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Research Article

Variations in insect-induced fruit damage and yield of okra *Abelmoschus esculentus* after insecticide treatments at different phenological growth stages

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Abstract: Several phytophagous insect pests are known to attack okra, *Abelmoschus esculentus* (L.) Moench in the field. However, information on the fruit-damaging species and the effective time for insecticide application(s) is still scanty. Field experiments were conducted in 2017 and 2018 to identify the categories of damage inflicted on okra fruits by associated insect herbivores and to ascertain the phenological growth stage in which insecticide applications will significantly reduce insect-induced fruit damage and improve crop yield. Treatments consisted of the application of Cypermethrin 20EC at two-week intervals on NHAe47-4 variety of okra during the vegetative stage (VGS), reproductive stage (RGS), VGS + RGS, and no spray (control). The setup was in randomized complete blocks with four replicates. Results showed that incisions, feeding lesions, localized discolorations, bumps, distortions, and larval exit holes are the major fruit damage symptoms caused by field insect pests of okra. Generally, fruit damage was significantly reduced, while fruit yield was higher in plots that received insecticide sprays at vegetative and reproductive stages than in the control. Fruit production increased significantly by 56.9–69.6% and 57.7–73.1% in 2017 and 2018 in treated plots compared to control, respectively. Fruit damage was reduced by 37.5-92.5% (2017) and 44.6–94.6% (2018), and fresh fruit yield of okra was increased by [58.8–75.0% (2017) and 63.1-76.1% (2018)]. We conclude that an effective field management strategy for insects associated with okra fruit damage should include potent control tactics at the crop's vegetative and reproductive growth stages.

Keywords: Crop phenology, cypermethrin, fruit damage, okra, pest control

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Introduction

Okra (*Abelmoschus esculentus* L. Moench) is one of the most important fruit-bearing vegetable crops in the Malvaceae family, and it is widely grown in the tropics, sub-tropics, and warmer areas of the temperate regions of the world for numerous purposes (Bawa and Badrie, 2016; Ekoja and Pitan, 2022). Different parts of the plant have been subjected to a variety of food, therapeutic, aesthetic, and industrial uses (Hinsley, 2008; Gemede *et al*., 2014; Adja *et al*., 2019). The fruit is particularly rich in protein, vitamins, and mineral elements needed for the development and

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maintenance of the human body and could be used either fresh, cooked, or fried (Tindall, 1983). In West Africa, they are boiled in water to make soups/ sauces (Ndunguru and Rajabu, 2004; Ahmed *et al*., 2006). They are also used in neutralizing the acidic substances produced in the course of digestion of meat and other foods, as plasma replacement, as blood volume expander, and for several medicinal and industrial applications (Siemonsma and Kouame, 2004; Ahmed *et al*., 2006; Gemede *et al*., 2014; Santini *et al*., 2017; Durazzo *et al*., 2018).

The importance of this multi-purpose crop is not comprehended by man alone but by insects as well. Several insect pests have been reported to attack the leaves, stem, bud, flowers, calyx, roots, and fruits with estimated yield loss exceeding 69% of total harvests (Pitan and Ekoja, 2011; 2012; Samaila and Oaya, 2014; Adja *et al*., 2019). Damage caused by insects in the field is one of the major production constraints, making a significant proportion of harvested okra fruit fall short of relevant standards required for agricultural commodity acceptance in export and local markets. Many insects from different orders (such as Coleoptera, Lepidoptera, Hemiptera, and Orthoptera) have been identified as biotic sources of damage associated with okra fruits (Nair *et al*., 2017; N'guettia *et al*., 2017; Adja *et al*., 2019). The damages caused are diverse; on different occasions, some studies have reported isolated instances of feeding lesions, fruit distortion, lumps, and larval exit holes (Obeng-Ofori and Sackey, 2003; Pitan and Ekoja, 2012; Brandenberger *et al*., 2019).

Various research efforts have identified different methods for controlling okra insect pests. Examples include early harvesting of fruits to avoid damage by fruit borers (Brandenberger *et al*., 2019), the use of yellow sticky traps (Ekoja and Pitan, 2022), and the use of bioactive extracts from plants like *Azadirachta indica* A. Juss., *Annona squamosa* Linn., *Jatropha curcas* Linn., *Monodora myristica* Gaertn., *Vernonia amygdalina* Del., etc. (Emosairue and Uguru, 1999; Mohammed, 2000; Anaso and Lale, 2002; Onunkun, 2012). Furthermore, good field sanitation practices/ removal of alternate weed hosts (Kumar *et al*., 2021) and intercropping okra with crops like tomato, cowpea, groundnut, etc., have been recommended for the practical field management of okra insect pests (Ahmed *et al*., 2006; Pitan and Olatunde, 2006). However, synthetic insecticides are one of the best-known and most extensively used control options against the insect pests of okra. A vast majority of farmers rely on chemical groups, such as organophosphates, carbamates, organochlorine, and pyrethroids, to suppress insect pest population whenever there is an outbreak or a resurgence of their population (Mohankumar *et al*., 2016; Adja *et al*., 2019).

Cypermethrin is one of the highly potent pyrethroids widely used against insect herbivores associated with okra in the field (Singh *et al*., 2012; Ahmad *et al*., 2017; Mayannavar *et al*., 2017). However, information on the best time to effectively apply the insecticide to reduce infestation and damage caused by fruit-damaging insects is still scarce. There is also insufficient information about the categories of direct fruit damage caused by insect pests of okra. In most cases, this aspect is completely ignored when insect damage assessments are made in okra fields, with notable exceptions to studies involving fruit borers (such as *Earias vitelli* Fabricius, *E. insulana* Boisduval, and *Helicoverpa armigera* Hübner). Information on these important variables could boost our knowledge of the insect problems associated with okra fruits and how to manage them effectively, especially when planning a sustainable pest management program for insects associated with the crop. Hence, this study was carried out to identify the fruit-damaging insect species of okra at Makurdi, Nigeria; to determine the categories of damage(s) they inflict on okra fruits, and to ascertain the plant growth stage in which insecticide interventions will significantly reduce fruit damage by insects and improve crop yield.

Materials and Methods

Experimental site

The experiment was carried out between June and September 2017 and 2018 at the Agronomy unit of the Teaching and Research Farms of the Federal University of Agriculture, Makurdi (FUAM), Benue State, Nigeria (NG) (Longitude 8°36'45.4"E, Latitude 7°47'40.1"N and 104 m above sea level). Makurdi falls within the Southern Guinea savanna agroecological zone of Nigeria.

Source of planting material

NHAe47-4 variety of okra obtained from the National Horticultural Institute (NIHORT), Ibadan NG was used for the experiment. It is an improved variety that grows up to 1 m, flowers within 42-50 days, and fruiting commences in about 4-6 days afterward.

Experimental procedure

Land clearing and ridges were done manually using a cutlass and hoe. The field comprised 16 plots (dimension: 5 m × 4 m per plot). Each plot was separated from the other by 2 m alleyways. Sowing was done on the 5th and 4th of June in 2017 and 2018, respectively. Three okra seeds were sown per hole and later thinned to one plant per stand ten days after sowing. A row spacing of 60 cm × 40 cm was maintained in each plot in both years. Supplying missing crop stands was carried out until 2 WAS to ensure a uniform number of plants per plot. NPK 20:10:10 fertilizer was applied at 3 WAS at 150 kg ha^{-1} based on recommendations from a preliminary soil test result. Weeding was done manually at 3, 6, and 9 WAS. While fruit harvesting was carried out four times in each cropping year.

Cyperkill® (Cypermethrin 20EC) was used in the study. Three spray regimes and a control were used in both years. The treatments comprised of cypermethrin application at the rate of 1.0 ml/ L, at 2-week intervals, during the vegetative growth stage (VGS) (crops were sprayed at 2, 4, and 6 WAS), reproductive growth stage (RGS) (crops were sprayed at 8, 10 and 12 WAS), VGS + RGS (plots were sprayed at 2, 4, 6, 8, 10 and 12 WAS) and untreated plots served as the control. The treatments were laid out in randomized complete blocks with four replicates. During insecticide sprays, the four sides of each plot were temporarily covered with a 2 m tall tarpaulin sheet to avoid drifts to neighboring plots.

Data collection

Plots were examined daily between 07:00 and 10:00 h GMT when the insects were relatively inactive and visible on the fruits. Apart from yield, all data were taken from two middle rows (net plots) within each unit. Records on the insect species found on fruits, the damage caused, the number of plants with damaged fruits, and the number of days to 50% fruiting were made per plot. Apart from fruit borers and aphids, a sweep net (38 cm diameter) was used to collect six individuals (both male and female) of each insect species encountered on the fruits. An intact fresh fruit was then infested artificially with the captured species, covered with a 1 mm mesh net, and observed for ≥7 days in the field to confirm the nature of damage caused by the insect species. The fruits of the crop were used to assess the severity of damage caused by the insects. The ratings used were: very severe = >70% of plants in the control plots were damaged; severe = 50 – 69% crop damage in control plots; moderate = 20 - 49% damage; mild = 1- 19% crops were damaged, and the insects damaged none = no plant. At each harvest, the fruits were sorted into damaged and undamaged categories. The number of fruits with damage symptoms such as incisions, lesions, discolorations, bumps, distortions, and exit holes was recorded. Data on the weight of damaged fruits and crop yield were also taken at each harvest and cumulated.

Identification of insect species

The larvae of fruit borers encountered in the field were reared to the adult stage at the Crop and Environmental Protection Laboratory of FUAM, NG, before subjecting them to the species identification processes. Samples of insects collected were identified at the Insect Museum of the Institute for Agricultural Research, Samaru, Zaria.

Determination of cypermethrin residue in okra fruits

The Shimadzu® Gas Chromatography-Tandem Mass Spectrometry (GC-MS/MS) was used for this analysis. Fruit samples were collected at 0 (2 h after spray), 7 days, and 14 days after the last dose of cypermethrin was applied in the field (12 WAS). The residue analysis was conducted at Multi-Lab, Ikorodu, NG. The procedures for preparation of the standard, validation of the method, extraction, and clean-up were as described by Agilent Technologies Inc (2015).

Statistical analyses

Numerical data collected were subjected to analysis of variance using SAS Institute (2009). Where *F*-statistics were significant, means were separated using Student Newman Keul's (SNK) ($\alpha = 0.05$). Pearson's correlation analysis between insect-induced fruit damage and yield parameters was also carried out on data from both years.

Results

Podagrica uniforma Jacoby, *Nisotra dilecta* Dalman, *Monolepta goldingi* Bryant, and *Monolepta nigerae* Bryant made incisions on fruits, leading to feeding lesions and distortions in fruit shape (Table 1). While fruit feeding by *Dysdercus volkeri* Schmidt, *Aphis gossypii* Clover, and *Bemisia tabaci* Gennadius caused lesions and localized discolorations on the exocarp of fruits. "Stings" (fruit piercing and sucking) by *Nezara viridula* Linnaeus caused bumps on the fruit's skin with yellowish-white discolorations at the points of damage. Fruit boring by *E. vittella* and *H. armigera* resulted in exit holes and localized brownish-black discolorations. *Zonocerus variegatus* Linnaeus also made incisions and feeding lesions on the exocarps of infested fruits. Only the larval stage of the lepidopterans identified caused damage to the okra fruits. Whereas the adult stage of insects in the Coleoptera made incisions on the fruits. Both adult and the nymphal stages of insects in the Heteroptera, Homoptera and Orthoptera identified caused damage to the okra fruits. Damages caused by *P. uniforma* (80.5%) and *N. dilecta* (70.5%) were considered to be very severe, while those of *E. vittella* (55%) and *H. armigera* (50%) were rated as severe. Moderate damage was inflicted by *D. volkeri* (48.5%) and *M. goldingi* (25%). Whereas *M. nigerae* (15.5%), *N. viridula* (12.5%), *A. gossypii* (8.5%), *B. tabaci* (9.5%), and *Z. variegatus* (15.5%) caused mild damages to the crops.

Table 1 Insect species encountered and nature of damage they caused on fruits of okra *Abelmoschus esculentus*.

Scientific name	Order	Family	Pest stage attacking fruits	Severity of damage	Nature of damage to fruits			
					Incisions	Lesions/ Discolourations	Bumps/ Distortions	Exit holes
Podagrica uniforma Jacoby	Coleoptera	Chrysomelidae	Adult	Very severe	✓	✓	✓	-
Nisotra dilecta Dalman,	Coleoptera	Chrysomelidae	Adult	Very severe	✓	✓	✓	-
Monolepta goldingi Bryant	Coleoptera	Chrysomelidae	Adult	Moderate	✓	✓	✓	-
Monolepta nigerae Bryant	Coleoptera	Chrysomelidae	Adult	Mild	✓	✓	✓	-
Dysdercus volkeri Schmidt	Heteroptera	Pyrrhocoridae	Adult, Nymph	Moderate	-	✓	-	-
Nezara viridula Linnaeus	Heteroptera	Pentatomidae	Adult, Nymph	Mild	-	✓	✓	-
Aphis gossypii Clover	Homoptera	Aphididae	Adult, Nymph	Mild	-	✓	-	-
Bemisia tabaci Gennadius	Homoptera	Aleyrodidae	Adult, Nymph	Mild	-	✓	-	-
Earias vittella Fabricius	Lepidoptera	Noctuidae	Larvae	Severe	-	✓	-	✓
Helicoverpa armigera Hübner	Lepidoptera	Noctuidae	Larvae	Severe	-	✓	-	✓
Zonocerus variegatus Linnaeus	Orthoptera	Pyrgomorphidae	Adult, Nymph	Mild	✓	✓	-	-

Severity ratings: very severe = >70% of plants in the control plots were damaged; severe = 50 – 69% crop damage; moderate = 20 - 49% damage; and mild = 1- 19% damage; ✓ = Present, - = No occurrence.

Okra plants in plots that were sprayed at both vegetative and reproductive growth stages achieved 50% fruiting earlier, and they differed significantly (2017: $F_{3,9} = 111.60$; $P < 0.001$, 2018: $F_{3,9} = 58.36$; $P < 0.001$) from plants in other treated plots and the control in both years (Figure 1). However, fruit initiation by plants in control plots was significantly prolonged (56 and 55 days in 2017 and 2018, respectively) compared with those in treated plots. Generally, applying the insecticide at vegetative and reproductive growth stages enabled plants in those plots to fruit earlier than those in control.

There were no insect-induced incisions, lesions, distortions, or exit holes on okra fruits treated with the insecticide at vegetative and reproductive growth stages, except in 2017, when few lesions were observed on the fruits. It was not significantly different ($P > 0.05$) from the observations made in plots where all their fruits were undamaged (Table 2). Insecticide sprays at both vegetative and reproductive growth stages of okra brought about a significant reduction of all the fruit damage categories [incisions (2017: $F_{3,9}$ = 82.06; $P < 0.001$, 2018: $F_{3,9}$ = 147.00; $P < 0.001$), lesion/discolorations (2017: $F_{3,9}$ = 15.25; $P < 0.001$, 2018: $F_{3,9}$ = 15.00; $P < 0.001$), bumps/ distortions (2017: $F_{3,9}$ = 71.14; $P < 0.001$, 2018: $F_{3,9}$ = 23.45; $P < 0.001$) and exit holes (2017: $F_{3,9}$ = 118.09; $P < 0.001$, 2018: $F_{3,9}$ = 63.44; $P < 0.001$)] observed in both years. However, insect damage on fruits sprayed at both vegetative and reproductive growth stages and those sprayed only at the vegetative stage were not significantly different ($P > 0.05$) in both years. All the categories of fruit damage evaluated in both years were found on plants sprayed at the vegetative growth stage alone, and the fruit damage observed in those plots was higher than in other treated plots.

Using cypermethrin for insect pest control increased okra fruit production by 56.9–69.6% and 57.7–73.1% in 2017 and 2018 compared to control, respectively (Table 3). The pyrethroid also reduced insect-induced fruit damage by 37.5 - 92.5% and 44.6 – 94.6% in 2017 and 2018 compared to the control. Damage to fruits of plants sprayed at both vegetative and reproductive growth stages was not significantly different ($P > 0.05$) from those treated only at the reproductive growth stage.

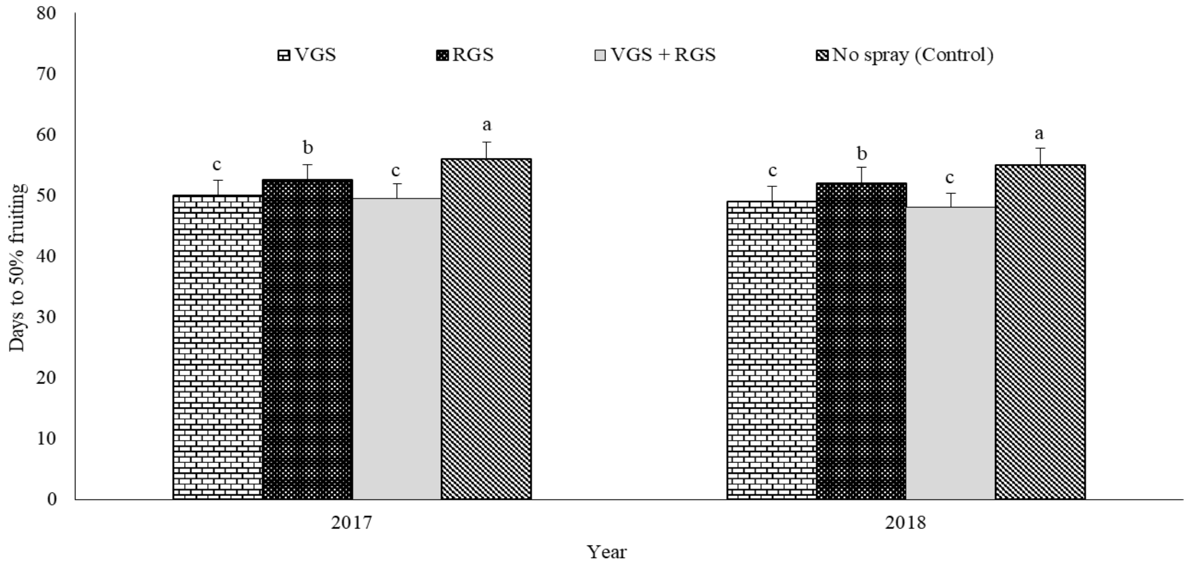

Figure 1 Effect of Cypermethrin on the number of days to 50% fruiting of okra *Abelmoschus esculentus* plants treated at different growth stages in Makurdi, Nigeria
VGS = Vegetative growth stage; RGS = Reproductive growth stage; VGS + RGS = sprayed at both vegetative and reproductive growth stages.

Compared with the control, about 58.8 – 75.0% and 63.1 - 76.1% increase in fresh fruit yield of okra was also observed in 2017 and 2018, respectively (Table 4). Plots sprayed with the insecticide at both vegetative and reproductive growth stages recorded the highest number of okra fruits (2017: $F_{3,\ 9}$ = 208.46; P < 0.001, 2018: $F_{3,\ 9}$ = 166.00; P < 0.001) and yield (2017: $F_{3,\ 9}$ = 221.33; P < 0.001, 2018: $F_{3,\ 9}$ = 174.35; P < 0.001) and they differed significantly from other treated plots and the control. Furthermore, in both years, fruit production and yield obtained from plots treated with the insecticide at the vegetative stage and those sprayed at both vegetative and reproductive growth stages were not significantly different (P > 0.05).

There were strong negative associations between fruit damage and okra yield parameters measured in both years (r > -0.755; n = 16; P < 0.001) (Table 5). Furthermore, fruit samples from plants treated with cypermethrin at both vegetative and reproductive growth stages showed an initial residue level of 0.86 mg kg^{-1} after 2 h of spray, followed by 0.04 mg kg^{-1} at 7 days (95.4% dissipation), which was lower than the recommended European Union maximum residue limit (EU-MRL) of 0.5 mg kg^{-1} for okra fruits.

Table 2 Effect of Cypermethrin on insect-induced damage on okra *Abelmoschus esculentus* fruits at different phenological growth stages.

	7							
	Incisions		Lesions/ Discolourations		Bumps/ Distortions		Exit holes	
Time of insecticide application	2017	2018	2017	2018	2017	2018	2017	2018
VGS	8.00 ± 0.82 b	7.00 ± 0.58 b	4.00 ± 0.82 b	2.50 ± 1.50 b	4.00 ± 0.82 b	3.00 ± 0.58 b	7.50 ± 0.50 b	3.50 ± 0.96 b
RGS	1.50 ± 0.50 c	0.00 ± 0.00 c	2.00 ± 0.82 b	0.00 ± 0.00 b	2.00 ± 0.82 c	0.00 ± 0.00 c	0.50 ± 0.50 c	0.00 ± 0.00 c
VGS + RGS	0.00 ± 0.00 c	0.00 ± 0.00 c	1.50 ± 0.76 b	0.00 ± 000 b	0.00 ± 0.00 d	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c
No spray (Control)	13.50 ± 0.96 a	14.00 ± 0.82 a	8.50 ± 0.96 a	7.50 ± 0.96 a	12.00 ± 0.82 a	8.00 ± 0.82 a	10.50 ± 0.50 a	9.00 ± 1.58 a
Cv (%)	13.90	11.06	10.82	13.02	14.72	10.20	10.70	14.15

Means (± Standard error) are values of four replicates; WAS = Weeks after sowing; VGS = Vegetative growth stage; RGS = Reproductive growth stage; VGS + RGS = sprayed at both vegetative and reproductive growth stages; Means with the same lower case letter in a column are not significantly different from each other (SNK: P > 0.05); Cv (%) = Coefficient of variation.

Table 3 Variations in the number of fruits produced and number damaged by insect pests on okra *Abelmoschus esculentus* plants treated with cypermethrin at different growth stages.

Time of insecticide application	Fruit production per plot				Total number of damaged fruits per plot			
	2017	% increase	2018	% increase	2017	% reduction	2018	% reduction
VGS	121.50 ± 1.50 b	58.8	125.25 ± 2.25 b	60.6	37.50 ± 4.66 b	37.5	30.75 ± 4.48 b	44.6
RGS	120.00 ± 2.45 b	56.9	123.00 ± 2.12 b	57.7	10.50 ± 1.50 c	82.5	8.25 ± 1.44 c	85.1
VGS + RGS	129.75 ± 0.75 a	69.6	135.00 ± 2.12 a	73.1	4.50 ± 0.87 c	92.5	3.00 ± 1.22 c	94.6
No spray (Control)	76.50 ± 2.60 c	0.0	78.00 ± 1.22 c	0.0	60.00 ± 2.12 a	0.0	55.50 ± 2.87 a	0.0
Cv (%)	2.97		3.42		7.51		8.30	

Means (± standard error) are values of four replicates; WAS = Weeks after sowing; VGS = Vegetative growth stage; RGS = Reproductive growth stage; VGS + RGS = sprayed at both vegetative and reproductive growth stages; Means with the same lower case letters in a column are not significantly different from each other (SNK: P > 0.05); Cv (%) = Coefficient of variation; % increase in fruit production per plot = [(Number of fruits produced in treated plots – Number of fruits produced in control plots)/ Number of fruits produced in control plots] × 100; % reduction in fruit damage per plot = [(Number of fruits damaged in control plots – Number of fruits damaged in treated plots)/ Number of fruits damaged in control plots] × 100.

Table 4 Differences in fresh fruit yield of okra *Abelmoschus esculentus* treated with cypermethrin at different growth stages.

Time of insecticide application	Fresh fruit yield (t ha^{-1})			
	2017	% increase	2018	% increase
VGS	8.41 ± 0.17 b	64.9	8.61 ± 0.15 b	65.3
RGS	8.10 ± 0.10 b	58.8	8.50 ± 0.86 b	63.1
VGS + RGS	8.97 ± 0.11 a	75.9	9.20 ± 0.12 a	76.6
No spray (Control)	5.10 ± 0.11 c	0.0	5.21 ± 0.16 c	0.0
Cv (%)	3.05		3.74	

Means (± standard error) are values of four replicates; WAS = Weeks after sowing; VGS = Vegetative growth stage; RGS = Reproductive growth stage; VGS + RGS = sprayed at both vegetative and reproductive growth stages; Means with the same lower case letters in a column are not significantly different from each other (SNK: $P > 0.05$); Cv (%) = Coefficient of variation; % increase in fresh fruit yield = [(Fresh fruit yield from treated plots – fresh fruit yield from control plots)/ fresh fruit yield from the control plots] × 100.

Table 5 Correlation coefficients for fruit damage and yield parameters in 2017 and 2018 cropping seasons.

Fruit damage parameters	Fruits production per plot		Fresh fruit yield (t ha^{-1})	
	2017	2018	2017	2018
Number of fruits with incisions	-0.840**	-0.856**	-0.803**	-0.857**
Number of fruits with exit holes	-0.766**	-0.876**	-0.755**	-0.877**
Number of fruits with lesions	-0.827**	-0.873**	-0.795**	-0.874**
Number of distorted fruits	-0.925**	-0.914**	-0.929**	-0.910**
Total number of damaged fruits per plot	-0.837**	-0.879**	-0.807**	-0.888**

** = Significant at $P < 0.001$.

Discussion

The study showed that insect damage could severely impact the yield and quality of okra fruits if the timely use of artificial control measures is not employed. This further underscored the high risks associated with the presence of insect pests in an okra field, as earlier reported by Praveen and Dhandapani (2001), Kanwar and Ameta (2007), Pitan and Ekoja (2011, 2012), and Adja *et al*. (2019). The efficacy of cypermethrin in mitigating attacks from all the fruit-damaging species encountered in this study conformed to earlier reports by Al-Haj *et al.* (2005), Solangi and Lohar (2007), and Singh *et al*. (2015). The significant reduction in fruit damage and the increase in yield in plots receiving insecticide treatment at both vegetative and reproductive growth stages also agreed with the findings of Momo (2014), who observed that frequently treated plots were less damaged and yielded more fruits than the untreated and plots that were seldom treated.

The delays in fruit initiation observed in untreated plots and plants treated only at the reproductive growth stage may be due to stress induced by the feeding activities of insect species at the vegetative growth stage. This stress may have impaired the flowering phenology and overall performance of the plants, negatively impacting fruit production. Although most plants have been reported to increase their growth investments (McNickle and Evans, 2018), physical/ chemical defense systems (Sánchez-Sánchez and Morquecho-Contreras, 2017), and fruit/ seeds production biomass (West, 2012) in response to insect-induced herbivory. However, there are shreds of evidence showing that at high levels of herbivore activities, plants may undercompensate for leaf feeding, leading to delays in flowering/ fruiting and yield (Crawley, 1983; Fornoni *et al.*, 2003; Kettenring *et al*., 2009; West, 2012). Herbert (2002) and Pitan and Ekoja (2012) reported a similar phenological delay due to herbivory. Tiffin (2000) also reported that herbivore damages could induce delayed growth, flower, and fruit production.

Our results showed that the termination of artificial control measures at either the

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vegetative or reproductive growth stage would expose the crop to insect damage during any untreated phases, which could cause a loss in crop yield. However, it is important to note that cypermethrin is a broad-spectrum pyrethroid and could be toxic to non-target organisms, such as bees, aquatic insects, fish, etc., if they are not used based on scientific judgments (Sedaghati and Hokmabadi, 2014). In future studies, isolated investigations into the effects (selectivity, repellent, feeding deterrent, toxicant, growth retardant, chemosterilant, and attractant) of botanicals/ bioinsecticides on insect pests associated with okra at both vegetative and reproductive growth stages may provide empirical insights into their efficacy as bio-rational alternatives to cypermethrin.

Most of the consumers of okra fruits rely on qualities [*viz*: external (presentation, appearance, uniformity, ripeness, freshness, and absence of damage) or internal (flavor, aroma, texture, nutritional value, and absence of biotic and non-biotic contaminants)] to make purchase decisions (FAO, 2004). As identified in the study, the presence of incisions, feeding lesions, localized discolorations, bumps/lumps, distortions, and larval exit holes may reduce the market (both local and export) value of harvested okra fruits. Studies also showed that openings created on fruit skin by these insects might provide entry points for pathogens responsible for postharvest fruit decay (Obeng-Ofori and Sackey, 2003; Yahaya and Mardiyya, 2019). However, the present study showed that insecticide application during vegetative and reproductive growth stages minimizes these adverse effects of insect herbivory.

The negative association between the fruit damage and okra yield in both years further showed that stress induced by the feeding activities of insects on okra could reduce their fruit yield, as previously reported by Ekoja *et al*. (2012). Mazed *et al*. (2017) also reported a significant reduction in insect-induced fruit damage and an increase in the yield of okra treated with insecticides in an investigation in Gazipur, Bangladesh.

As observed in this study, the insecticidal efficacy of cypermethrin may be due to the characteristic quick action associated with the pyrethroid. The chemical compound is about 2250 times more toxic to insects than to higher animals (probably due to the smaller size, lower body temperature, and more sensitive sodium channels of insects), and it is considered to be relatively non-toxic to humans in all life stages (Bradberry *et al*., 2005; Chrustek *et al*., 2018). It is also known to have a fast dissipation rate in plant tissues (Gupta *et al*., 2011; Parmar *et al*., 2012; Chandra *et al*., 2014; Sedaghati and Hokmabadi, 2014; Patel *et al.*, 2016; Chau *et al*., 2020). The low MRL value obtained after seven days of treatment further confirmed this attribute of the pyrethroid and the relatively low risk posed by their use in crop fields. However, a pre-harvest interval of ≥ 7 days should be considered when cypermethrin is used for field management of insect pests associated with okra fruits.

Conclusion

Our results showed that incisions, feeding lesions, localized discolorations, bumps, distortions, and larval exit holes are the major fruit damage caused by field insect pests of okra at Makurdi, NG. Cypermethrin 20EC at both vegetative and reproductive growth stages provided better protection for okra fruits in the field. In addition, fruits harvested at ≥ 7 days after sprays did not violate the EU-MRL for okra. The information provided by this study could facilitate decision-making concerning the timing of insecticide interventions. It could provide valuable guidance when planning a sustainable pest management program for insect herbivores associated with okra.

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ارزیابی خسارت روی میوه بامیه *Abelmoschus esculentus* پس از تیمارهای حشره‌کش در مراحل مختلف رشد گیاه

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چکیده: چندین آفت حشره گیاهخوار برای حمله به بامیه، *Abelmoschus esculentus* (L.) Moench در مزرعه شناخته شده‌اند. با این حال، اطلاعات در مورد گونه‌های آسیب‌رسان میوه و زمان مؤثر برای کاربرد(های) حشره‌کش هنوز اندک است. آزمایش‌های مزرعه‌ای در سال‌های ۲۰۱۷ و ۲۰۱۸ برای شناسایی دسته‌های آسیب وارد شده به میوه‌های بامیه و تعیین مرحله رشد فنولوژیکی انجام شد که در آن کاربرد حشره‌کش به‌طور قابل‌توجهی آسیب میوه‌های ناشی از حشرات را کاهش می‌دهد و عملکرد محصول را بهبود می‌بخشد. تیمارها شامل استفاده از سایپرمترین 20EC در فواصل دو هفته‌ای بر روی رقم NHAe47-4 بامیه در مرحله رویشی (VGS)، مرحله زایشی (RGS)، VGS + RGS و بدون اسپری (شاهد) بود. راه‌اندازی در بلوک‌های کامل تصادفی با چهار تکرار انجام شد. نتایج نشان داد که برش‌ها، ضایعات تغذیه‌ای، تغییر رنگ‌های موضعی، برجستگی‌ها، اعوجاج و سوراخ‌های خروجی لارو از علائم اصلی آسیب میوه ناشی از آفات حشرات بامیه هستند. به‌طور کلی، خسارت میوه به‌طور قابل‌توجهی کاهش یافت، درحالی‌که عملکرد میوه در کرت‌هایی که حشره‌کش در مراحل رویشی و زایشی دریافت کردند بیش‌تر از شاهد بود. تولید میوه در سال‌های ۲۰۱۷ و ۲۰۱۸ در کرت‌های تیمار شده به‌ترتیب ۵۶/۹-۶۹/۶ درصد و ۵۷/۷-۷۳/۱ درصد نسبت به شاهد افزایش معنی‌داری داشت. خسارت میوه ۳۷/۵-۹۲/۵ درصد (۲۰۱۷) و ۴۴/۶-۹۴/۶ درصد (۲۰۱۸) کاهش یافت و عملکرد میوه تازه بامیه به میزان [۵۸/۸-۷۵/. درصد (۲۰۱۷) و ۶۳/۱-۷۶/۱ درصد (۲۰۱۸)] افزایش یافت. نتیجه می‌گیریم که یک استراتژی مدیریت مزرعه مؤثر برای حشرات مرتبط با آسیب میوه بامیه باید شامل تاکتیک‌های کنترل قوی در مراحل رشد رویشی و زایشی محصول باشد.

واژگان کلیدی: فنولوژی محصول، سیپرمترین، خسارت میوه، بامیه، کنترل آفات

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