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Insect Pest Diversity and Damage Assessment in Field Grown Okra *(Abelmoschus esculentus* (L.) Moench) in the Coastal Savannah Agro-ecological Zone of Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. Authors FB and ASA performed the statistical analysis and wrote the first draft of the manuscript. Authors DM and BKO helped in collecting the data. Authors ASA and SEKO designed the study. Authors HA, SEKO, ASA and SA 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

Aims: The specific objectives of this study were: to identify the diversity of insect species associated with ten okra cultivars, and to assess the abundance of the insect species and the extent of leaf damage during vegetative, flowering and fruiting stages of ten okra cultivars under field conditions.
Study Design: The experimental treatments were deployed in a Randomized Complete Block

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Design (RCBD), replicated four times.
Place and Duration of Study: The research was conducted at 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), between July 2017 and March 2018. The study area is located at Kwabenya, Accra on latitude 5º40' N, longitude 0º13' W with Ochrosol (Ferric Acrisol) soil type, derived from quartzite Schist.
Methodology: Plant materials used for the study consisted of five local and five exotic okra cultivars. The local cultivars were Asutem (AS), Togo (TG), Labadi dwarf (LD), Kwab (K1) and Adom (AD). These were obtained from the market (Asamankese and Dome) and okra farmers' fields. The exotic cultivars were Lucky 19F1 (LF1), F1 Kirene (F1K), F1 Sahari (F1S), Kirikou F1 (KF1) and Clemson Spineless (CS). These cultivars were obtained from a commercial seed shop, Technisem, Accra. Land preparation of the research site involved plowing and harrowing. The prepared land was lined and pegged into 40 plots using a Randomized Complete Block Design with four replications. Each replicate measured 35 m x 7 m and separated by 2 m from each other with 10 subplots within a block. Each subplot measured 3 m x 3 m and spaced from one another by 1 m. The total size of the experimental area was 646 m^2. The okra seeds were manually sown to a depth of 2 cm directly at a spacing of 0.50 m x 0.60 m. Four seeds per hill were sown and later thinned to one seedling per hill after emergence. Field management practices such as weed control and watering were done as and when required. Data on insects were collected from five okra plants randomly selected from the middle rows. Okra leaves were carefully examined by observing both the abaxial and adaxial surfaces. Insects found on the surfaces of the leaves were identified, counted manually and recorded as either major or minor based on their incidence pattern. Data was taken daily because the ten cultivars have different vegetative, flowering and fruiting dates. Insects were counted between the hours of 6.00 am and 8.00 am when they are inactive and cannot fly. In order to determine the extent of leaf damage, the following described scoring scale was designed for this work. Leaf damage was determined by counting the total number of perforations created by the insects in all leaves found on the five randomly selected test plants. This was then divided by the total number of leaves on the five selected test plants to obtain the average number of perforations per leaf. Leaves were visually assessed and scored for severity of damage using a damage rating where; 1 very mild damage (1 to 15 perforations); 2 mild damage (16 to 30 perforations); 3 moderately severe damage (31 to 45 perforations); 4 very severe damage (46 to 60 perforations); 5 extremely severe damage (more than 60 perforations).
Results: A total of thirteen insect pests belonging to six orders (*Coleoptera*, *Homoptera, Lepidoptera, Hymenoptera, Orthoptera and Mantodea*), and thirteen families *Chrysomelidae*, Coccinellidae, Pyrgomorphidae, Meloidae, Noctuidae, Nolidae, Cicadellidae, Aleyrodidae*, Aphididae, Pseudococcidae, Mantidae, Formicidae* and *Acrididae*) were found to be abundant in the field. Among these, the highest number of insect species belonged to Homoptera group viz., Green Peach Aphid (*Myzus persicae*) Okra leafhopper (*Amrasca biguttula*), Whitefly (*Bemisia tabaci*), and striped mealybug (*Ferrisia virgata*) followed by Coleoptera (Flea beetle (*Podagrica* sp.) and Ladybird beetle (*Cheilomenes lunata*). On the vegetative stage of the okra, Flea beetle had the highest number on Lucky 19F1 (36.00±9.66 insects/plant). During the flowering stage, plants of L-19F1 had the highest mean number of Flea beetles (32.25±10.30 insects/plant). On the fruiting stage, plants of LD had the highest mean abundance of flea beetles (47.50±13.53 per plant).
Conclusion: A total of 1,439 insects were recorded at the fruiting stage which was significantly higher than the flowering (855) and vegetative stages (693). Mean Whitefly counts were relatively low at the vegetative, flowering and fruiting stages of the cultivars. However, Flea beetle (*Podagrica* sp.) and Green Peach aphids (*Myzus persicae*) mean numbers increased progressively throughout all the stages. In the present study, the severity of leaf damage was significantly higher at the fruiting stage compared with the flowering and vegetative stages. Plants of cultivars LD and AS were the most promising recording the least leaf damage (111.95) and (119.10) respectively.

Keywords: Okra; abundance; severity; numbers; stages; accessions.

1. INTRODUCTION

Okra *(Abelmoschus esculentus* (L.) Moench) is an annual cultivated mainly for the fresh fruits that are consumed immature as a vegetable in a variety of ways. The crop also serves important medicinal and industrial purposes. Besides, the cultivation, processing and marketing of okra present opportunities for income generation among rural small-holder farmers. All over the growing regions of the tropics and subtropics, production of the crop faces serious challenges of insect pest infestation and viral diseases responsible for considerable yield loss. Consequently, in West Africa in particular, the average yield has been very low at an estimated 2.5 t/ha [1].

In Ghana, low yields in okra are attributed to several production constraints among which low soil fertility and damage caused by insect pests are most critical [2]. Damage caused by insect pests has been reported as the major constraint in the production of okra [3;4]. Tindal [5] reported several insect species infesting okra in Ghana. These include Leaf roller, *Sylepta derogata* (F.), Cotton stainer, *Dysdercus superstitiosus* (F), Cotton aphid, *Aphis gossypii* (Glov.) and flea beetle, *Podagrica uniformis* (Jac.). Critchley [4] reported of 22 insect pests from 12 families in four orders (*Coleoptera*, *Hemiptera, Lepidoptera* and *Orthoptera*) infesting okra in Brong-Ahafo region of Ghana. Of these, the most important are the *Podagrica uniformis* Jacoby and *P. sjostedti* Jacoby, followed by *Aphis gossypii* Glover, *Dysdercus superstitiosus* (Fab) and *Sylepta derogata* (Fab.) and *Heliothis armigera* (Hub.). The blister beetle, *Mylabris* spp., feeds on the flowers, reducing the number of fruits formed, while both adults and nymphs of *A. gossypii* suck sap from young leaves and buds, thus reducing the efficiency of the leaves [6;7].

Two flea beetle species, *P. uniformis* and *P. sjostedti* are responsible for heavy leaf damage of the crop [8]. Extensive leaf damage in the form of feeding holes on the leaves results in a significant reduction of the photosynthetic ability of the plant. The insect pests also feed on fruits, stems, and flowers culminating in poor crop performance and low yields. The *Podagrica* species have also been implicated in the transmission of okra mosaic virus [9;10]. The other insect pests of economic importance in okra production, whiteflies (*Bemisia tabaci*) feed on plant sap and cause the okra leaf curl and yellow vein mosaic diseases [9;11]. The species diversity of insects and their pest status varies from region to region with the variation in agro-climatic conditions. Asare-Bediako et al. [12] indicated that there is always a phenomenon of the continual significant increase in insect populations globally. In Ghana, for instance, rising insect pest populations have been attributed to poor agronomic practices such as the use of untreated seeds for cultivation and the continuous practice of mono-cropping by the majority of local farmers in order to meet the increasing demand of the various staples in the country [12].

As a prerequisite for putting in place an effective integrated insect pest management regime, it is necessary to properly identify which species of insects are major pests, establish their diversity, abundance, and severity of damage they cause to plant parts. It is, therefore, worrying that information on insect pests of okra at its various growth stages in the coastal savannah agro-ecological zone of Ghana is lacking. Thus a specific objective was set out to identify the diversity of insect species associated with ten cultivars of okra, to assess the abundance of the insect species during the vegetative, flowering and fruiting stages and the extent of leaf damage under field conditions. Such information will help farmers to know which insect pests to target, the best time to target control practices and the appropriate approach to use. In addition, the findings of this work will serve as a useful guide in the development of an effective pest management system for okra production, particularly within the coastal savannah agro-ecological zone.

2. MATERIALS AND METHODS

2.1 Soil and Rainfall Pattern of Study Area

The research was conducted in Biotechnology and Nuclear Agriculture Research Institute (BNARI) of the Ghana Atomic Energy Commission (GAEC) between July 2017 and March 2018. The study area is located at Kwabenya, Accra on latitude 5º40' N, longitude 0º13' W with Ochrosol (Ferric Acrisol) soil type, derived from quartzite Schist [13]. The maximum and minimum average temperatures for the period of study were 30.7^{0}C and 26.0^{0}C respectively with an average annual rainfall of 220 mm. The highest and lowest relative humidity is between 75 and 60% [14;15]. The experimental site is also well drained and has an elevation of 76 m above sea level within the coastal savannah agro-ecological zone.

2.2 Plant Materials and Field Design

Plant materials used for the study consisted of five local and five exotic okra cultivars. The local cultivars were Asutem (AS), Togo (TG), Labadi dwarf (LD), Kwabenya (K1) and Adom (AD). These were obtained from Markets (Asamankese and Dome) and okra farmers' fields. The exotic cultivars were Lucky 19F1 (LF1), F1 Kirene (FIK), FI Sahari (FIS), Kirikou F1 (KFI) and Clemson Spineless (CS). These cultivars were obtained from a commercial seed shop, Technisem, Accra. The land was plowed, harrowed and lined and pegged into 40 plots using a Randomized Complete Block Design with four replications. Each replicates measured 35 m x 7 m and separated by 2 m from each other with 10 subplots within a block. Each subplot measured 3 m x 3 m and spaced from one another by 1 m. The total size of the experimental area was 646 m^2. The okra seeds were manually sown to a depth of 2 cm directly at a spacing of 0.50 m x 0.60 m. Four seeds per hill were sown and later thinned to one seedling per hill after emergence. Field management practices such as weed control and watering were done as and when required.

2.3 Data Collection

2.3.1 Insect abundance

Insect abundance was estimated from five okra plants randomly selected from the middle rows. Okra leaves were carefully examined by observing both the abaxial and ad axial surfaces. Insects found on the surfaces of the leaves were identified, counted and recorded as either major or minor based on their incidence pattern. Data was taken daily between the hours of 6.00 am and 8.00 am.

2.3.2 Determination of leaf damage

In order to determine the extent of leaf damage, a scoring scale was designed for this work. Leaf damage was determined by estimating the total number of perforations created by the insects in all leaves found on each of the five randomly selected test plants. This was then divided by the total number of leaves on the plant to obtain the average number of perforations per leaf. The five-point scoring scale is as follows: 1 very mild damage (1 to 15 perforations); 2 mild damage (16 to 30 perforations); 3 moderately severe damage (31 to 45 perforations); 4 very severe damage (46 to 60 perforations); 5 extremely severe damage (more than 60 perforations) (Fig. 1).

2.3.3 Data analysis

The quantitative data on the abundance of insects on ten okra cultivars at vegetative, flowering and fruiting stages were subjected to Analysis of variance (ANOVA) in order to determine the level of significance among ten okra cultivars for leaf damage severity. Duncan's multiple range test was used to determine differences among the means. Statsgraphics Centurion Software (version 16.1) and Microsoft Excel Software (2010 edition) were used for the data analyses and a p-value of 0.05 or less was considered significant.

3. RESULTS AND DISCUSSION

3.1 Diversity of Insect Species Associated with Okra under Field Conditions

Insects present on the ten cultivars of okra under open field conditions observed during the growth stages of the crop are shown in Fig. 2.

Results of the study revealed that all ten cultivars of okra were susceptible to insect pest infestation (Table 1). A total of thirteen insect species belonging to six orders (*Coleoptera, Lepidoptera, Homoptera, Hemiptera, Hymenoptera, Mantodea and Orthoptera*), and twelve families namely *Chrysomelidae, Coccinellidae, Pyrgomorphidae, Meloidae, Noctuidae, Nolidae, Cicadellidae, Aleyrodidae, Aphididae, Pseudococcidae, Mantidae and Formicidae*) were recorded at the study site. The highest number of insect species belong to the order Homoptera and included Okra leafhopper (*Amrasca biguttula*), Whitefly (*Bemisia tabaci*), and Green Peach aphid (*Myzus persicae*). Those found in order Coleoptera were Flea beetle (*Podagrica* sp.), Blister beetle (*Mylabris pustulata*) and ladybird beetle (*Cheilomenes lunata*). The Striped mealy bug (*Ferrisia virgata*) and the Black carpenter ants (*Camponotus* sp were the only insects found in the order Hemiptera and Hymenoptera respectively.). Members of the order Orthoptera identified in this study included the Variegated grasshopper (*Zonocerus variegatus*) and Tobacco grasshopper (*Atractomorpha crenulata*). The order Mantodea had Praying mantis (*Mantis religiosa*) while Lepidoptera included Cotton Semilooper (*Anomis flava*) and Transverse Moth (*Xanthodes transversa*). The Flea beetle and Aphids were the most abundant insect pests. The insect species were grouped into the major and minor following [12] (Table 1).

Although all the insects identified can attack the crop, the level of damage and their abundance varied among the cultivars. Based on the level of damage and their abundance, *Podagrica* sp. and *B. tabaci* were observed as major insect pests of the okra. These findings are consistent with reports of Obeng-Ofori and Sackey [8] and Asare bediako et al. [12]. It was observed that the low numbers of ladybird beetle (*C. lunata*) were responsible for the increase in Whitefly (*B. tabaci*) population. Ladybird beetle (*C. lunata*) have been used as natural enemies to control whitefly population in many plants [16;17;18;19;20].

3.2 Mean Abundance of Insect Species at the Vegetative Stage

The average incidence of flea beetle, whitefly, ants, aphids, spider, ladybird beetle, okra leafhopper, praying mantis, mealy bug and variegated grasshopper at the vegetative stage differed significantly (*P* = .05) among all okra cultivars. Flea beetle had the highest number on Lucky 19F1 (36.00±9.66 insects/plant) followed by K-F1, LD, AS, CS, AD, TG, F1-S, F1-K and K1 with abundance level of32.75±22.88, 28.25±8.10, 23.00±19.06, 19.00±16.63, 18.75±5.12, 17.50±10.66, 16.50±4.20, 11.00±4.97 and 9.00±2.83 respectively. With respect to whitefly, F1-S had the highest number of insects (6.25±2.18) per plant, while LD had the least (1.25±0.50). Cultivar TG recorded the highest mean number of ants (43.25±23.94) and praying mantis (0.70±1.00) per plant, whereas, cultivar AS and F1-S had the minimum infestation of ants (3.25±3.10) and praying mantis (0.24±0.10). Similarly, CS had the highest mean number of spiders and okra leafhopper of 0.75±0.50 and 0.75±1.50 per

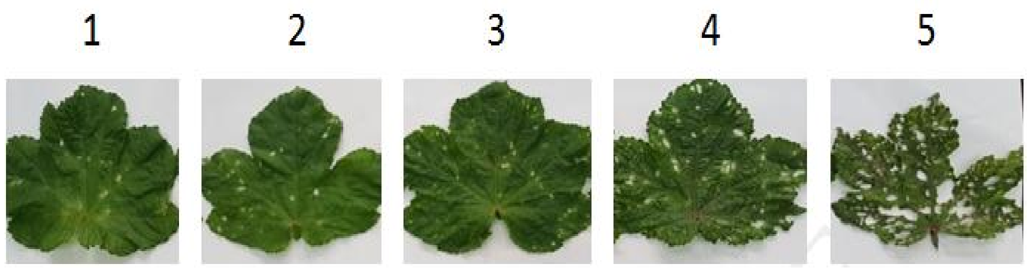

Fig. 1. Rating of the severity of leaf damage

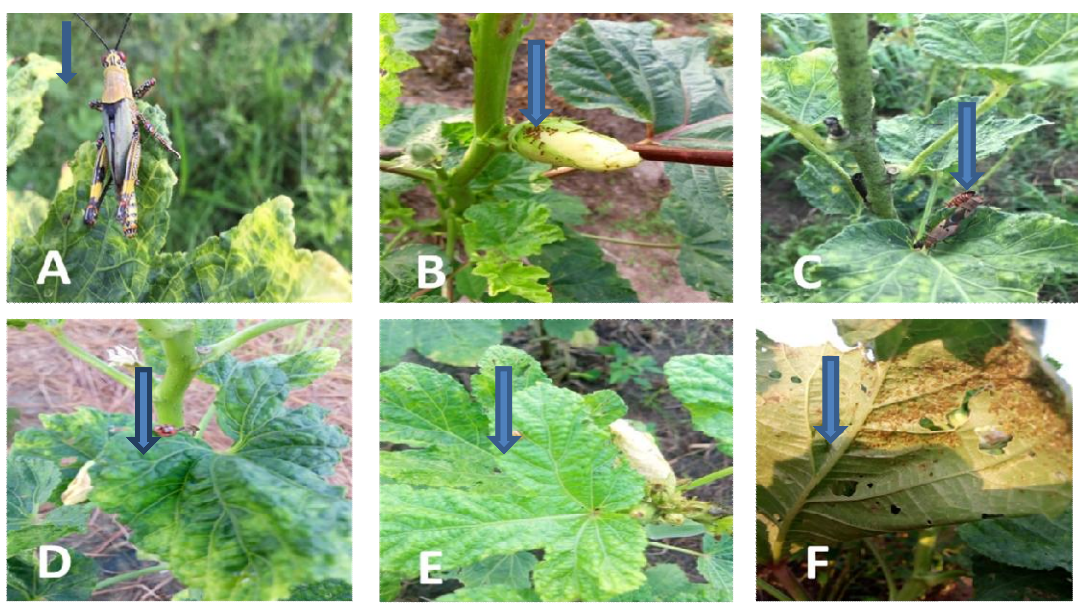

Fig. 2. Some insect species identified in the studied okra cultivars
A = Variegated grasshopper, B = Ants, C = Cotton stainer, D = Lady bird beetle, E = Flea beetle, F = Aphid

Table 1. Insect species associated with the ten okra cultivars under field conditions

Family	Common name	Scientific name	Plant part infested	Relative abundance	Pest status
Chrysomelidae	Flea beetle	*Podagrica* sp.	Leaf	11.97	Major
Aleyrodidae	Whitefly	*Bemisia tabaci* (Gennadius)	Leaf	6.1	Minor
Aphididae	Green peach aphids	*Myzus persicae* (Sulzer)	Leaf, flower buds, flowers	66.46	Major
Formicidae	Black carpenter ants	*Camponotus* sp.	None	8.51	None
Lycosidae	Spider	*Hogna lenta* (Hentz)	None	0.21	None
Coccinellidae	Ladybird beetle	*Cheilomenes lunata* (Fabricius)	None	0.54	None
Cicadellidae	Okra leaf hopper	*Amrasca biguttula biguttula* (Ishida)	Leaf	5.12	Minor
Mantidae	Praying mantis	*Mantis religiosa* (Burmeister)	None	0.04	None
Pseudococcidae	Striped mealybugs	*Ferrisia virgata* (Cockerell)	Leaf, fruit	0.94	Minor
Pyrgomorphidae	Variegated grasshopper	*Zonocerus variegatus* (Linnaeus)	Leaf	0.02	Minor
	Tobacco grass hopper	*Atractomorpha crenulata* (Fabricius)	Leaf	0.04	Minor
Meloidae	Blister beetle	*Mylabris pustulata* (Thunberg)	Flower buds and flowers	0.04	Minor
Noctuidae	Cotton semilooper	*Anomis flava* (Fabricius)	Leaf	0.004	Minor
Nolidae	Transverse moth	*Xanthodes transversa* (Guenee)	Leaf	0.002	Minor

Table 2. Mean abundance of insect species of the ten okra cultivars at the vegetative stage

Accessions	Flea beetle	Whitefly	Ants	Aphids	Ladybird beetle	Okra leafhopper	Praying mantis	Mealybug	Grass hopper
AD	18.75 ± 5.12^{ab}	2.00 ± 1.15^{a}	7.00 ± 4.54^{b}	25.65 ± 7.10^{a}	0.25 ± 0.10^{ab}	1.00 ± 0.41^{a}	0.25 ± 0.10^{a}	1.00 ± 0.41^{ab}	1.50 ± 0.20^{ab}
AS	23.00 ± 19.06^{ab}	5.75 ± 3.94^{a}	3.25 ± 3.10^{b}	25.05 ± 17.53^{a}	0.20 ± 0.10^{b}	0.57 ± 0.50^{a}	0.50 ± 0.20^{a}	1.50 ± 0.33^{ab}	0.25 ± 0.10^{ab}
CS	19.00 ± 16.63^{ab}	1.75 ± 0.21^{a}	20.75 ± 17.42^{ab}	22.30 ± 7.40^{a}	0.25 ± 0.10^{ab}	0.75 ± 1.50^{a}	0.50 ± 0.10^{a}	1.25 ± 0.50^{ab}	0.50 ± 0.07^{ab}
F1-K	11.00 ± 4.97^{b}	3.50 ± 2.90^{a}	28.25 ± 14.63^{ab}	23.08 ± 16.3^{a}	0.18 ± 0.10^{b}	1.25 ± 1.00^{a}	0.25 ± 0.10^{a}	0.75 ± 0.50^{ab}	0.50 ± 0.20^{ab}
F1-S	16.50 ± 4.20^{ab}	6.25 ± 2.18^{a}	12.50 ± 10.10^{b}	19.25 ± 12.6^{a}	1.00 ± 0.20^{ab}	0.25 ± 0.10^{a}	0.24 ± 0.10^{a}	0.75 ± 0.10^{ab}	0.50 ± 0.37^{ab}
K1	9.00 ± 2.83^{b}	3.75 ± 1.92^{a}	17.50 ± 16.86^{ab}	25.25 ± 15.10^{a}	0.25 ± 0.20^{ab}	0.50 ± 0.20^{a}	0.50 ± 0.20^{a}	2.25 ± 1.50^{a}	1.00 ± 0.81^{ab}
K- F1	32.75 ± 22.88^{a}	3.75 ± 2.97^{a}	19.50 ± 14.80^{ab}	27.00 ± 12.76^{a}	0.25 ± 0.20^{ab}	1.00 ± 0.20^{a}	0.51 ± 0.10^{a}	1.50 ± 1.11^{ab}	0.20 ± 0.10^{b}
L D	28.25 ± 8.10^{ab}	1.25 ± 0.50^{a}	9.25 ± 3.40^{b}	28.10 ± 10.44^{a}	1.50 ± 1.00^{a}	1.25 ± 0.50^{a}	0.50 ± 0.20^{a}	1.75 ± 0.26^{ab}	1.75 ± 0.40^{a}
L-19F1	36.00 ± 9.66^{a}	3.50 ± 0.32^{a}	12.00 ± 11.52^{b}	19.25 ± 9.50^{a}	0.75 ± 1.00^{ab}	2.00 ± 0.44^{a}	0.60 ± 0.30^{a}	0.25 ± 0.10^{b}	1.50 ± 1.30^{ab}
TG	17.50 ± 10.66^{ab}	2.50 ± 1.38^{a}	43.25 ± 23.94^{a}	14.60 ± 9.20^{a}	0.50 ± 1.00^{ab}	2.50 ± 1.10^{a}	0.70 ± 0.10^{a}	1.25 ± 1.00^{ab}	0.75 ± 0.50^{ab}

Note: Means followed by the same superscript in the same column are not significantly different at 5% probability level according to Duncan's multiple range tests

Table 3. Mean abundance of insect species of the ten okra cultivars at the flowering stage

Cultivar	Flea beetle	Whitefly	Ants	Aphids	Ladybird beetle	Okra leafhopper	Praying mantis	Mealybug	Grass hopper
AD	31.75±24.66^{a}	13.00±5.64^{a}	8.00±6.50^{b}	10.57±0.44^{a}	1.00±0.82^{a}	9.75±6.60^{ab}	1.50±1.30^{ab}	0.75±0.50^{bc}	0.75±0.50^{ab}
AS	23.25±22.64^{a}	18.75±13.12^{a}	17.50±4.73^{b}	11.13±5.88^{a}	0.75±0.96^{a}	9.50±5.68^{ab}	0.75±1.50^{b}	2.75±2.22^{a}	2.75±2.21^{a}
CS	20.50±12.76^{a}	14.00±4.40^{a}	12.75±2.87^{b}	11.20±5.92^{a}	0.75±1.50^{a}	7.25±5.90^{ab}	2.50±1.73^{a}	0.50±0.27^{c}	1.25±0.50^{ab}
F1-K	13.25±3.00^{a}	14.25±5.85^{a}	9.00±6.10^{b}	18.20±7.55^{a}	0.75±0.96^{a}	5.00±3.56^{b}	1.50±1.30^{ab}	0.50±0.10^{c}	1.25±0.50^{ab}
F1-S	20.50±14.86^{a}	22.25±4.03^{a}	20.75±12.40^{b}	16.75±7.30^{a}	1.25±1.50^{a}	9.50±7.14^{ab}	0.10±0.00^{b}	0.10±0.00^{c}	2.75±2.22^{a}
K1	13.75±11.50^{a}	18.75±0.60^{a}	6.00±1.50^{b}	17.77±5.30^{a}	1.00±1.41^{a}	8.25±5.12^{ab}	0.50±0.10^{b}	1.25±1.50^{abc}	1.25±0.50^{ab}
K- F1	18.50±12.50^{a}	18.25±3.40^{a}	21.50±9.20^{b}	13.95±9.06^{a}	0.50±0.18^{a}	10.5±3.11^{ab}	0.50±0.10^{b}	0.75±0.16^{bc}	0.75±0.50^{ab}
L D	28.00±14.07^{a}	21.25±14.60^{a}	18.75±13.20^{b}	13.80±6.87^{a}	0.75±0.50^{a}	12.5±7.93^{ab}	1.50±0.73^{ab}	0.25±0.10^{c}	3.75±0.40^{b}
L-19F1	32.25±10.30^{a}	22.50±14.64^{a}	20.00±10.04^{b}	12.53±2.63^{a}	0.50±1.00^{a}	14.0±5.71^{a}	0.50±0.10^{b}	2.50±0.08^{ab}	2.25±1.70^{ab}
TG	22.75±12.78^{a}	26.75±19.94^{a}	51.50±20.73^{a}	12.07±3.78^{a}	1.25±1.26^{a}	8.25±3.77^{ab}	1.00±0.82^{ab}	0.26±0.10^{c}	0.20±0.10^{b}

Note: Means followed by the same superscript in the same column are not significantly different at 5% probability level according to Duncan's multiple range tests

Table 4. Mean abundance of insect of ten okra accessions at the fruiting stage during the study

Accessions	Flea beetle	Whitefly	Ants	Aphids	Ladybird beetle	Okra leafhopper	Praying mantis	Mealybug	Grass hopper
AD	29.75±7.80^{bc}	22.50±9.45^{a}	29.25±4.55^{ab}	75.00±2.42^{ab}	1.00±1.15^{a}	15.00±13.08a	1.50±1.73^{a}	0.75±1.50^{ab}	0.50±1.00^{a}
AS	22.00±7.44^{bc}	19.00±4.25^{a}	19.50±5.05^{ab}	76.50±8.63^{ab}	0.50±1.00^{a}	14.25±12.20a	1.00±0.81^{a}	1.25±0.96^{ab}	0.40±1.00^{a}
CS	27.50±4.80^{bc}	18.00±4.31^{a}	15.50±11.00^{ab}	77.50±4.70^{ab}	1.50±1.30^{a}	5.75±6.18a	0.75±0.50^{a}	1.00±1.15^{ab}	2.25±2.06^{a}
F1-K	22.00±16.10^{bc}	11.25±3.77^{a}	13.50±12.01^{ab}	33.75±5.10^{b}	0.25±0.50^{a}	3.50±0.68a	1.50±1.73^{a}	1.25±1.50^{ab}	0.75±0.50^{a}
F1-S	32.00±12.30^{abc}	15.25±2.75^{a}	9.00±2.94^{b}	53.75±8.50^{ab}	1.00±1.41^{a}	4.25±1.43a	2.00±2.82^{a}	2.75±2.21^{a}	0.50±0.58^{a}
K1	21.75±2.90^{bc}	9.75±7.41^{a}	30.50±11.73^{a}	12.50±0.34^{a}	0.50±1.00^{a}	12.25±2.12a	3.25±2.63^{a}	0.75±0.96^{ab}	0.50±1.00^{a}
K- F1	33.25±14.30^{ab}	14.00±3.98^{a}	17.00±12.02^{ab}	71.75±9.54^{ab}	0.50±1.00^{a}	17.00±8.05a	2.75±2.21^{a}	0.25±0.50^{b}	1.50±1.91^{a}
L D	47.50±13.53^{a}	21.00±9.20^{a}	16.75±8.40^{ab}	75.00±4.90^{ab}	1.00±2.00^{a}	10.75±9.32a	1.00±1.41^{a}	1.75±2.22^{ab}	1.25±1.50^{a}
L-19F1	46.00±3.20^{a}	28.50±3.23^{a}	16.00±0.60^{ab}	56.75±2.74^{ab}	1.75±2.06	13.75±3.09a	2.00±0.82^{a}	0.75±0.96^{ab}	1.50±1.30^{a}
TG	17.25±14.86^{c}	22.00±6.77^{a}	13.75±7.37^{ab}	77.50±1.64^{ab}	2.50±3.11^{a}	12.50±8.50a	2.00±1.15^{a}	2.00±1.15^{ab}	0.75±0.96^{a}

Note: Means followed by the same superscript in the same column are not significantly different at 5% probability level according to Duncan's multiple range tests plant respectively, whilst cultivar F1-S had the least infestation of spider (0.20±0.11) and okra leafhopper (0.25±0.10). Cultivar LD had the highest mean number of mealy bugs (1.75±0.26) and grasshopper (1.75±0.40) whereas cultivar L-19F1 and K-F1 had the least mean numbers of mealybugs (0.25±0.10) and grasshopper (0.20±0.10) per plant. Cultivars K-F1 and LD had the highest mean abundance of aphids and ladybird (27.00±12.76 and 1.50±1.00 respectively) while the least was recorded on TG (14.60±9.20) and F1-K (0.18±0.10) [Table 2].

3.3 Abundance of Insect Species at the Flowering Stage

The mean abundance of insect species recorded at the flowering stage on the okra cultivars was significantly different (*P* = .05) from each other. Plants of L-19F1 had the highest mean number of Flea beetles/plant (32.25±10.30) while cultivar F1-K had the least number per plant (13.25±14.86). In the case of whitefly, cultivar TG had the highest mean abundance per plant (26.75±19.94) while AD had the least. Cultivar K-F1 recorded the highest mean number of ants (21.50±15.20) and spider (1.25±1.00) per plant whilst cultivar AD recorded the least infestation of ants (8.00±6.50) and spider (0.12±0.10). Mealy bug infestation was highest in cultivar AS (2.75±2.22) and least in LD (0.25±0.10). Cultivar LD had the highest mean number of grasshoppers per plant (3.75±0.40) whilst the least mean number (0.20±0.10) was recorded on TG. Cultivar K1, F1-S, L-19F1 and CS had the highest mean number of Aphids, Ladybird beetle, okra leafhopper and Praying mantis of 17.77±5.30, 1.25±0.50, 14.0±5.71 and 2.50±1.73 respectively [Table 3].

3.4 Mean Abundance of Insect Species at the Fruiting Stage

Significant differences (*P* = .05) were obtained in the abundance of insects among the ten okra cultivars at the fruiting stage. Plants of LD had the highest mean abundance of flea beetles per plant (47.50±13.53) whereas F1-K recorded the least (13.50±3.00). With respect to whitefly infestation, plants of L-19F1 had the highest mean abundance of 28.50±13.23 per plant with K1 recording the least (9.75±7.41). Plants of cultivar TG recorded the highest infestation of aphids (77.50±1.64) and ladybird (2.50±3.11) whereas K1 and F1-K had the least (12.50±10.34 and 0.25±0.50 respectively). Similarly, cultivar K-F1 recorded the highest mean number of okra leafhopper (17.00±8.05) whilst CS had the highest number of grasshoppers (2.25±2.06). Cultivar K1 recorded the highest mean incidence of ants (30.50±11.73) and praying mantis (3.25±2.63) [Table 4].

Green peach aphid (*M. persicae*), flea beetle (*Podagrica* sp.), Okra leafhopper (*A. biguttula biguttula*), whitefly (*B. tabaci*), striped mealybug (*F. virgata*), Black carpenter ants (*Camponotus* sp.), spider (*H. lenta*), ladybird beetle (*C. lunata*), variegated grasshopper (*Z. variegatus*) and praying mantis (*M. religiosa*) were the common insects observed at vegetative, flowering and fruiting stages. The total number of insects differed from one stage to another. A total of 1,439 insects were recorded at the fruiting stage which was significantly higher than the flowering (855) and vegetative stages (693). The variation in the number of insect species observed at the different developmental stages could be due to environmental changes as suggested by Abro et al. [21]. Mean whitefly count was relatively low at the vegetative, flowering and fruiting stages of the cultivars. However, Flea beetle (*Podagrica* sp.) and Green peach aphid numbers increased progressively throughout all the stages.

3.5 Severity of Leaf Damage by Flea Beetle (*Podagrica* Sp.)

Mean severity scores of leaf damage by flea beetles (*Podagrica* sp.) during the vegetative, flowering and fruiting stages of the various cultivars are shown in Table 5. The results showed that the severity of damage during the above stages differed significantly among the ten okra cultivars. Cultivar F1-S had the highest severity score (4.56.50 perforations) whilst the least score (2; 16.40 perforations) was associated with CS. There were significant differences in the leaf damage by the flea beetle, and among the okra cultivars during the vegetative stage. At the flowering stage, the highest damage was observed in L-19F1 (5; 68.60 perforations) whilst the least was observed in LD (3; 33.10 perforations). With respect to the fruiting stage, plants from accession CS recorded the highest mean leaf damage (5; 79.70 perforations) followed by L-19F1 (5;78.10) with AS having the least leaf damage, (3;41.10). According to Echezona and Offordile [9], the feeding activity of flea beetle (*Podagrica* sp.) causes damage consisting of characteristic perforations of leaves resulting in uneven holes which decrease the photosynthetic surface area of the leaves, culminating in high yield loss of

Table 5. The severity of leaf damage by flea beetle (*Podagrica* sp.) during three developmental stages of ten okra accessions

Accession	Number of perforations per leaf		
	Vegetative* stage	Flowering* stage	Fruiting* stage
AD	(2)17.10	(4)51.40	(5)64.70
AS	(3)38.00	(3)40.10	(3)41.10
CS	(2)16.70	(5)68.60	(5)79.70
F1-K	(2)16.40	(4)54.90	(5)68.10
F1-S	(4)56.50	(4)50.55	(5)64.45
K1	(2)20.00	(4)59.85	(4)57.55
K- F1	(3)33.10	(4)49.95	(4)54.15
L D	(2)22.20	(3)33.10	(4)56.65
L-19F1	(3)39.50	(5)61.65	(5)78.10
TG	(2)29.40	(3)44.25	(5)72.70

**Bolded value in bracket indicates damage level on a five-point scale whereas corresponding value represents the number of leaf perforations. The scoring scale is as follows: 1 very mild damage (1 to 15 perforations); 2 mild damage (16 to 30 perforations); 3 moderately severe damage (31 to 45 perforations); 4 very severe damage (46 to 60 perforations); 5 extremely severe damage (more than 60 perforations)*

okra. In the present study, leaf damage was significantly higher at the fruiting stage compared with the flowering and vegetative stages. These results are consistent with those of Eguatu and Taylor [22] and Schipers [23] who reported increase in leaf damage caused by *Podagrica* sp. at the reproductive stages than the vegetative stage due to abundance of food sources such as pods, flowers and buds that attract a lot of the flea beetle to the okra plant. Plants of cultivars LD and AS were the most promising, recording the least leaf damage. These cultivars exhibit a good inherent potential to withstand insect attack and as such would be good materials for cultivation by farmers and for breeding.

4. CONCLUSION

A total of thirteen insect types belonging to five orders (*Coleoptera, Homoptera, Hymenoptera, Mantodea* and *Orthoptera*) and thirteen families (*Chrysomelidae, Coccinellidae, Pyrgomorphidae, Meloidae, Noctuidae, Nolidae, Cicadellidae, Aleyrodidae, Aphididae, Pseudococcidae, Mantidae, Formicidae*, and *Acrididae*) were identified in the field. Out of the thirteen families recorded, two beneficial organisms Ladybird beetle and Spider belonging to the *Coccinellidae* and *Lycosidae* respectively were also found to be present in the field. A total of 1,439 insects were recorded at the fruiting stage which was significantly higher than the flowering (855) and vegetative stages (693). Whitefly (*B. tabaci*) count was relatively low at the vegetative, flowering and fruiting stages of the cultivars. However, *Podagrica* sp. numbers increased progressively throughout all the stages., Leaf damage was significantly higher at the fruiting stage compared to the flowering and vegetative stages. Plants of cultivars LD and AS were the most promising recording the least leaf damage.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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