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Incidence of Pests and Natural Enemies on Okra (*Abelmoschus esculentus* L. Moench) as Influenced by Plant Spacing and Stand Density in Benin City, Edo State, Nigeria

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ABSTRACT: Okra (*Abelmoschus esculentus* L. Moench) productivity is often constrained by insect pests, though natural enemies help regulate populations. Agronomic practices such as plant spacing and stand density may influence pest colonization and natural enemy activity, yet studies in Nigerian okra systems remain limited. Consequently, the objective of this paper was to assess the Incidence of Pests and Natural Enemies on Okra (*Abelmoschus Esculentus* L. Moench) as Influenced by Plant Spacing and Stand Density in Benin City, Edo State, Nigeria using standard procedures. Seven insect pest families were identified, with Aphididae most abundant (93.70%). In most treatments, pest incidence did not differ significantly with spacing or density ($P > 0.05$), but varied across weeks ($P < 0.01$), peaking between 4 – 10 WAS. Natural enemies included parasitoids (Braconidae) and predators (Coccinellidae, Syrphidae, Araneae), with Braconidae dominant (72.16%). Their abundance was unaffected by spacing or plant number ($P > 0.05$), but varied significantly across weeks ($P < 0.05$), with highest counts at 4 WAS (3.50 ± 0.44) and 7 WAS (5.50 ± 0.67). Overall, planting configuration had minimal influence on pest or natural enemy abundance. Natural enemies peaked during early to mid-growth stages in response to rising pest populations. These findings emphasize the importance of conserving beneficial arthropods, early-season monitoring, and integrating cultural practices with ecological pest management to promote sustainable okra production.

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Okra (*Abelmoschus esculentus* L. Moench), a member of the family Malvaceae (Kwok *et al.*, 2025), is a widely cultivated vegetable crop across tropical and subtropical regions (Omolade *et al.*, 2024), particularly in West Africa (Uwiringiyimana *et al.*, 2024). It serves as an important source of vitamins, minerals, and dietary fiber (Gaul *et al.*, 2025), and is valued for its adaptability to diverse environmental conditions, including hot and dry climates (Uwiringiyimana *et al.*, 2024). In Nigeria, okra plays a vital role in food security and rural livelihoods where it is consumed as a vegetable, raw, cooked or fried or as a common ingredient of soups and sauces (Omotoso *et al.*, 2018), yet its productivity is frequently threatened by insect pest infestations that reduce both yield and market quality (Subba *et al.*, 2022). More than 70 insect species have been documented on okra (Srinivasa and Rajendran, 2002); around 23-54 % yield losses have been reported in okra due to different insect-pest

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infestation (Sharma *et al.,* 2017). Common pests include aphids, leafhoppers, whiteflies, and flea beetles, which inflict damage through feeding and disease transmission (Khethari, 2025). However, natural enemies such as predators and parasitoids can suppress pest populations and contribute to ecological stability in cropping systems (Van Driesche *et al.,* 2008). Predators like lacewing larvae (Chrysopidae), spiders (Araneae), predatory bugs (e.g., *Podisus* spp.), and ladybird beetles (Coccinellidae) are known to reduce pest densities through direct predation and behavioral disruption (Seni and Halder, 2022; Pang and Li, 2025). Parasitoids also play a key role in pest regulation (Clark *et al.,* 2019), with their effectiveness influenced by host availability, crop phenology, and environmental conditions (Singh 2023; Berryman, 1999; Jeff and Lewis 2013). Agronomic practices, particularly plant spacing and stand density, significantly influence the microclimate of crop fields affecting pest colonization and the activity of natural enemies (Hooks and Johnson 2003; Bastos *et al.,* 2020). While closer spacing may favor pest buildup through increased humidity and canopy cover, wider spacing can enhance predator mobility and visibility (Andow, 1991). Spatial arrangement, crop growth stages, and local conditions further shape the distribution and performance of beneficial arthropods (Ratnadass *et al.,* 2012). Despite these known interactions, field-based studies examining the impact of plant configuration on insect dynamics in okra systems remain limited, particularly within Nigerian agroecological contexts. Consequently, the objective of this paper was to assess the incidence of pests and natural enemies on okra (*Abelmoschus esculentus* L. Moench) as influenced by plant spacing and stand density in Benin City, Edo State, Nigeria.

MATERIALS AND METHODS

Experimental Site: The experiment was carried out during the late okra cropping season between September to November 2024, at the Teaching and Research Farm of the Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City, Edo State, Nigeria. The research site is situated at latitude 6°24′6″N and longitude 5°37′44.8″E, with an average elevation of 95 meters above sea level.

Source of Experimental Materials/ Treatments and Experimental design: A local okra cultivar was sourced from Ogan, Edo State. The experiment comprised six treatment combinations based on plant spacing and the number of plants per stand: 40 × 25 cm with one plant per stand (40 × 25 × 1), 40 × 25 cm with two plants per stand (40 × 25 × 2), 40 × 25 cm with three plants per stand (40 × 25 × 3), 50 × 25 cm with one plant per stand (50 × 25 × 1), 50 × 25 cm with two plants per stand (50 × 25 × 2), and 50 × 25 cm with three plants per stand (50 × 25 × 3). The trial was laid out in a Randomized Complete Block Design (RCBD) with four replications. Each treatment plot measured 2 m × 2.5 m, and a spacing of 0.5 m was maintained between blocks and between plots.

Site Preparation/Sowing/Fertilizer Application and Weeding: The experimental plot, measuring 18.5 m × 10.5 m, was manually ploughed and cleared of debris prior to sowing. Okra seeds were sown following a substantial rainfall, with six seeds initially placed per hill. Thinning was carried out three weeks after sowing to achieve the required plant density per stand. Nitrogen fertilizer, applied in the form of urea, was administered three times at a consistent rate of 60 kg ha–1 per application. The first treatment was conducted two weeks after sowing, with subsequent applications at two-week intervals. Weeding was performed twice—at two and six weeks after sowing.

Data Collection: The population densities of insect pests, predators, and parasitoids associated with okra plants were assessed weekly from two to ten weeks after sowing. Observations were made on five randomly selected plants per plot. The upper and lower leaf surfaces of each plant were carefully examined. Pests and natural enemies were identified, counted and recorded.

Data Analysis: The collected data were subjected to square-root transformation prior to statistical analysis. Analysis of Variance (ANOVA) was employed to evaluate treatment effects, with significance determined at the 5 % probability level ($P < 0.05$). Where significant differences were detected, means were separated using Duncan's Multiple Range Test (DMRT). All statistical procedures were performed using Genstat software, version 12.1. Relative abundance was calculated using the formula in equation 1:

$$\% RA = \frac{N_{is}}{TN_S} * 100 \quad (1)$$

Where RA = Relative abundance (%); N_{is} = Number of individual species; TN_S= Total number of species

RESULTS AND DISCUSSION

Occurrence and Relative Abundance of Insect Pests and Natural Enemies: A total of seven insect pest families were identified on okra during the study

period. These included Aphididae (aphids), Cicadellidae (leafhoppers), Pseudococcidae (mealybugs), Pentatomidae (cotton strainers) (Order Hemiptera), Chrysomelidae (leaf beetles) (Order Coleoptera), Tortricidae (leaf rollers) (Order Lepidoptera), and Thripidae (thrips) (Order Thysanoptera). Their respective relative abundances were 93.70 %, 5.41 %, 0.23 %, 0.02 %, 0.37 %, 0.26 %, and 0.01 % (Table 1). Similar pest profiles have been reported by Norman *et al.* (2019), Rai and Halder (2022) and Rivers *et al.* (2024), who documented aphids, leafhoppers, whiteflies, and fruit borers as major pests of okra across different seasons and regions. Study by Bhatt *et al.* (2018) further confirms the abundance of Hemiptera, Coleoptera, and Lepidoptera in okra pest communities. In this study, species in the family Aphididae dominated the pest community, accounting for 93.70% of the total population. This finding is consistent with earlier report by Yohanna *et al.* (2022), who identified aphids as the most persistent and damaging pests of okra in Nigeria. Aphids are known for their rapid reproduction, sap-sucking behavior, and ability to transmit viral diseases, which can significantly impair crop yield and quality (Blackman and Eastop, 2006). Other hemipteran pests such as leafhoppers, mealybugs, and stink bugs were present in lower proportions but remain economically significant. Leafhoppers can cause hopper burn and transmit phytopathogens (Weintraub *et al.,* 2019; Santos *et al.,* 2024), while mealybugs and stink bugs contribute to fruit deformation and reduced marketability. Flea beetles (Chrysomelidae) were also observed; causing characteristic shot-hole damage that impairs photosynthesis and stunts plant growth (Eutrema, 2025). Lepidopteran (Tortricidae) and thysanopteran (Thripidae) pests, though least represented, are known to cause foliar damage and flower abortion under favorable conditions (Paine**,** 2009**;** Jamian *et al.,* 2024).

Natural enemies observed in the okra field comprised parasitoids and predators from four major groups. These included parasitoid wasps (Braconidae, Order Hymenoptera), hoverfly larvae (Syrphidae, Order Diptera), ladybird beetles (Coccinellidae, Order Coleoptera), and spiders (Order Araneae). Their relative abundances were 72.16 %, 22.35 %, 4.31 %, and 1.18 %, respectively (Table 1). Braconid wasps were the most abundant, comprising 72.16 % of the natural enemy population. These parasitoids are well-established biological control agents, particularly effective against aphids and other soft-bodied pests (Van Driesche *et al.,* 2008). Tendeng *et al.* (2022) similarly reported high biodiversity among parasitoid Hymenoptera and predatory Hemiptera in okra fields, with parasitism rates ranging from 0 – 50 % depending on pest density. Syrphid flies and ladybird beetles contributed 22.35 % and 4.31 % of the natural enemy population, respectively. Syrphid larvae are voracious aphid feeders, while coccinellids are generalist predators known for their effectiveness in suppressing a wide range of pests (Obrycki and Kring, 1998). Although spiders were least abundant (1.18 %), their role as opportunistic predators adds to the ecological resilience of the system (Obuid-Allah *et al.,* 2018). Satti *et al.* (2012) reported seasonal variations in predator populations, with spiders and chrysopids dominating during warmer months and syrphids and coccinellids more prevalent in cooler seasons. The abundance of natural enemies during early to mid-growth stages emphasizes the importance of conserving beneficial arthropods through habitat management, reduced pesticide use, and integrated pest management (IPM) strategies. Hooks and Johnson (2003) advocate for IPM approaches that enhance natural enemy activity and reduce reliance on chemical controls.

Table 1: abundance and relative abundance of insect pests and their natural enemies on okra

Order	Family	Abundance	(%) RA
Pests			
Hemiptera	Aphidae	20297	93.70
	Cicadellidae	1171	5.41
	Pseudococcidae	50	0.23
	Pentatomidae	5	0.02
Coleoptera	Chrysomelidae	80	0.37
Lepidoptera	Tortricidae	57	0.26
Thysanoptera	Thripidae	2	0.01
Total		**21662**	**100.00**
Natural Enemies			
Hemiptera	Braconidae	184	72.16
Diptera	Syrphidae	57	22.35
Coleoptera	Coccinellidae	11	4.31
Araneae		3	1.18
Total		**255**	**100.00**

Where RA = relative abundance

Effect of Plant Spacing and Stand Density on Pest and Natural Enemy Abundance: The mean abundance of insect pests under different plant spacing and stand density treatments is presented in Table 2. For most observation periods, there were no significant differences in pest abundance among treatments ($P > 0.05$), suggesting that spatial configuration alone may not be a strong determinant of pest pressure. However, at 4 weeks after sowing (WAS), the 40 × 25 cm spacing with two plants per stand recorded the highest pest count (187.00 ± 2.85 insects per five plants; $P < 0.05$), indicating that denser planting may create favorable microclimatic conditions for pest colonization. This observation aligns with Andow (1991), who reported that

increased plant density, can enhance humidity and reduce air circulation, promoting pest establishment. Significant temporal variation in pest abundance was observed for 40 × 25 × 1 ($P < 0.01$), with lowest counts at 2–3 WAS and highest counts from 4–10 WAS. Similarly, significant differences across weeks were recorded for 40 × 25 × 2 ($P < 0.01$), 50 × 25 × 1 ($P < 0.001$), 50 × 25 × 2 ($P < 0.01$), and 50 × 25 × 3 ($P < 0.01$), with peak pest abundance occurring between 7–10 WAS. These trends reflect typical pest population dynamics, where infestations escalate as crops mature due to increased foliage and resource availability (Umeh *et al.,* 2001). Natural enemy populations were not significantly affected by plant spacing or density ($P > 0.05$) (Table 3), suggesting that these beneficial arthropods respond more to prey availability and habitat complexity than to planting geometry (Van Driesche *et al.,* 2008). However, natural enemy populations varied significantly across weeks ($P < 0.05$) in the 50 × 25 × 1 and 50 × 25 × 3 treatments, with peak counts observed at 4 WAS (3.50 ± 0.44 insects per five plants) and 7 WAS (5.50 ± 0.67 insects per five plants) respectively. These periods coincided with rising pest populations, indicating a density-dependent response by natural enemies (Obrycki and Kring, 1998; Singh and Singh, 2005).

Table 2: mean ± SE of pest abundance as influenced by plant spacing and number of plants per stand across weeks after sowing

	Treatments						
WAS	**40×25×1**	**40×25×2**	**40×25 ×3**	**50×25×1**	**50×25×2**	**50×25×3**	**Sig.**
2	1.25 ± 0.24^{b}	0.25 ± 0.13^{c}	1.50 ± 0.39	0.25 ± 0.13^{d}	5.25 ± 0.72^{d}	0.25 ± 0.13^{c}	ns
3	7.00 ± 0.62^{b}	33.50 ± 1.75^{bc}	32.00 ± 2.06	6.25 ± 0.85^{d}	11.75 ± 1.24^{cd}	4.75 ± 0.36^{bc}	ns
4	113.80 ± 1.72^{a*}	187.00 ± 2.85^{ab*}	68.25 ± 3.10	25.50 ± 0.95^{cd}	62.25 ± 0.48^{abcd}	70.25 ± 1.45^{a}	*
5	136.80 ± 1.04^{a}	89.50 ± 1.41^{ab}	117.30 ± 4.15	82.75 ± 1.12^{bc}	93.75 ± 0.65^{abc}	56.75 ± 2.15^{ab}	ns
6	192.50 ± 2.90^{a}	159.20 ± 2.14^{ab}	186.80 ± 3.22	129.80 ± 0.97^{abc}	73.50 ± 1.24^{abcd}	41.75 ± 0.52^{ab}	ns
7	97.25 ± 1.58^{a}	132.50 ± 1.01^{ab}	458.50 ± 8.54	274.50 ± 1.94^{a}	43.25 ± 1.44^{bcd}	70.50 ± 2.37^{ab}	ns
8	244.80 ± 5.15^{a}	182.80 ± 2.58^{ab}	460.00 ± 6.53	141.00 ± 1.58^{abc}	152.20 ± 3.87^{ab}	122.80 ± 2.52^{a}	ns
9	261.20 ± 4.90^{a}	189.00 ± 2.13^{a}	241.50 ± 4.08	139.00 ± 3.12^{abc}	98.50 ± 2.18^{abc}	116.8 ± 3.07^{a}	ns
10	130.80 ± 1.80^{a}	351.00 ± 4.31^{a}	185.00 ± 4.27	220.50 ± 4.66^{ab}	271.50 ± 4.68^{a}	98.25 ± 2.08^{a}	ns
Sig.	**	**	ns	***	**	**	

Means in the same row with asterisk (*) are significantly different (* = p<0.05); [abcd]Means in the same column with different letter superscript are significantly different (= p<0.01 and *** = p<0.001); ns = Means in the same row and column are not significantly different at p > 0.05*

Table 3: okra pest' natural enemy abundance (mean ± standard error) as influenced by plant spacing and number of plants per stand across weeks after sowing

	Treatments						
WAS	**40×25×1**	**40×25×2**	**40×25 ×3**	**50×25×1**	**50×25×2**	**50×25×3**	**Sig.**
2	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.25 ± 0.13^{b}	0.00 ± 0.00	0.00 ± 0.00^{b}	ns
3	0.25 ± 0.13	0.50 ± 0.15	0.00 ± 0.00	0.25 ± 0.13^{b}	0.50 ± 0.15	0.00 ± 0.00^{b}	ns
4	3.50 ± 0.36	1.25 ± 0.21	2.00 ± 0.55	2.00 ± 0.41^{ab}	2.25 ± 0.31	3.50 ± 0.44^{a}	ns
5	1.75 ± 0.44	4.50 ± 0.51	2.25 ± 0.39	2.50 ± 0.16^{ab}	1.75 ± 0.16	1.00 ± 0.28^{b}	ns
6	2.00 ± 0.32	0.75 ± 0.21	0.50 ± 0.15	0.00 ± 0.00^{b}	1.00 ± 0.28	0.25 ± 0.13^{b}	ns
7	1.75 ± 0.32	2.00 ± 0.32	0.25 ± 0.13	5.50 ± 0.67^{a}	1.00 ± 0.18	0.00 ± 0.00^{b}	ns
8	6.50 ± 0.98	2.00 ± 0.21	1.50 ± 0.39	0.50 ± 0.15^{b}	1.25 ± 0.24	0.75 ± 0.21^{b}	ns
9	1.25 ± 0.09	1.50 ± 0.16	2.50 ± 0.49	0.50 ± 0.22^{b}	0.75 ± 0.21	0.25 ± 0.13^{b}	ns
10	0.75 ± 0.21	0.75 ± 0.21	0.25 ± 0.13	1.00 ± 0.35^{b}	0.75 ± 0.21	1.50 ± 0.25^{ab}	ns
Sig.	ns	ns	ns	*	ns	*	

[ab]Means in the same column with different letter superscript are significantly different (= p<0.05); ns = Means in the same row and column are not significantly different at p > 0.05*

Conclusion: This study reveals the ecological dynamics within okra (*Abelmoschus esculentus*) agroecosystems, shaped by the diversity and relative abundance of insect pests and their natural enemies. Aphididae was the most dominant pest family, representing the majority of infestations across the sampling period. Braconid wasps were the most prevalent natural enemies, underscoring their potential significance in biological control. While plant spacing and stand density exerted limited direct effects on pest and natural enemy populations, natural enemies peaked during early to mid-growth stages, reflecting density-dependent responses to rising pest numbers. These findings highlight the importance of conserving beneficial arthropods, prioritizing early-season monitoring, and integrating

cultural practices with ecological pest management to enhance sustainable okra production.

DECLARATIONS

Ethical Approval: This study did not involve human participants or animal experimentation and therefore did not require formal ethical approval. All procedures involving data handling and analysis were conducted responsibly and in accordance with standard academic and institutional guidelines.

Disclaimer (Artificial Intelligence): Author(s) hereby declare that Microsoft Copilot AI companion was used during writing or editing of this manuscript. Input prompts include: rewrite this sentence, recast this phrase, rewrite concisely and search for this reference.

Declaration of Conflict of Interest: The authors declare no known conflict of interest.

Declaration of Data Availability: Data are available upon request from the corresponding author.

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