.

4.3 Economic Importance of Identified Insect Species on Nine Genotypes of Pepper

In this study, the insect pests recorded were *A. craccivora*, *B. tabaci*, *N. viridula*, *O. virudulus*, *Z. variegatus*, *Podagrica* sp., and *Phenacoccus* sp. These normally cause damage by sucking and defoliation thereby reducing economic yield of pepper.

Butani [28] identified *A. craccivora* as a pest of pepper at the vegetative stage. Damage caused by this insect resulted in upward curling of leaves. Reddy and Puttaswamy [33] reported *A. craccivora*, *B. tabaci* and *N. viridula* as major pests found damaging pepper leaves during the vegetative stage of growth. Vasicek et al. [34] also reported that, among the important pests of pepper, *A. craccivora* was found to be a major pests. Akinlosotu [35] reported that *Z. variegatus* was a major pest of capsicum at the vegetative stage due to the defoliating effect.

The present findings are also in agreement with Asena [36], Yasarakinci and Hincal [37], Halima and Hamouda [38] all of whom reported that aphids are the major pests of pepper at the reproductive stage. In their study, *A. craccivora* continued to ravage the crop foliage resulting in wilting and chlorosis of leaves. Six major insect pests were associated with the matured stage of the crop in the current study. Of these, *N. viridula* is a major pest of pepper as it uses the pepper fruit as source of food.

5. CONCLUSION

Thirteen different insect species were identified on the nine genotypes of pepper from the vegetative through to the maturity stage. These comprised six beneficial (*C. lunata*, *Camponotus* sp., *Formica* sp., *S. invicta*, *M. religiosa* and *C. aurata*.) and seven pests (*A. craccivora*, *B. tabaci*, *Podagrica* sp., *O. virudulus*, *N. viridulus*, *Phenacoccus* sp. and *Z. variegatus*). Their relative abundance ranged from 0.04– 17.67% for beneficial insects and 0.09 – 54.29 % for pests. The highest numbers of insects were found on the genotypes Forever F1 (26.2 %) and Anloga (25.9%). Legon 18 and Sunny F1 registered the highest diversity of insect species, while PCW, Big Sun and Forever F1 recorded the least diversity. The high abundance of insect pests in the study area coupled with the pest status of the majority (53.28 %) necessitates prompt institution of control measures, in the case of commercial cultivation, to prevent economic loss.

Further work needs to be done on designing a friendly IPM strategy for the major insects encountered in the study so that crop loss due to insect pest infestation can be reduced while causing minimal damage to beneficial insects.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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