International Journal of Plant & Soil Science

Volume 38, Issue 6, Page 350-360, 2026; Article no.IJPSS.158851
ISSN: 2320-7035

Effect of Varying Spacing and Pigeon Pea/ Maize Intercrop Patterns on the Weed Pressure, Growth and Yield Performance of Pigeon Pea across Diverse Agroecologies

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2026/v38i66128

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/158851

Original Research Article

Received: 30/03/2026
Published: 10/06/2026

Abstract

Pigeon pea productivity is often constrained by weed infestation due to its slow initial growth and wide plant spacing. Optimizing plant spacing in intercropping systems is therefore essential for enhancing yield, improving resource use efficiency, and suppressing weeds. This study evaluated the effects of plant spacing on pigeon pea–maize intercropping systems and associated weed dynamics in two agroecological zones: Ibadan (Forest–Savannah Transition) and Kishi (Southern Guinea Savannah–Northern Fringe). Two pigeon pea accessions (NSWCC-28 and NSWCC-50B), two inter-row spacings (1.0 m and 0.75 m), and intra-row spacing arrangements (0.25 m and 0.50 m for single plant stands, and 0.50 m for double maize stands) were evaluated in a split–split plot factorial experiment arranged in a randomized complete block design with three replications. Agronomic performance and weed growth parameters were assessed.

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Cite as: *Aluko, O. A., Adewumi, A. D., Adeleke, M. A., & Adeniyan, O. N. (2026). Effect of Varying Spacing and Pigeon Pea/ Maize Intercrop Patterns on the Weed Pressure, Growth and Yield Performance of Pigeon Pea across Diverse Agroecologies. International Journal of Plant & Soil Science, 38(6), 350–360. https://doi.org/10.9734/ijpss/2026/v38i66128*

Results showed that maize plants in Ibadan were significantly taller than those in Kishi at 12 weeks after sowing (WAS), whereas pigeon pea plant height did not differ significantly between locations. However, maize grain yield was higher in Kishi than in Ibadan, while pigeon pea grain yield in Ibadan was almost double that recorded in Kishi. Among accessions, NSWCC-28 produced higher grain yield and heavier seeds than NSWCC-50B, indicating superior performance in both sole and intercropping systems. Maize yield was higher under 0.75 m inter-row spacing, whereas pigeon pea performed better under 1.0 m inter-row spacing. Land equivalent ratio (LER) values indicated greater system efficiency in maize-dominated systems at 0.75 m spacing (0.98), while pigeon pea showed higher efficiency at 1.0 m spacing (0.95). The highest weed suppression was observed in treatments with 0.25 m intra-row spacing (single plant per stand). Overall, the study demonstrates that spatial configuration significantly influences crop performance, weed suppression, and resource use efficiency in pigeon pea–maize intercropping systems, highlighting its potential for reducing herbicide dependence and improving sustainable production.

Keywords: Pigeon pea; maize intercropping; plant spacing; weed suppression; agroecological zones; land equivalent ratio; yield performance; resource use efficiency.

1. Introduction

Intercropping is a multiple cropping system in which two or more crop species are grown simultaneously on the same field during a single growing season (Boto & Bassa, 2025). It is widely practised in both developed and developing agricultural systems due to its biological, environmental, and economic advantages. Among its key benefits, intercropping is commonly recognised as a risk-reduction strategy, since the presence of multiple crops reduces the likelihood of total crop failure; if one crop performs poorly, the companion crop may still yield satisfactorily, thereby ensuring partial harvest stability (Araj et al., 2024; Devika et al., 2025).

Pigeon pea-maize intercropping systems are common in tropical and subtropical regions because they can increase land productivity and improve food security, especially for smallholder farmers (Kushwaha & Mehta, 2023; Frimpong et al., 2025). However, the complex interactions among plant spacing, crop genotypes, and weed dynamics in these systems remain poorly understood and require further research to maximize their benefits. Effective weed management is essential for maximizing yields and ensuring sustainable food production, especially since manual weeding is labor-intensive and herbicide use raises environmental concerns (Sharma et al., 2021). Therefore, exploring alternative weed-suppression methods, such as optimized planting patterns, offers a promising way to improve the sustainability of intercropping systems and reduce dependence on chemicals (Behera et al., 2024). This study examines how different plant spacing configurations affect the growth of pigeon pea and maize and how they influence weed competition in the distinct climates of Ibadan and Kishi in Nigeria. The research investigates how various inter-row and intra-row spacing, along with specific pigeon pea varieties, affect crop development, yield, and weed suppression. Analyzing these spatial arrangements and varietal choices provides valuable insights into better resource use and weed control through ecological intensification (Boutagayout et al., 2025). This comprehensive work contributes to developing strong, eco-friendly farming practices that boost crop resilience and reduce the need for external inputs in pigeon pea-maize intercropping systems. Different planting patterns, including inter-row and intra-row spacing, have been shown to significantly improve weed suppression and resource use efficiency (Tang et al., 2025) in intercrop systems. These arrangements can help crops compete better with weeds by promoting faster canopy closure and altering microclimates, thereby reducing weed establishment and growth (Eslami, 2025). Effective weed management strategies are crucial for maximizing crop yield and ensuring sustainable food production, particularly given the labor-intensive nature of manual weeding and the environmental concerns associated with herbicide use (Monteiro & Santos, 2022). Consequently, exploring alternative weed-suppression methods, such as optimized planting patterns, offers a promising avenue to enhance intercropping sustainability and reduce reliance on chemical interventions (Nath et al., 2024; Solanki et al., 2023).

Despite the apparent benefits of strategic plant spacing in intercropping systems, a gap remains in region-specific, empirical evidence that guides spacing recommendations for pigeon pea–maize systems under different agroecological conditions. This study, therefore, aimed to evaluate the impact of varied plant spacing configurations on the agronomic performance of pigeon pea and maize, as well as the competitive dynamics of weed populations, within the distinct agroecologies of Ibadan and Kishi in Nigeria. This research explores how different inter-row and intra-row spacings, in conjunction with specific pigeon pea accessions, influence crop growth, yield, and the suppression of diverse weed species. Studies conducted on different crops have shown that varied planting patterns, including inter-row and intra-row spacing, significantly influence the effectiveness of intercropping systems in suppressing weed growth and optimizing resource allocation (Tang et al., 2025). The investigation into these spatial arrangements and varietal selections offers insights into optimizing resource utilization and mitigating weed pressure through ecological intensification (Brooker et al., 2023; Boutagayout et al., 2025). This comprehensive analysis contributes to the development of robust, ecologically sound agricultural practices that bolster crop resilience and reduce the need for external inputs in pigeon pea-maize intercropping systems. These configurations can enhance crop competitive ability against weeds by promoting rapid canopy closure and altering microclimates, thereby minimizing weed establishment and growth (Behera et al., 2024). This study evaluates the effects of varying inter-row and intra-row spacing, along with pigeon pea accessions, on crop growth, yield performance, and weed suppression in the contrasting agroecological conditions of Ibadan and Kishi, Nigeria. By examining these spatial arrangements, the study aims to generate insights into improved resource utilisation, enhanced weed control, and sustainable productivity in pigeon pea–maize intercropping systems.

2. Methodology

2.1 Study Area

The study was conducted during the rainy seasons of 2023 and 2024 in two agroecological zones in Nigeria: Ibadan (Derived Savanna/Forest–Savanna Transition zone) and Kishi (Southern Guinea Savanna–Northern fringe). The selection of these locations was based on their contrasting climatic and edaphic conditions, which allowed for evaluation of crop performance under diverse agroecological environments.

2.2 Experimental Design and Treatment Structure

The experiment was laid out as a factorial arrangement fitted into a Randomized Complete Block Design (RCBD) with three replications. The treatments consisted of:

- Two pigeon pea accessions: NSWCC-28 and NSWCC-50B
- Two inter-row spacings: 1.0 m and 0.75 m
- Three intra-row maize planting configurations:
  - 0.25 m spacing with 2 plants per stand
  - 0.50 m spacing with 2 plants per stand
  - 0.50 m spacing with 1 plant per stand

This resulted in a 2 × 2 × 3 factorial combination. Each experimental plot measured 5 m × 5 m.

2.3 Crop Selection, Establishment and Management

The pigeon pea genotypes were selected due to their adaptability to these agroecologies as earlier reported by Aluko et al., (2023). Pigeon pea and maize were sown simultaneously according to the assigned spacing treatments. Standard agronomic practices, including land preparation, fertilizer application, and weed management (manual weeding where necessary), were uniformly applied across all treatments to minimize bias. Crop management was kept consistent across locations.

2.4 Data Collection

Data were collected on both crops at specified growth stages. The parameters measured included:

- Plant height at 12 weeks after sowing (12 WAS)
- Grain yield (kg/ha) for maize and pigeon pea
- 100-seed weight (g)
- Weed dry matter (g/m²) under maize and pigeon pea canopy
- Land Equivalent Ratio (LER)

2.5 Data Analysis

All collected data were subjected to analysis of variance (ANOVA) to test treatment effects on the measured variables. Where significant differences occurred, means were separated using the Least Significant Difference (LSD) test at a 5% probability level.

2.6 Productivity Assessment of the Intercropping System

2.6.1 Land Equivalent Ratio (LER)

The productivity advantage and resource use efficiency of the intercropping system were evaluated using the Land Equivalent Ratio (LER). LER quantifies the relative land area required under sole cropping to achieve the same yield obtained under intercropping (Mead and Willey, 1980).

LER was calculated using the expression:

$$LER = \frac{Ymp + Ypm}{Ym + Yp}$$

Where:

Ymp = yield of maize in intercropping
Ypm = yield of pigeon pea in intercropping
Ym = yield of maize in sole cropping
Yp = yield of pigeon pea in sole cropping

An LER value greater than 1 indicates a yield advantage of intercropping over sole cropping, while values less than 1 indicate a disadvantage. A value equal to 1 suggests no difference in land use efficiency between intercropping and sole cropping systems.

3. Results and Discussion

Table 1 shows the effects of locations (Rainforest-savanna transition – Ibadan**)** and Southern Guinea savanna-Northern fringe-Kishi) on the performance of a pigeon pea/maize intercrop system. The parameters include crop plant heights at 12 weeks after sowing (WAS), grain yield for maize (MGY) and pigeon pea (PGY), 100-seed weight for both crops (M100-S and P100-S), weed dry weight (WDW) under maize (WDWm) and pigeon pea (WDWp), and land equivalent ratio (LER) for maize (LERm) and pigeon pea (LERp).

3.1 Effect of Locations on Crop Agronomic Parameters

Ibadan recorded significantly taller maize (127.43 cm) than Kishi (122.47 cm), possibly due to better soil fertility or more favourable microclimatic conditions such as temperature and rainfall. Whereas Pigeon Pea height showed no significant difference between locations, suggesting pigeon pea is more stable across these environments, possibly due to its deeper rooting system and drought tolerance (Bakala et al., 2024).

Maize Grain Yield (MGY) was significantly higher in Kishi (880.47 kg/ha) than in Ibadan (531.34 kg/ha). This may reflect better light penetration or lower interspecific competition at Kishi. Another factor could be maize's better response to local soil and moisture conditions, consistent with reports by Nykytiuk & Kravchenko (2025). Contrastingly, pigeon pea performed better in Ibadan (520.81 kg/ha) than in Kishi (295.64 kg/ha). This inverse yield trend could suggest spatial and resource-use complementarity but also points to location-specific advantages for pigeon pea in Ibadan, e.g., delayed rainfall cessation and Kishi, characterized with prolonged dry months as earlier recorded by Aluko et al., (2023), might account for lower grain yield in pigeon pea (Aluko et al., 2023).

Ibadan showed significantly higher 100-seed weights for both crops, which typically correlates with better grain filling, likely due to more consistent moisture and nutrient availability during reproductive stages (Bhattacharya, 2021; Carrera et al., 2024). This trait can be an important yield component, reflecting photosynthetic efficiency and assimilate partitioning.

No significant difference was observed for weed dry matter in both crops across the two locations. However, values were numerically higher in Ibadan. The similarity in weed biomass might suggest that weed suppression was equally effective across locations, possibly due to canopy coverage or allelopathic interactions in the intercrop system (Smith et al., 2023).

Maize land equivalent ratio (LERm) was higher in Kishi (0.90), indicating that maize benefited more from intercropping there. Likewise, pigeon pea had a higher land equivalent ratio in Ibadan (0.87), reinforcing the earlier observation on pigeon pea yield. Since total LER (LERm + LERp) > 1 in both cases (Ibadan: 1.41; Kishi: 1.40), this confirms that intercropping was advantageous at both locations, indicating better resource-use efficiency, an important principle in sustainable agriculture (Maitra et al., 2021).

3.2 Agronomic and Weed Implications

Site-specific management is crucial (Souza et al., 2025). While Kishi supports higher maize productivity, Ibadan favours pigeon pea. Hence, targeted varietal selection or adjustments in planting density may optimise the system. Weed management appears consistent, but integrating legume cover crops or adjusting planting geometry could enhance weed suppression further. Intercrop compatibility depends not only on species selection but on location-specific interactions with climate and soil. Economic and nutritional goals must balance the trade-off in grain yields between the two crops.

3.3 Growth Indices as Influenced by Pigeon Pea Genotypes

Both maize and pea pigeon showed no significant differences between the genotypes, indicating similar early vegetative growth (Table 2). This suggests that the intercrop canopy structure and light interception are comparable between genotypes at 12 WAS, which is important for early weed suppression (Smith et al., 2023).

Maize Yield (MGY) in NSWCC-28 (719.46 kg/ha) and NSWCC-50B (692.35 kg/ha) was statistically similar. This consistency suggests both genotypes can support maize productivity equally in an intercrop. Pigeon Pea genotype NSWCC-28 significantly outperformed NSWCC-50B (428.87 vs. 387.58 kg/ha). This indicates that NSWCC-28 has a higher yield stability and resource-use competitiveness in intercropping, possibly due to better partitioning of assimilates or stronger sink strength during reproductive stages (Maitra et al., 2021).

NSWCC-28 produced heavier maize seeds (19.85 g) than NSWCC-50B (18.65 g), a statistically significant difference. This implies a better grain-filling process, which often reflects efficient photosynthate allocation. However, there was n**o** significant difference between the 100-seed weight of pigeon pea genotypes (6.46 g vs. 6.59 g), suggesting similar genetic potential for seed size, despite yield differences.

Weed dry matter under both maize and pigeon pea canopies showed no significant differences between genotypes. However, numerically, NSWCC-50B had a higher weed dry weight at pigeon pea harvest (13.79 g/sqm) than NSWCC-28 (11.58 g/sqm), which could suggest less effective ground shading or canopy closure in NSWCC-50B. Efficient weed suppression is critical in intercropping and often correlates with early canopy establishment and allelopathic activity (Wacławowicz et al., 2023). This reinforces the idea that NSWCC-28 might possess slightly superior weed competitiveness, though not statistically confirmed.

The Land Equivalent Ratio of maize intercropped has n**o** significant difference in both genotypes (NSWCC-28 (0.73) vs NSWCC-50B (0.71), suggesting both genotypes enable maize to perform well under intercropping. LERp (pigeon pea**)**: NSWCC-28 had significantly higher LERp (0.72 vs. 0.65). This affirms that NSWCC-28 uses intercropping resources more efficiently from the pigeon pea side, indicating superior complementarity and niche differentiation. The total LER for NSWCC-28 = 1.45, and for NSWCC-50B = 1.36**,** both >1.0, indicating intercropping was beneficial for land use efficiency, but NSWCC-28 was more productive per unit area.

NSWCC-28 is a more promising genotype in pigeon pea/maize intercrops due to its higher grain yield, heavier maize seeds, slightly better weed suppression potential, and greater land use efficiency (LER). Genotype selection plays a crucial role in intercropping systems and can amplify or mitigate competitive interactions. This aligns with recent findings by Mhlanga et al. (2024), who emphasised genotype-environment-management (G×E×M) interactions in enhancing intercrop sustainability. Weed management strategies should be integrated with genotype performance, as denser and taller genotypes may naturally reduce weed pressure, potentially lowering the need for herbicides (Harker et al., 2021).

3.4 Effect of Interrow Spacing on Maize and Pigeon Pea Performance

Maize height (MH12WAS) was significantly greater at 0.75 m spacing (142.88 cm) than at 1.00 m (107.02 cm) (Table 3). The denser spacing likely induced stem elongation due to increased competition for light, a phenomenon commonly observed in cereal crops (Anjorin & Adebayo, 2024). Pigeon pea height (PH12WAS) was significantly higher at 1.00 m (100.61 cm), suggesting less interspecific competition, which allowed for more robust vegetative development. This shows that narrower spacing favours maize, while wider spacing benefits pigeon pea in terms of vegetative growth, reflecting differing competitive abilities and growth habits.

Table 1. Effects of location on pigeon pea/maize intercrop

Location	MH12WAS	PH12WAS	MGY kg/ha	PGY kg/ha	M100-S g	P100-S g	WDWm g/sqm	WDWp g/sqm	LERm	LERp
Ibadan	127.43a	90.04a	531.34b	520.81a	20.28a	6.83a	20.10a	12.99a	0.54b	0.87a
Kishi	122.47b	88.77a	880.47a	295.64b	18.22b	6.22b	18.17a	12.18a	0.90a	0.50b
LSD	4.29	4.58	65.78	30.17	0.68	0.18	4.18	2.88	0.03	0.08

Legend: MH12WAS- Maize height at 12 weeks after sowing (WAS), PH12WAS-pigeon pea height 12WAS, MGY – maize grain yield, PGY-Pigeon pea grain yield, M100- maize 100-seed weight, P100 – Pigeon pea 100-seed weight, WDWm-weed dry weight at maize harvest, WDWp–weed dry weight at pigeon pea harvest, LERm-land equivalent ratio (maize), and LERp-land equivalent ratio (pigeon pea)

Table 2. Effects of performance of genotypes in pigeon pea/maize intercrop

Genotype	MH12WAS	PH12WAS	MGY kg/ha	PGY kg/ha	M100-S g	P100-S g	WDWm g/sqm	WDWp g/sqm	LERm	LERp
NSWCC-28	125.9a	89.77a	719.46a	428.87a	19.85a	6.46a	19.98a	11.58a	0.73a	0.72a
NSWCC-50^{B}	124.05a	89.03a	692.35a	387.58b	18.65b	6.59a	18.28a	13.79a	0.71a	0.65b
LSD	4.29	4.58	65.78	30.17	0.68	0.18	4.18	2.88	0.03	0.08

Legend: MH12WAS- Maize height at 12 weeks after sowing (WAS), PH12WAS-pigeon pea height 12WAS, MGY – maize grain yield, PGY-Pigeon pea grain yield, M100- maize 100-seed weight, P100 – Pigeon pea 100-seed weight, WDWm-weed dry weight at maize harvest, WDWp – weed dry weight at pigeon pea harvest, LERm-land equivalent ratio (maize), and LERp-land equivalent ratio (pigeon pea)

Table 3. Effects of inter-row spacing on pigeon pea/maize intercrop

Inter-row (m)	MH12WAS	PH12WAS	MGY kg/ha	PGY kg/ha	M100 (g)	P100(g)	WDWm g/sqm	WDWp g/sqm	LERm	LERp
0.75	142.88a	78.19b	961.15a	250.36b	22.00a	5.58b	18.90a	20.83a	0.98a	0.42b
1.00	107.02b	100.61a	450.66b	566.09b	16.50b	7.46a	19.37a	4.32b	0.46b	0.95a
LSD	4.29	4.58	65.78	30.17	0.68	0.18	4.18	2.88	0.03	0.08

Legend: MH12WAS- Maize height at 12 weeks after sowing (WAS), PH12WAS-pigeon pea height 12WAS, MGY – maize grain yield, M100-maize 100-seed weight, P100 – Pigeon pea 100-seed weight, WDWm-weed dry weight at maize harvest, WDWp – weed dry weight at pigeon pea harvest, LERm-land equivalent ratio (maize), and LERp-land equivalent ratio (pigeon pea)

Table 4. Effects of intra-row spacing on pigeon pea/maize intercrop

Intra-row (m)	MH12WAS	PH12WAS	MGY (kg/ha)	PGY (kg/ha)	M100 (g)	P100 (g)	WDWm (g/sqm)	WDWp (g/sqm)	LERm	LERp
P/M Sp1	173.21b	131.44a	718.16b	419.95b	27.96a	9.27ab	23.29a	6.21c	0.74b	0.70b
P/M Sp2	182.46a	127.37a	729.63b	411.64b	27.17a	9.17b	22.33a	8.54bc	0.75b	0.69b
P/M Sp3	183.29a	126.38a	718.08b	449.10b	27.42a	9.50a	22.92a	6.83bc	0.74b	0.75b
SP	-	46.67b	-	597.09a	-	8.60b	14.92b	11.08b	-	1.00a
SM	64.12c	-	976.15a	-	20.58b	-	12.21b	30.21a	1.00a	-
LSD	6.79	7.24	104.01	47.69	1.07	0.28	6.61	4.56	0.04	0.14

Legend: P/M SP1 – Pigeon pea/Maize 0.25 m 1plants/stand, P/M SP2 – Pigeon pea/Maize 0.50 m 2plant/stand, P/M SP3 – Pigeon pea/Maize 0.50 m 1plant/stand), SP – sole pigeon pea, SM – Sole Maize, MGY – maize grain yield, PGY-Pigeon pea grain yield, M100-maize 100-seed weight, P100 – Pigeon pea 100-seed weight, WDWm-weed dry weight at maize harvest, WDWp – weed dry weight at pigeon pea harvest, LERm-land equivalent ratio (maize) and LERp-land equivalent ratio (pigeon pea)

Maize Yield (MGY): 0.75 m spacing had a significantly higher yield (961.15 kg/ha) than 1.00 m (450.66 kg/ha). Closer spacing likely enabled maize to dominate resource capture (light, water, nutrients), as supported by Shao et al., (2025), who noted yield boosts in maize at higher planting densities in intercrops. Pigeon Pea Yield

(PGY): Conversely, pigeon pea thrived at 1.00 m spacing (566.09 kg/ha) compared to 250.36 kg/ha at 0.75 m. This is expected due to reduced shading and root competition, in line with findings from Singh (2024). These results underscore a trade-off: maize benefits from narrower spacing, while pigeon pea yields better at wider spacing.

Maize seed weight was significantly higher at 0.75 m (22.00 g) than at 1.00 m (16.50 g), indicating better grain filling due to higher plant density and light competition, prompting early reproductive development. Pigeon pea seed weight was greater at 1.00 m (7.46 g), indicating better resource availability and less crowding stress, supporting findings by Barsisa et al., (2025) that wider spacing in faba bean improves grain quality.

Weed growth at maize harvest showed no significant difference, though it was numerically lower at 0.75 m (18.90 g/sqm), indicating that a denser maize canopy at narrower spacing more effectively suppresses weed growth through faster closure and light exclusion. Weed growth at pigeon pea harvest was significantly lower at 1.00 m (4.32 g/sqm) compared to 0.75 m (20.83 g/sqm). This seems counterintuitive, but it may be due to better pigeon pea growth and canopy development at wider spacing, which enhances weed suppression under its canopy. These trends align with studies by Patel et al., (2021) and Smith et al., (2023), showing that weed dynamics in intercrops are strongly affected by both canopy structure and root zone occupancy.

LERm (maize) was significantly higher at 0.75 m (0.98) than at 1.00 m (0.46), indicating that denser maize spacing improved its competitive success and cumulative yield in intercropping. LERp (pigeon pea) was higher at 1.00 m (0.95) compared to 0.42 at 0.75 m. The total LER is more than unity for both inter-row spacing (0.75 m spacing: 1.40 and 1.00 m spacing: 1.41). Both spacings exceed unity, confirming that intercropping was advantageous in both cases, but crop-specific advantages shifted with spacing. This supports the principle that spatial arrangements modulate competitive balance and complementarity in intercrops (Luo et al., 2024).

Though 0.75 m spacing favoured maize yield and weed suppression, it suppressed pigeon pea yield and seed size. Inter-row spacing of 1.00 m promoted pigeon pea productivity and seed quality, but significantly reduced maize yield. Total LERs were similar, but each spacing offered different crop-specific advantages.

The choice of spacing should be guided by the dominant crop objective. For maize-dominant intercrops, inter-row spacing of 0.75 m gave superior performance. While pigeon pea-focused systems had better performance at 1.00 m. Maize yield declines from 961 to 451 kg/ha as spacing widens (0.75 → 1.00 m), while pigeon pea yield rises from 250 to 566 kg/ha. Showing LER for maize dropping (0.98 → 0.46) and pigeon pea increasing (0.42 → 0.95) across the same spacing gradient. These highlight the trade-off between maize dominance at narrow spacing and pigeon pea performance at wider spacing, framing spatial arrangement decisions for system optimization. Balanced intercrops may benefit from staggered or strip planting, which can allow each crop to optimize space use without strong yield trade-offs (Wu, 2025).

3.5 Effects of Intra-row Spacing on Crop Agronomic Traits and Weed Dynamics

This table evaluates the effect of different intra-row spacing configurations on the growth, yield, weed suppression, and land use efficiency of a pigeon pea/maize intercrop.

Maize Height at 12WAS in Sp3 (183.29 cm) and Sp2 (182.46 cm), indicating slightly wider intra-row spacing supports vertical growth, likely due to better light and resource access. Pigeon Pea Height at 12WAS in Sp1 (131.44 cm) suggests narrower intra-row spacing may increase height due to interspecific competition, forcing elongation, a common shade avoidance response in legumes (Haque & Sakimin, 2022).

Maize grain yield was similar across intra-row spacing configurations (~718–729 kg/ha), but significantly higher in sole maize (976.15 kg/ha). This confirms intercropping reduces maize yield due to interspecific competition. Pigeon Pea grain yield (PGY) was best in Sp3 (449.10 kg/ha), indicating that slightly wider intra-row spacing for pigeon pea improves yield, likely by reducing competition for space and light. Sole pigeon pea (SP) had the highest yield (597.09 kg/ha), reinforcing the yield-reducing effect of intercropping on pigeon pea.

Maize seed weight (M100) had significantly larger seeds (27–28 g/100 seeds) in intercropping than in sole (20.58 g), likely due to fewer cobs per plant in intercrop, which enhances grain filling. Pigeon pea 100-seed weight was highest in Sp3 (9.50 g), showing that slightly wider spacing enhances grain quality through improved assimilate partitioning (Barsisa et al., 2025).

Weed dry weight was higher in intercropped plots (22–23 g/sqm) than in sole maize (12.21 g/sqm), suggesting weeds faced less suppression in intercrops, possibly due to reduced canopy density or delayed closure in intercrop rows. This reflects Yadav et al. (2025), who emphasized that row configurations affect canopy cover and weed interception. The highest weed weight was recorded in Sole Maize (30.21 g/sqm) and the lowest in Sp1 (6.21 g/sqm). This demonstrates that intercropping sharply suppresses weed pressure under pigeon pea, likely due to the prolonged canopy coverage outcompeting weeds.

Land equivalent ratios of crops (LERm and LERp) values for intercropped treatments are all below 1, indicating partial land use efficiency. Total LER (LERm + LERp): Sp1: 1.44, Sp2: 1.44, Sp3: 1.49 (highest) and Sole crops have LER = 1 by definition. This confirms intercropping is advantageous in all treatments, but Sp3 (wider intra-row spacing) offered the best land use efficiency, consistent with Luo et al. (2024), who found that spatial arrangement fine-tuning boosts intercrop complementarity.

4. Conclusion and Recommendations

This study confirms that location significantly affects intercrop dynamics, with clear implications for productivity and resource use. The pigeon pea/maize intercrop remains viable in both Ibadan and Kishi, but optimisation strategies should consider crop-specific responses to local environmental conditions.

The findings in Table 2 underscore the importance of genotype selection in improving the productivity and sustainability of cereal-legume intercrop systems. While both genotypes offer intercropping benefits, NSWCC-28 outperforms NSWCC-50B in yield-related and efficiency traits. Such information is vital for breeding programs and farmers targeting site-specific and competitive intercropping systems.

Though 0.75 m spacing favoured maize yield and weed suppression, it suppressed pigeon pea yield and seed size. Inter-row spacing of 1.00 m promoted pigeon pea productivity and seed quality, but significantly reduced maize yield. Total LERs were similar, but each spacing offered different crop-specific advantages. The choice of spacing should be guided by the dominant crop objective. For maize-dominant intercrops, inter-row spacing of 0.75 m gave superior performance. While pigeon pea-focused systems had better performance at 1.00 m.

Intra-row spacing significantly affects intercrop performance through its impact on competition, growth form, and resource partitioning. Sp3 appears optimal for maximizing LER and pigeon pea productivity without compromising maize yield. Weed suppression was most effective under intercropping, particularly for pigeon pea. Future intercropping systems should consider adjustable intra-row spacing based on the primary crop or economic goals.

Disclaimer (Artificial Intelligence)

The author (s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/158851