

INFLUENCE OF PLANT DENSITY AND SPACING ON FLEA BEETLE (*Podagrica uniforma* Jacoby) INFESTATION AND AGRONOMIC PERFORMANCE OF OKRA (*Abelmoschus esculentus* L. Moench)

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Abstract

Okra (*Abelmoschus esculentus* L. Moench) production in Nigeria is frequently limited by flea beetle (*Podagrica uniforma* Jacoby) infestation, which causes foliar damage and reduces yield. Optimizing plant density is a key strategy for balancing pest pressure and crop performance. This study examined the effects of plant density and spacing on flea beetle infestation and agronomic traits of okra in Benin City, Edo State, Nigeria. A randomized complete block design was employed with six treatments combining two spacing regimes (40 × 25 cm and 50 × 25 cm) and three planting densities (one, two, and three plants per stand). Infestation was assessed weekly, while growth and yield parameters were recorded throughout the cropping cycle. Results indicated that spacing and density did not significantly affect beetle populations or damage severity ($p > 0.05$). Infestation peaked at 6–7 weeks after sowing, with maximum leaf perforation at 10 weeks. However, closer spacing with higher density (40 × 25 cm × 3) significantly ($p < 0.001$) enhanced flowering, maturity, and yield components, producing the highest capsule, seed, and stover yields. Correlation analysis confirmed plant population as the strongest determinant of productivity, while capsule length showed weak associations with yield traits. These findings suggest that while plant density may not directly influence *P. uniforma* infestation, it plays a critical role in optimizing okra growth and yield. For late-season production, 40 × 25 cm spacing with three plants per stand is recommended, coupled with targeted pest management during mid-vegetative to flowering stages.

Keywords: Okra productivity, Plant density, Flea beetle infestation, Spacing regimes, Agronomic performance

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is a widely cultivated vegetable in tropical and subtropical regions, especially in Nigeria, where it is grown nationwide by smallholder farmers. Nigeria ranks second globally in okra production, with an estimated 1.5 million hectares under cultivation (Adeniyi, 2025). Valued for its nutritional and economic importance, okra provides essential vitamins and minerals that help combat micronutrient deficiencies

(Bawa and Badrie 2016). Its pods are consumed fresh or processed, and the mucilage offers medicinal benefits, particularly for managing diabetes and cholesterol (Adetuyi *et al.*, 2011). Additionally, okra seeds yield oil used in industrial applications such as soap, lubricants, and biodiesel (Oyelade *et al.*, 2003), making it vital for food security and agro-industrial development.

Despite its benefits, okra production faces challenges from insect pests, particularly

flea beetles (*Podagrica uniforma* Jacoby; Coleoptera: Chrysomelidae). These beetles attack leaves, stems, and pods, reducing photosynthetic efficiency and overall plant vigour (Pitan and Ekoja, 2011). Their feeding creates characteristic shot-hole damage, which increases plant susceptibility to stress and secondary infections (Vanlommel *et al.*, 1996). Heavy infestations often result in defoliation, stunted growth, and significant yield losses (Pitan and Ekoja, 2011). While chemical insecticides remain a common control measure, issues of resistance, environmental impact, and high costs have driven growing interest in cultural management practices.

Agronomic practices like plant spacing and stand density can influence pest dynamics by altering microclimates and pest colonization patterns (Kedar, 2015; Norman *et al.*, 2019). These practices also affect crop growth and resource competition, offering potential for both pest suppression and yield improvement. However, limited field-based evidence exists on their effectiveness in southern Nigeria. This study was therefore conducted to assess how different spacing and planting densities impact flea beetle infestation, growth, and yield of okra, aiming to inform sustainable crop management and integrated pest control strategies.

Materials and Methods

Experimental Site

The study was conducted during the late cropping season (September–November 2024) at the Teaching and Research Farm, Department of Crop Science, University of

Benin, Benin City, Nigeria (Latitude 6°24'6"N, Longitude 5°37'44.8"E, Elevation 95 m) on sandy loam soil.

Flea beetles in southern Nigeria are most abundant during the rainy season and early post-rainy months, when host plants such as okra are widely cultivated. Their lifecycle is closely tied to crop phenology: Conducting the study in the late cropping season (September–November) coincided with this period of natural infestation.

Source of Experimental Materials/ Treatments and Experimental Design

A local okra cultivar known as 'Ariukhon' obtained from farmers in Ogan, Edo State was used. Six treatments combined two spacings (40 cm × 25 cm and 50 cm × 25 cm) with one, two, or three plants per stand: 40×25×1, 40×25×2, 40×25×3, 50×25×1, 50×25×2, and 50×25×3. The experiment followed a Randomized Complete Block Design (RCBD) with four replications. Each plot measured 2 m × 2.5 m, with 0.5 m spacing between plots and blocks. Border rows were not sampled to minimize edge effect.

Site Preparation/Sowing/Fertilizer Application and Weeding

A plot size measuring 18.5 m × 10.5 m field was cleared and manually ploughed. Seeds were sown after rainfall, six per hill, and thinned to the required number after three weeks. Urea fertilizer was applied at 60 kg/ha in three doses—two, four, and six weeks after sowing. Weeding occurred at two and six weeks. The site is characterized by high pest infestation and no insecticides were applied during the experiment to allow

for natural infestation. It was located at least 5 m away from neighbouring farms.

Data Collection

Determination of Flea Beetle Infestation and Severity

Flea beetles (*P. uniforma*) were identified using morphological keys by Bland and Jaques (2010) and descriptions by Oke and Odebiyi (2010) (Plate 1). Weekly sampling was conducted from two to ten weeks after sowing on plants located in the middle rows, with border plants excluded from each treatment plot. Natural infestation and damage severity were assessed on five randomly selected plants. Data on number of flea beetles and number of infested plants were recorded. Damage severity was determined by counting perforated leaves and calculating the average perforations per leaf. Severity was rated using the five-point scale of Boateng *et al.* (2019): 1 = very mild (1–15 perforations); 2 = mild (16–30 perforations); 3 = moderately severe (31–45 perforations); 4 = very severe (46–60 perforations); and 5 = extremely severe (>60 perforations) (Plate 2).



Plate 1: Flea beetle, *Podagrica uniforma*

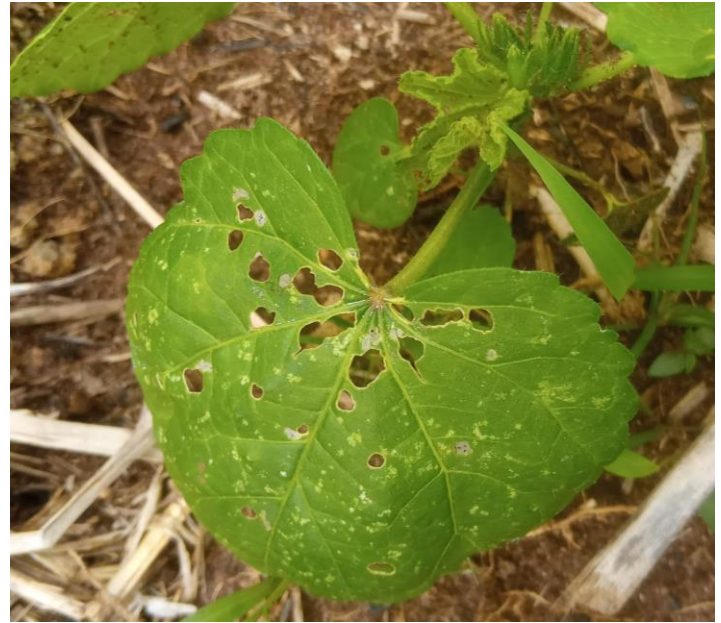


Plate 2: Okra (*Abelmoschus esculentus*) with perforations due to *P. uniforma*

Determination of Plant Growth and Yield

The following growth and yield parameters were recorded: percentage emergence, percentage establishment, days to first flowering, days to 50% flowering, days to 95% maturity, plant population at harvesting, number of capsules per plant, length of capsule, field yield of capsules, dry yield of capsules, seed yield, 1000-seed weight, stover weight.

Data Analysis

Data from the experiment was analyzed using Two-way Analysis of Variance (ANOVA). Data on number of flea beetles were square root transformed before analysis. Significant means ($p < 0.05$) were compared using Duncan's New Multiple Range Test (DMRT). All analyses were done using GenStat version 12.1

Results and Discussion

Effect of Plant Spacing and Number of Plants per Stand on Flea Beetle Infestation and Damage Severity

Figures 1–3 illustrate the influence of plant spacing and stand density on natural infestation of flea beetle (*Podagrica unifirma*) and damage severity in okra in the late cropping season of 2024. Beetle counts were generally similar across treatments ($p > 0.05$), except at 3 weeks after sowing (WAS), when the $40 \times 25 \times 2$ spacing recorded a significantly higher population (0.50 beetles per 5 plants; $p < 0.05$) (Fig. 1). This aligns with Osipitan *et al.* (2012), who noted that spacing influenced yield but had little impact on flea beetle incidence. Across treatments, no significant differences ($p > 0.05$) were observed in the number of infested plants or perforation severity at any given WAS. Infestation ranged from 2.25 out of 5 plants in the $40 \times 25 \times 1$ treatment at 2 WAS to complete infestation (5/5 plants) across all treatments by 6 WAS (Fig. 2). Damage severity followed a progressive pattern, increasing from 0.10 perforations per leaf in the $40 \times 25 \times 3$ treatment at 2 WAS to 11.38 perforations per leaf in the $40 \times 25 \times 2$ treatment at 10 WAS (Fig. 3).

While treatment differences were not significant, beetle population, number of infested plants and damage severity varied

significantly across weeks ($p < 0.001$). Highest number of beetles was recorded at 8 WAS, peak infestation occurred at 6–7 WAS, whereas maximum damage severity was recorded at 10 WAS. The uniform infestation observed at 6 WAS suggests a threshold period likely driven by beetle life cycles and environmental cues rather than planting geometry (Ekholm *et al.*, 2020). This progression—from partial infestation at 2 WAS to full infestation by mid-vegetative stages—reflects synchronization with crop phenology, when leaf area is greatest. Previous studies (Osipitan *et al.*, 2012) similarly reported that while closer spacing occasionally increased beetle numbers, damage severity was more strongly influenced by crop stage and environmental conditions. The sharp rise in infestation during vegetative and flowering phases corroborates Oyerinde *et al.* (2017), who documented rapid population growth of flea beetles at these stages. Overall, the findings indicate that spacing and stand density exert minimal influence on flea beetle pressure under field conditions. Pest dynamics appear more closely tied to environmental factors and crop phenology than to planting arrangements (Samura, 2022; Agba *et al.*, 2011). Although denser canopies from closer spacing may create favourable microhabitats, *Podagrica* spp. are highly mobile and remain attracted to okra regardless of plant density, particularly during peak infestation periods (Kabeh and Balogun, 2021).

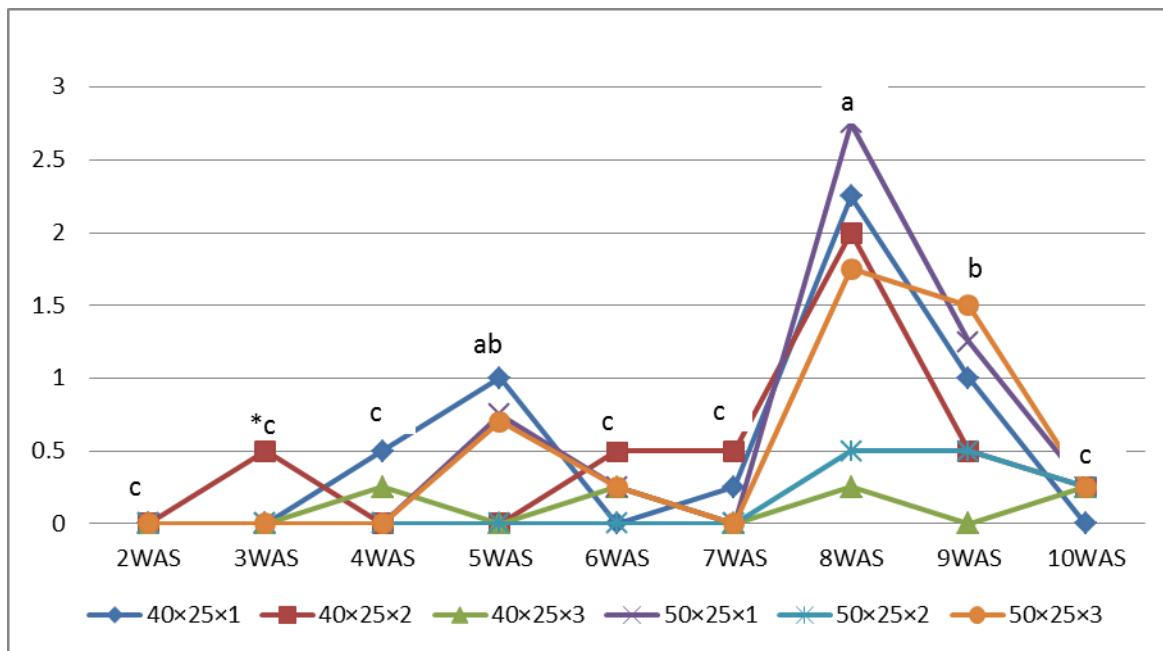


Fig. 1: Mean number of *P. uniforma* per 5 plants as influenced by plant spacing and number of plants per stand across WAS on okra (* = significant at $p < 0.05$; ^{abc}Means with different letter superscript are significantly different, *** = $p < 0.001$)

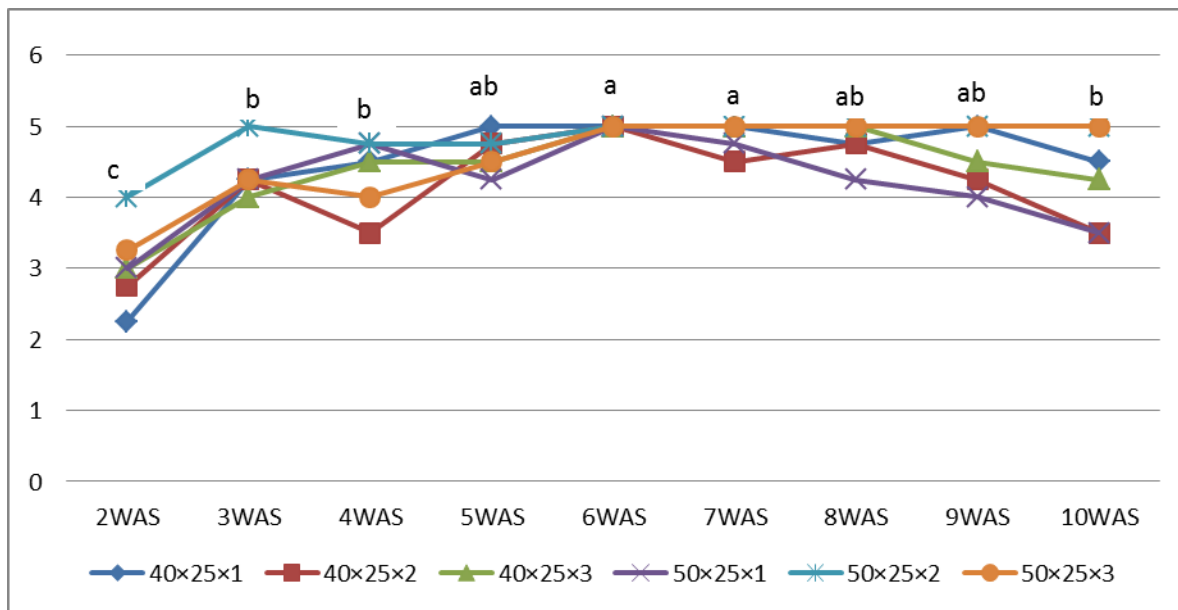


Fig. 2: Mean number of infested plants as influenced by plant spacing and number of plants per stand across WAS (^{abc}Means with different letter superscript are significantly different, *** = $p < 0.001$)

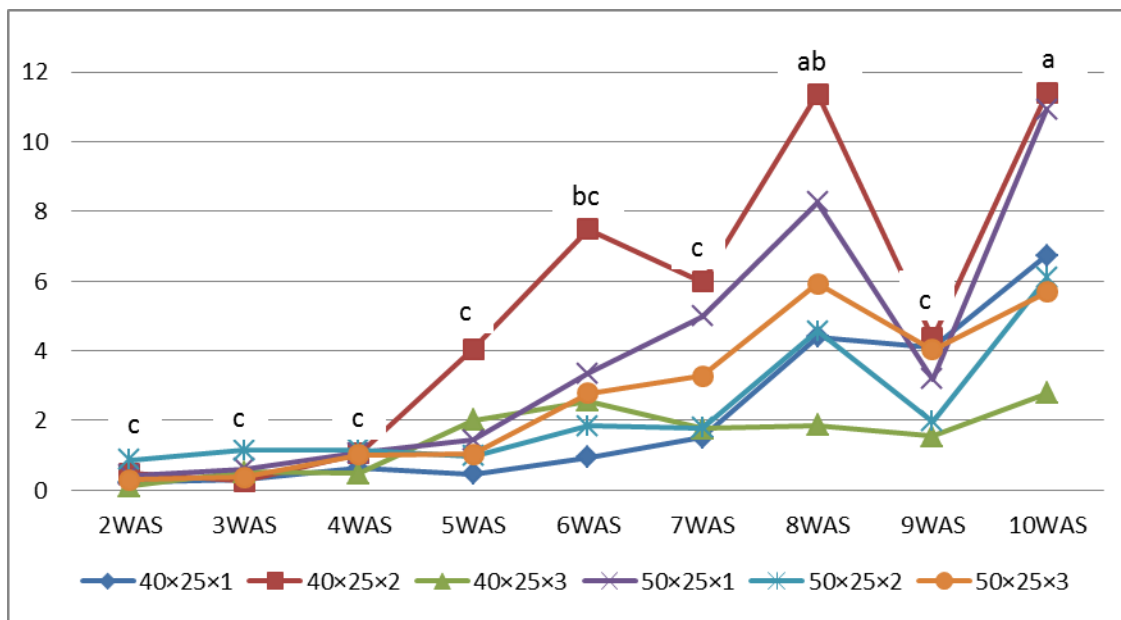


Fig. 3: Mean damage severity as influenced by plant spacing and number of plants per stand across WAS (^{abc}Means with different letter superscript are significantly different (***) = $p < 0.001$)

Effect of Plant Spacing and Number of Plants per Stand on Growth and Yield of Okra

The effect of plant spacing and number of plants per stand on growth and yield of okra are presented in Tables 1 and 2. Percentage emergence and establishment did not differ significantly ($p > 0.05$) among treatments, indicating that seedling vigour was unaffected by spacing or density. This supports earlier findings that emergence is largely determined by seed quality, soil moisture, and temperature rather than planting geometry (Falodun and Ogedegbe, 2016; Adesina and Wiro, 2020).

In contrast, phenological traits such as days to first flowering, 50% flowering, and 95% maturity varied significantly ($p < 0.001$). Wider spacing ($50 \times 25 \text{ cm} \times 3$) promoted earlier flowering and maturity, likely due to reduced competition for light, nutrients, and

water. These results align with Lesi (2018), who reported that wider spacing promotes early flowering through improved physiological efficiency and hormonal signalling. It also supports Agba *et al.* (2011), who observed that wider spacing fosters more vigorous growth and earlier pod formation.

Yield components—including capsule number, fresh and dry capsule weight, seed yield, 1000-seed weight, and stover yield—were significantly higher ($p < 0.001$) under closer spacing with more plants per stand, particularly in the $40 \times 25 \times 3$ treatment. This highlights the role of plant density in maximizing productivity. Previous studies by Falodun and Ogedegbe (2016), Akinpelu *et al.* (2023), and Adesina and Wiro (2020) similarly found that closer spacing improves pod yield through efficient land use and canopy coverage. Higher density also suppresses weeds and reduces soil

evaporation, contributing to better resource use.

Correlation analysis (Table 3) further confirmed that plant population strongly influenced yield outcomes. Plant population at harvest was perfectly correlated with stover yield and strongly associated with capsule yield, dry yield, seed yield, and 1000-seed weight, underscoring density as a key driver of both vegetative and reproductive performance (Akinpelu *et al.*, 2023). Capsule number per plant showed moderate correlations with yield traits, while capsule length was weakly and negatively associated, indicating that capsule size is not

a reliable determinant of productivity (Adesina and Wiro, 2020). Field capsule yield was perfectly correlated with dry yield and seed yield, highlighting capsule production as the primary determinant of seed output. Dry capsule yield also correlated strongly with seed yield and 1000-seed weight, confirming its predictive value. These relationships align with Beerasha *et al.* (2025), who identified seed weight and capsule number, as critical yield components in okra breeding. Seed weight itself was strongly correlated with all yield traits, reinforcing its central role in productivity.

Table 1: Effect of plant spacing and number of plants per stand on emergence, establishment, days to flowering and maturity of okra

Treatments	Percentage emergence (%)	Percentage establishment (%)	Days to first flowering	Days to 50% flowering	Days to 95% maturity
40×25×1	83.13	62.5	39.50 ^a	53.50 ^a	74.50 ^a
40×25×2	96.25	73.13	39.75 ^a	53.75 ^a	74.75 ^a
40×25×3	82.08	65.83	39.50 ^a	53.5 ^a	74.50 ^a
50×25×1	83.59	68.75	38.00 ^{bc}	51.00 ^{bc}	72.00 ^{bc}
50×25×2	85.16	71.88	38.25 ^b	51.25 ^b	72.25 ^b
50×25×3	80.73	55.73	37.00 ^c	50.00 ^c	71.00 ^c
LSD	ns	ns	***	***	***

ns = not significant at $p > 0.05$, *** = highly significant at $p < 0.001$

Table 2: Effect of plant spacing and number of plants per stand on number of capsule and seed yield of okra

Treatments	Plant population at harvest	No. of capsules per plant	Length of capsule (cm)	Field yield of capsules (t/ha)	Dry yield of capsules (t/ha)	Seed yield (t/ha)	1000-seed weight (g)	Stover yield (t/ha)
40×25×1	8.50 ^d	2.55	10.78	0.74 ^e	0.68 ^e	0.42 ^e	18.22 ^d	0.35 ^{de}
40×25×2	36.25 ^b	2.45	10.07	1.12 ^c	1.06 ^c	0.66 ^c	28.32 ^b	0.48 ^{bc}
40×25×3	55.75 ^a	2.34	10.17	1.57 ^a	1.49 ^a	0.93 ^a	34.49 ^a	0.66 ^a
50×25×1	9.00 ^d	2.39	11.31	0.59 ^f	0.54 ^f	0.33 ^f	18.18 ^d	0.29 ^e
50×25×2	21.25 ^{cd}	2.41	10.65	0.94 ^d	0.88 ^d	0.55 ^d	22.69 ^{cd}	0.41 ^{cd}
50×25×3	34.25 ^{bc}	2.33	9.05	1.29 ^b	1.22 ^b	0.76 ^b	27.12 ^{bc}	0.55 ^b
LSD	***	ns	ns	***	***	***	***	***

ns = not significant at $p > 0.05$, *** = Highly significant at $p < 0.001$

Table 3: Correlation between yield components of okra

	Plant population at harvest	No. of capsules per plant	Length of capsule (cm)	Field yield of capsules (t/ha)	Dry yield of capsules (t/ha)	Seed yield (t/ha)	1000-seed weight (g)	Stover yield (t/ha)
Plant population at harvest	-							
No. of capsules per plant	0.71***	-						
Length of capsule (cm)	-0.15ns	-0.14ns	-					
Field yield of capsules (t/ha)	0.82***	0.57**	-0.37ns	-				
Dry yield of capsules (t/ha)	0.84***	0.59**	-0.36ns	1.00***	-			
Seed yield (t/ha)	0.84***	0.59**	-0.36ns	1.00***	1.00***	-		
1000-seed weight (g)	0.76***	0.52**	-0.40*	0.99***	0.98***	0.98** *	-	
Stover yield (t/ha)	1.00***	0.69***	-0.14ns	0.81***	0.83***	0.83** *	0.75***	-

***correlation is significant at $p < 0.001$

**correlation is significant at $p < 0.01$

ns = correlation not significant at $p > 0.05$

Conclusion

This study demonstrates that plant spacing and stand density exert minimal influence on flea beetle (*P. uniforma*) infestation and damage severity in the local okra species, with peak infestation occurring at 6 – 7 weeks after sowing and maximum damage at 10 weeks. In contrast, yield performance was significantly enhanced under closer spacing with three plants per stand (40 × 25 × 3), which produced higher capsule, seed, and stover yields. Correlation analysis confirmed that plant population was the strongest determinant of both vegetative and reproductive output, while capsule length showed weak or negative associations with yield traits.

Recommendations

For late-season okra production, closer spacing with three plants per stand at 40 × 25 cm is recommended to maximize capsule, seed, and stover yields, as plant density was the strongest driver of productivity. Also, pest management strategies for *P. uniforma* should focus on timely interventions during the mid-vegetative to flowering stages rather than altering planting geometry. This integrated approach ensures optimal yield while mitigating pest pressure.

Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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