

Effect of Intra-row Spacing and Seed Rate on the Growth and Yield of Maize in Abuja, Nigeria

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Abstract

Maize is an important cereal crop in the humid tropics and sub-Saharan Africa, ranking third behind wheat and rice. Therefore, optimal plant density and good agronomic procedures are essential for enhancing maize. Two field trials were conducted at the Teaching and Research Farm of the Faculty of Agriculture, University of Abuja, Nigeria, during the growing seasons of 2023 and 2024, to investigate the impacts of intra-row spacing (75 cm × 25 cm, 75 cm × 35 cm, 75 cm × 45 cm and 75 cm × 75 cm) and the number of seeds per hole, (1, 2 and 3) on the growth and yield of maize. A 3 × 4 factorial Randomised Complete Design with 3 replications was used. Data collected includes percentage germination, plant height, number of leaves/plant, leaf area, stem girth, cob length, cob diameter, shelling percentage and grain yield. Percentage germination, plant height, leaf area, and number of leaves per plant were not influenced by the seed rate and intra-row spacing. The parameters were also not influenced by the interaction of intra-row spacing and the number of seeds per hole. While the number of seeds per hole significantly influenced stem girth, the effect of intra-row spacing was not significant. The results showed that plant spacing of 75 cm × 25 cm yielded the highest grain yield (5.11 t/ha in 2023 and 5.3 t/ha in 2024). One seed per hole produced the highest grain yield (3.9 t/ha). The study recommends planting one seed per hole at a spacing of 75 cm × 25 cm for optimal maize production in Abuja.

Key Words: Growth, Intra-row spacing, Maize, Number of seeds per hole and Yield.

1.0 Introduction

Maize (*Zea mays* L.) belongs to the Poaceae family of grasses. Maize is among the key cereal crops globally, ranking third in production behind rice and wheat (FAOSTAT, 2016). Its diverse applications encompass food, animal feed, and industrial uses, including maize starch, dextrose, and maize syrup (Gul *et al.*, 2021). Maize is a staple food crop in Africa, particularly in eastern, southern, and western regions. With global demand projected to

increase by 50% and sub-Saharan Africa's demand expected to surge by 93% (FAO, 2015; Temesgen, 2019), driven by population growth, urbanisation, and the expanding livestock industry's reliance on maize as a key feed source. Effective maize cultivation necessitates a thorough grasp of multiple management techniques, including plant density, which greatly influences yield potential and consistency (Morugán-Coronado *et al.*, 2020; Efretuei *et al.*, 2024). The spacing among plants is crucial in influencing the arrangement of their location, as it impacts canopy development, light absorption, and efficiency in radiation use, which in turn affects biomass and grain yield (Mhango *et al.*, 2021). The organisation of plants within a given area significantly influences resource use, including light, nutrients, and water, thus impacting factors like vegetative growth, leaf area index, plant height, root length,—and density (Chen & Zhang, 2019; Shao *et al.*, 2021).

In Nigeria, a significant percentage of rural farmers, around 65% of the agricultural population, lack a critical understanding of crop production methods, resulting in reduced yields from inadequate plant spacing and density (Shiferaw *et al.*, 2011). The ideal plant density is essential for maximising yield since excessively high population density can exhaust soil moisture and nutrients before crops reach maturity, whereas insufficient density could result in poor resource utilisation (Chandrasekaran *et al.*, 2010). The density of plants influences yield factors, including the count of ears, kernels each ear contains, and kernel weight (Zhang *et al.*, 2020). Plant density has a considerable effect on maize yield because of its limited tillering capacity, underscoring the need to establish the ideal plant population for yield maximisation (Sangoi *et al.*, 2002).

High plant density induces mutual shading, reduces light interception per plant and impairs the plant's capacity to supply photo-assimilates to secondary ears. Research by Assefa *et al.* (2018) shows that leaves above and below the primary ear preferentially supply assimilates to the closest sink, contributing most to grain filling. According to Tesfaye (2020), adequate plant density is critical for efficient utilisation of growth factors like water, light, nutrients, and carbon dioxide, ultimately maximising grain yield. To achieve this, optimising plant density through adjusted row spacing and seed numbers per hole can reduce competition for resources, thus promoting efficient growth and resource utilisation and enhancing crop productivity and yield.

With the increasing need for maize in Nigeria, driven by its importance in producing livestock and poultry feed, as well as its diverse industrial applications, it's essential to determine the optimum agronomic practices, such as seed density and plant spacing, to improve productivity (Tesfaye, 2020). The study aimed to determine the optimal plant spacing and seed density for improving maize production in Abuja. It specifically investigated the impact of intra-row spacing and the seed count per hole on maize growth and yield. The study sought to improve maize production, boost food security, and raise farmers' income by pinpointing optimal agronomic practices. The results can guide suggestions for maize farmers in Abuja and similar areas, enhancing agricultural productivity and food security, and ultimately narrowing the difference between actual and possible maize yields.

2.0 Materials and Methods

2.1 Study Area

The study was carried out in the 2023 and 2024 cropping seasons at the Teaching and Research Farm of the Department of Crop Science, University of Abuja, Gwagwalada, Nigeria. The exact coordinates of the experimental farm are 8°58'24.46943" North and

7°10'8.46707" East. The farm's climate is characterised by a rainy season from April to October, with mean temperatures around 30 °C, 14 % relative humidity, and annual rainfall between 1,100 mm and 1,800 mm (Barnabas & Nwaka, 2014).

According to Ishaya and Grace (2007), the soil is a deep, well-drained sandy loam of moderate fertility, pH 5.6–5.8, and a moderate runoff potential. The farm experiences a rainy season from April to October, with mean temperatures around 30 °C, 14 % relative humidity, and annual rainfall of 1,100–1,800 mm (Barnabas & Nwaka, 2014; Idoko & Bisong, 2010). In the dry season, temperatures range from 28 °C to 30 °C and can exceed 40 °C, especially in Gwagwalada, with 10 km/h north-easterly winds. The soil is a deep, well-drained sandy loam formed from granite and migmatite, with moderate runoff potential and a texture of loamy sand, clay loam, and sandy clay; fertility is average and pH 5.6–5.8 (Ishaya & Grace, 2007).

2.2 Land Preparation and Soil Sample Collection

The experimental site was cleared, levelled, and stumped with machetes, rakes, and dibbers, then ploughed and harrowed until the soil had a fine texture. Soil samples were collected from 10 locations within each experimental site at a depth of 0-30 cm using a handheld soil auger. These samples were bulked to form a composite sample, which was then air-dried, sieved through a 2mm sieve, and analysed in the laboratory following the FAO's standard procedure (FAO, 2019).

2.3 Experimental Material, Treatment and Design

The SAMMAZ 51 maize variety, obtained from the National Seed Council of Nigeria in Abuja, served as the experimental material; it matures quickly (90 days), is drought-tolerant, and resistant to armyworms and stem-borers.

The experimental treatments assessed for their effects consisted of the number of seeds per hole (Factor A) at 1 seed per hole (A1), 2 seeds per hole (A2), and 3 seeds per hole (A3); and the plant spacing (Factor B) at 75 cm × 25 cm (B1), 75 cm × 35 cm (B2), 75 cm × 45 cm (B3), and 75 cm × 75 cm (B4). A 3 × 4 factorial experiment was arranged in a randomised complete block design with three replications. The experiment comprised 12 plots per replication, yielding a total of 36 plots. Individual plots measured 3 m × 3 m, with 0.5 m pathways separating adjacent plots within a block and 1 m alleys between blocks for ease of access. The experimental field covered 456.5 m² (41.5 m × 11 m).

2.4 Agronomic Practices

Planting was done with 1, 2, and 3 seeds per hole at spacings of 75 cm x 25 cm, 75 cm x 35 cm, 75 cm x 45 cm, and 75 cm x 75 cm. Plant spacing of 75 cm x 25 cm with 1 seed per hole resulted in a plant density of (53,333/ha), 2 seeds per hole (106,667/ha), and 3 seeds per hole (160,000/ha). 75 cm x 35 cm with 1 seed per hole resulted in a plant density of (38,095/ha), 2 seeds per hole (76,190/ha), and 3 seeds per hole (114,2856/ha). Plant spacing of 75 cm x 45 cm with 1 seed per hole resulted in a plant density of (29,630/ha),

Plant spacing of 75 cm x 45 cm with 1 seed per hole resulted in a plant density of (29,630/ha), 2 seeds per hole (59,259/ha), and 3 seeds per hole (88,889/ha). Spacing plants at 75 cm x 75 cm with 1 seed per hole resulted in a population of (17,778/ha), with 2 seeds per hole (35,556/ha), and with 3 seeds per hole (53,333/ha). The initial weeding was done 3 weeks after planting with a hoe, and the subsequent weeding was done after 56 days. NPK 15:15:15 fertilisers were used at a rate of 300 kg/ha, three weeks after planting, with each plot receiving 0.54kg/plot. Consequently, the total NPK applied across the 36 net plots was 19.44 kg.

2.5 Data Collection and Analysis

Percentage germination, plant height, number of leaves per plant, leaf area (cm^2), stem girth, cob length, weight of 1,000 seeds, cob diameter, shelling percentage, and grain yield (kg/ha) are among the data collected. Analysis of variance (ANOVA) was performed on the collected data using the R Statistical Program's "agricolae" package (version 4.5.0). The Least Significant Difference (LSD) test was used to separate treatment means when they were significantly different ($p < 0.05$).

3.0 Results

3.1 The Soil's Physical and Chemical Properties at the Experimental Site Before Planting and after Harvest

Tables 3.1 display the physical and chemical characteristics of the soil at the site of the experiment prior to planting and following the harvest. The soil at the experimental location was Sandy Loam (SL), showing a pH of 4.5 in water and 4.8 in KCl, indicating acidity. Post-harvest, pH notably increased to 6.2 in water and to 6.0 in KCl. The Total N was 0.011 before planting and 0.091 post-harvest, whereas the available Phosphorus levels were 4.40 mg/kg before planting and 7.04 mg/kg following harvest. The Effective Cation Exchangeable Capacity demonstrated increases in Na (0.12 to $0.33 \text{ Cmol}^{-1}/100\text{g}$), K (0.51 to $1.52 \text{ Cmol}^{-1}/100\text{g}$), Mg (1.20 to $1.79 \text{ Cmol}^{-1}/100\text{g}$), Ca (2.33 to $3.67 \text{ Cmol}^{-1}/100\text{g}$), and Total Exchangeable Bases (TEB) from 5.79 to $7.44 \text{ Cmol}^{-1}/100\text{g}$, respectively, suggesting that the basic cations were initially found in fairly low concentrations before the two-year study.

Low levels of Organic Matter (0.98), Organic Carbon (0.31), electrical conductivity (EC) of 0.18 mS/cm, and inadequate base saturation were found in the soil analysis performed before planting. These results suggested low fertility and were in line with Anyaegbu's (2013) claim that acidic soil (pH 4.5) typically limits the productivity of cereal, root, and tuber crops. Since high pH levels can lead to toxicity, pest issues, and disease outbreaks, Nedunchezhiyan and Ray (2010) suggested a pH range of 5.5 to 6.5 for the best yields of cereals, root, and tuber crops. Following harvest, higher nitrogen levels showed that the use of fertiliser had enhanced soil fertility. Increased nitrogen levels following harvest demonstrated that fertiliser application had improved the soil fertility.

3.2 Percentage Germination

Table 3.2 presents the effects of plant spacing and seed number per hole on the percentage germination of maize during the 2023 and 2024 cropping seasons. In both seasons, varying the number of seeds per hole did not produce any significant differences in germination rates ($P > 0.05$). Plant spacing also showed no significant influence in 2023 ($P > 0.05$). Still, in 2024, a considerable effect emerged ($P < 0.05$): the $75 \text{ cm} \times 75 \text{ cm}$ spacing resulted in a noticeably lower germination percentage (88.2 %) compared with the $75 \text{ cm} \times 25 \text{ cm}$, $75 \text{ cm} \times 35 \text{ cm}$, and $75 \text{ cm} \times 45 \text{ cm}$ spacings, which were statistically similar to one another. Throughout both seasons, the interaction between seed number per hole and plant spacing was not statistically significant ($P > 0.05$), indicating that the two factors acted independently on maize germination.

Table 3.1: Laboratory soil properties of the experimental site

Soil property	Unit	Before planting	After harvest
pH (H ₂ O)	—	4.5	6.2
pH (KCl)	—	4.8	6.0
Organic carbon (OC)	%	0.31	1.44
Organic matter (OM)	%	0.98	2.51
Total nitrogen (TN)	%	0.011	0.091
Electrical conductivity (EC)	mS cm ⁻¹	0.18	0.31
Available phosphorus (P)	mg kg ⁻¹	4.40	7.04
Exchangeable Na	cmol kg ⁻¹	0.12	0.33
Exchangeable K	cmol kg ⁻¹	0.51	1.52
Exchangeable Mg	cmol kg ⁻¹	1.20	1.79
Exchangeable Ca	cmol kg ⁻¹	2.33	2.67
Total exchangeable bases (TEB)	cmol kg ⁻¹	5.79	7.44
Exchangeable acidity	cmol kg ⁻¹	0.77	1.10
Effective cation exchange capacity (ECEC)	cmol kg ⁻¹	6.54	8.54
Silt	g kg ⁻¹	102.11	118.29
Clay	g kg ⁻¹	188.29	190.31
Sand	g kg ⁻¹	693.39	691.41
Textural class	—	Sandy loam	Sandy loam

OC = Organic carbon; OM = Organic matter; TN = Total nitrogen; EC = Electrical conductivity; mS cm⁻¹ = milliSiemens per centimetre; mg kg⁻¹ = milligrams per kilogram; TEB = Total exchangeable bases; ECEC = Effective cation exchange capacity.

Table 3.2: Percentage Germination of maize as influenced by the number of seeds per hole and plant spacing

	Percentage Germination (%)	
	2023	2024
Treatments		
Seeds per Hole (S)		
1 seed	87.2	92.8
2 Seeds	89.0	91.4
3 Seeds	91.4	94.5
LSD	5.23	3.41
Significance	NS	NS
Plant Spacing (P)		
75cm x 25cm	84.5	95.0a
75cm x 35cm	93.2	93.4a
75cm x 45cm	95.0	95.0a
75cm x 75cm	84.1	88.2b
LSD	15.28	3.93
Significance	NS	*
Interaction		
S X P	NS	NS

Means followed by the same superscript within a treatment column are not significantly different using the LSD Test at 5% level of probability. NS = Not significant. * = Significant.

3.3 Plant Height

Table 3.3 shows how maize plant height is affected by the number of seeds per hole and plant spacing. The number of seeds per hole only significantly influenced maize height at 4 weeks after planting in the 2023 trial; it was not significant during any growth stages in the 2024 experiment. The plot with 1 seed per hole had the tallest plants, while the plot with 2 seeds per hole had the shortest at 4 weeks. Plant spacing had a significant effect ($p < 0.05$) on maize height at 8 weeks in the 2023 trial, but this effect was not observed in 2024. The greatest height was recorded at 75 cm \times 35 cm, while the shortest was at 8 weeks after planting in 2023 was observed with the 75 cm \times 25 cm spacing. The relationship between the number of seeds per hole and plant spacing was not significant.

3.4 Number of Leaves

Table 3.4 presents the effects of seed number per hole and plant spacing on maize leaf count during the 2023 and 2024 cropping seasons. In 2023, seed number significantly influenced leaf count only at 4 WAP ($P < 0.05$): 2 seeds per hole produced a mean of 7.5 leaves, 3 seeds gave 7.8 leaves, both significantly higher than the 1-seed treatment (6.6 leaves). Plant spacing showed no significant effect in 2023 ($P > 0.05$). In 2024, plant spacing was significant only at 4 WAP ($P < 0.05$): 75 cm \times 45 cm recorded the highest count (6.3), 75 cm \times 25 cm the lowest (5.3), and 75 cm \times 35 cm (6.1) was statistically similar to the 45 cm spacing. Seed number per hole had no significant impact in 2024 ($P > 0.05$), and the interaction between seed number and plant spacing was non-significant in both seasons.

Table 3.3: Plant height (cm²) of maize as influenced by the number of seeds per hole and plant spacing

Treatments	Plant height (cm)					
	2023			2024		
Seeds per Hole(S)	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP
1 seed	40.0a	116.6	207.7	40.0	112.7	210.6
2 Seeds	31.8b	119.2	207.5	45.1	121.2	208.9
3 Seeds	36.7ab	120.5	203.6	43.2	123.3	208.4
LSD	5.34	11.95	7.45	6.89	12.98	8.13
Significance	*	NS	NS	NS	NS	NS
Plant Spacing(P)						
75cm \times 25cm	35.2	116.6	200.8b	39.6	118.7	206.1
75cm \times 35cm	35.9	115.9	210.0a	45.9	116.0	210.2
75cm \times 45cm	37.9	119.9	206.7ab	45.1	120.3	209.2
75cm \times 75cm	35.7	122.7	207.5ab	40.5	121.2	211.4
LSD	6.16	13.80	8.61	7.96	14.99	9.39
Significance	NS	NS	*	NS	NS	NS
Interaction						
S \times P	NS	NS	NS	NS	NS	NS

Means followed by the same superscript within a treatment column are not significantly different using the LSD Test at 5% level of probability. NS = Not significant. * = Significant. WAP=Weeks after Planting.

Table 3.4: Number of leaves of maize as influenced by the number of seeds per hole and plant spacing

Treatments	Number of leaves					
	2023			2024		
Seeds per Hole(S)	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP
1 seed	6.6b	10.3	13.3	6.1	10.6	13.7
2 Seeds	7.5a	10.6	13.5	5.9	10.8	13.5
3 Seeds	7.8a	10.3	13.8	5.8	9.1	13.2
LSD	0.55	0.88	0.93	0.67	1.31	1.10
Significance	*	NS	NS	NS	NS	NS
Plant Spacing(P)						
75cm x 25cm	7.3	10.0	12.8	5.3b	10.1	13.1
75cm x 35cm	7.1	10.0	13.4	6.1a	10.0	13.0
75cm x 45cm	7.1	10.9	13.7	6.3a	11.1	14.0
75cm x 75cm	7.6	10.6	14.0	6.0ab	10.4	13.7
LSD	0.64	1.01	1.08	0.78	1.51	1.27
Significance	NS	NS	NS	*	NS	NS
Interaction						
S x P	NS	NS	NS	NS	NS	NS

Means followed by the same superscript within a treatment column are not significantly different using the LSD Test at 5% level of probability. NS = Not significant. * = Significant. WAP=Weeks after Planting.

3.5 Leaf Area

Table 3.5 depicts maize leaf area during the 2023 and 2024 cropping seasons as a function of plant spacing and the number of seeds per hole. In the 2023 cropping season, the number of seeds per hole at 4 weeks post-planting had a substantial impact on leaf area. Plot with 2 seeds per hole produced the largest leaf area at 4 WAP in 2023. However, during the 2024 cropping season, it was not significant at any of the sampling times. Plant spacing had no significant influence on the leaf area of maize in both cropping seasons. There was no significant interaction between the number of seeds per hole and plant spacing.

3.6 Stem Girth

Table 3.6 presents the stem girth of maize for both the 2023 and 2024 cropping seasons, considering the effects of plant spacing and the number of seeds per hole. In both years, the number of seeds per hole significantly influenced stem girth at 4 WAP and 8 WAP ($P < 0.05$). Plots with 1 seed per hole produced the largest stem girth, measuring 5.2 cm at 4 WAP and 20.1 cm at 8 WAP in 2023, and 5.0 cm at 4 WAP and 23.1 cm at 8 WAP in 2024. In contrast, 3 seeds per hole resulted in the smallest stem girth across both seasons. Notably, 2 seeds per hole were statistically similar to 1 seed per hole at 8 WAP in the 2023 trial. However, plant spacing and the interaction between seed number and spacing did not significantly affect stem girth in any season.

Table 3.5: Leaf area (cm²) of maize as influenced by the number of seeds per hole and plant spacing

Treatments	2023			2024		
	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP
Seeds per Hole(S)						
1 seed	142.3b	436.0	504.4	148.9	457.8	546.5
2 Seeds	193.5a	448.9	528.6	176.0	444.1	538.8
3 Seeds	148.9ab	453.4	534.3	140.9	442.4	511.8
LSD	48.41	75.15	70.60	38.12	79.55	66.66
Significance	*	NS	NS	NS	NS	NS
Plant Spacing (P)						
75cm x 25cm	135.2	456.5	546.2	132.5	468.8	553.6
75cm x 35cm	178.0	457.3	488.8	147.7	464.2	513.5
75cm x 45cm	178.4	434.1	538.5	173.9	436.0	547.9
75cm x 75cm	154.8	436.4	516.2	167.1	423.5	514.4
LSD	55.89	86.76	81.53	44.01	91.86	76.98
Significance	NS	NS	NS	NS	NS	NS
Interaction						
S x P	NS	NS	NS	NS	NS	NS

Means followed by the same superscript within a treatment column are not significantly different using the LSD Test at 5% level of probability. NS = Not significant. * = Significant. WAP=Weeks after Planting.

Table 3.6: Stem girth (cm) of maize as influenced by the number of seeds per hole and plant spacing

Treatments	Stem Girth (cm)				
	2023		2024		
Seeds per Hole(S)		4 WAP	8 WAP	4 WAP	8 WAP
1 seed	5.2a	20.1a		5.0a	23.1a
2 Seeds	4.3b	18.6a		4.1b	18.8ab
3 Seeds	4.4b	16.8b		4.2b	18.6b
LSD	0.62	1.74		0.73	4.47
Significance	*	*		*	*
Plant Spacings (P)					
75cm x 25cm	4.3	18.8		4.1	20.4
75cm x 35cm	4.4	18.1		4.3	21.1
75cm x 45cm	4.7	17.6		4.5	20.5
75cm x 75cm	5.0	19.4		4.7	18.6
LSD	0.72	2.01		0.85	5.16
Significance	NS	NS		NS	NS
Interaction					
S x P	NS	NS		NS	NS

Means followed by the same superscript within a treatment column are not significantly different using the LSD Test at 5% level of probability. NS = Not significant. * = Significant. WAP=Weeks after Planting.

3.7 Cob Length, Diameter and Size

Table 3.7 presents the cob length of maize for both the 2023 and 2024 cropping seasons, considering the effects of plant spacing and the number of seeds per hole. In both years, the number of seeds per hole significantly influenced cob length ($P < 0.05$), with 1 seed per hole producing the longest cobs (13.8 cm in 2023 and 14.8 cm in 2024), while 3 seeds per hole resulted in the shortest lengths (13.1 cm in 2023 and 13.9 cm in 2024). Plant spacing also had a significant impact in both trials ($P < 0.05$), with 75 cm \times 75 cm yielding the highest cob length (15.2 cm in 2023 and 16.20 cm in 2024), and 75 cm \times 25 cm producing the smallest length in the 2023 trial (12.6 cm). No significant interaction was observed between seed number and plant spacing in either season. Table 3.7 presents the cob diameter of maize for the 2023 and 2024 seasons, showing values for seeds per hole (1, 2, 3) and plant spacing (75 \times 25 cm, 75 \times 35 cm, 75 \times 45 cm, 75 \times 75 cm). In both years, neither the number of seeds per hole nor the plant spacing significantly affected cob diameter ($P > 0.05$), and the interaction between the two factors was also non-significant ($P > 0.05$). Table 3.7 summarises the ear size of maize in the 2023 and 2024 cropping seasons. In both years, neither the number of seeds per hole nor the plant spacing significantly affected ear size ($P > 0.05$), and no significant interaction was found between the two factors ($P > 0.05$). Ear size was calculated as the product of cob length and cob diameter and expressed in square centimetres (cm²).

Table 3.7: Cob length (cm), cob diameter (cm) and ear size of maize as influenced by the number of seeds per hole and plant spacing

Treatments	Cob length (cm)					
	2023			2024		
	Cob length (cm)	Cob diameter (cm)	Ear Size (cm)	Cob length (cm)	Cob diameter (cm)	Ear Size (cm)
Seeds per Hole(S)						
1 seed	13.8a	14.7	0.3	14.8a	14.7	0.3
2 Seeds	13.7ab	15.0	0.3	14.5a	15.1	0.3
3 Seeds	13.1b	14.8	0.3	13.9b	14.8	0.3
LSD	0.67	0.55	0.13	0.59	0.56	0.12
Significance	*	NS	NS	*	NS	NS
Plant Spacing (P)						
75cm \times 25cm	12.6c	14.73	0.210	13.60b	14.81	0.2
75cm \times 35cm	13.0bc	14.64	0.251	13.78b	14.70	0.3
75cm \times 45cm	13.4b	14.79	0.285	14.09b	14.77	0.3
75cm \times 75cm	15.2a	15.12	0.264	16.20a	15.17	0.3
LSD	0.77	0.64	0.15	0.68	0.65	0.15
Significance	*	NS	NS	*	NS	NS
Interaction						
S \times P	NS	NS	NS	NS	NS	NS

Means followed by the same superscript within a treatment column are not significantly different using the LSD Test at 5% level of probability. NS = Not significant. * = Significant.

3.8 Shelling Percentage

Table 3.8 presents the shelling percentage, 1,000-seed weight, and grain yield of maize as influenced by the number of seeds per hole and plant spacing during the 2023 and 2024 cropping seasons. In both seasons, the number of seeds per hole did not significantly affect

shelling percentage ($P > 0.05$), but it did significantly influence 1,000-seed weight in both years and grain yield in 2024 ($P < 0.05$).

Table 3.8: Shelling percentage (%), 1000 seed weight (g) and grain yield (t/ha) of maize as influenced by the number of seeds per hole and plant spacing

Treatments	2023			2024		
	Shelling Percentage	1,000Seed Weight	Grain Yield (t/ha)	Shelling Percentage	1,000Seed Weight	Grain Yield (t/ha)
Seeds per Hole(S)						
1 seed	40.0	0.4a	3.8	41.3	0.4a	3.9a
2 Seeds	57.4	0.4a	3.8	53.4	0.3ab	3.8ab
3 Seeds	50.9	0.3b	3.3	46.7	0.31b	3.3b
LSD	17.7	0.02	0.48	16.90	0.02	0.51
Significance	NS	*	NS	NS	*	*
Plant Spacing (P)						
75cm x 25cm	36.7b	0.3b	5.1a	38.1	0.3b	5.3a
75cm x 35cm	46.5ab	0.3b	3.8b	42.0	0.3b	4.0b
75cm x 45cm	54.6ab	0.3b	3.1c	51.4	0.3b	3.6b
75cm x 75cm	59.9a	0.4a	2.4d	57.0	0.4a	2.3c
LSD	20.44	0.02	0.55	19.51	0.02	0.59
Significance	*	*	*	NS	*	*
Interaction						
S x P	NS	NS	NS	NS	NS	NS

Means followed by the same superscript within a treatment column are not significantly different using the LSD Test at 5% level of probability. NS = Not significant. * = Significant.

Plant spacing significantly affected all three variables in 2023 ($P < 0.05$); in 2024, spacing significantly impacted 1,000-seed weight and grain yield ($P < 0.05$) but not shelling percentage ($P > 0.05$). The lowest shelling percentage was 36.7 % recorded in 2023 from the 75 cm \times 25 cm spacing, while the highest shelling percentage was 59.9 % obtained in 2023 from the 75 cm \times 75 cm spacing. No significant interaction between seed number per hole and plant spacing was observed for any of the measured variables in either season.

3.9. Thousand Seed Weight (g)

Table 3.8 shows the influence of seed number per hole and plant spacing on the 1,000-seed weight of maize during the 2023 and 2024 cropping seasons. The number of seeds per hole significantly affected 1,000-seed weight in both seasons ($P < 0.05$). In 2023, three seeds per hole produced the lowest weight of 0.30 g, while one seed per hole gave the highest weight of 0.40 g, which was statistically similar to the two-seed treatment (0.40 g). In 2024, the highest weight was again 0.40 g with one seed per hole, and the lowest was 0.31 g with three seeds per hole. Plant spacing also had a significant effect in both years ($P < 0.05$), with the 75 cm \times 75 cm spacing yielding the highest weight of 0.40 g in both trials. The overall lowest 1,000-seed weight across the study was 0.30 g (three seeds per hole in 2023), and the overall highest was 0.40 g (one seed per hole and 75 cm \times 75 cm spacing in both seasons). No significant interaction between seed number and spacing was found in either season.

3.9 Grain Yield (t/ha)

Table 3.8 shows the influence of seed number per hole and plant spacing on the grain yield of maize during the 2023 and 2024 cropping seasons. In 2023, the number of seeds per hole did not significantly affect grain yield ($P > 0.05$), with yields of 3.8 t/ha for 1 seed per hole, 3.8 t/ha for 2 seeds per hole, and 3.3 t/ha for 3 seeds per hole. In 2024, however, the effect was significant ($P < 0.05$); 1 seed per hole produced the highest yield of 3.9 t/ha, 3 seeds per hole gave the lowest yield of 3.3 t/ha, and 2 seeds per hole resulted in 3.8 t/ha. Plant spacing significantly influenced grain yield in both seasons ($P < 0.05$). The 75 cm \times 25 cm spacing produced the highest yield of 5.1 t/ha in 2023 and 5.3 t/ha in 2024, followed by 75 cm \times 35 cm with 3.8 t/ha in 2023 and 4.0 t/ha in 2024, then 75 cm \times 45 cm with 3.1 t/ha in 2023 and 3.6 t/ha in 2024, and 75 cm \times 75 cm produced the lowest yield of 2.4 t/ha in 2023 and 2.3 t/ha in 2024. No significant interaction between seed number per hole and plant spacing was observed in either season.

4.0 Discussion

The vegetative development of maize was greatly affected by the seed count per hole and intra-row spacing in the 2023 and 2024 field experiments, although their interaction was not significant for all evaluated parameters, including plant height, leaf count, leaf area, and stem diameter. This suggests that the two elements operated separately. This aligns with the findings of Lesk *et al.* (2016), who stated that when water, temperature, and nutrients are sufficient, the interception of solar radiation becomes the main factor influencing growth, enabling density effects to function independently.

Throughout different seasons, the height of plants exhibited varying reactions. In 2023, having 1 seed per hole resulted in considerably taller plants measuring 40.0 cm at 4 WAP compared to the 31.8 cm noted for 2 seeds per hole. At 8 WAP, the spacing of 75 cm by 35 cm resulted in the tallest plants at 210.0 cm, whereas the spacing of 75 cm by 25 cm resulted in the shortest plants at 200.8 cm. In 2024, the number of seeds and their spacing did not result in notable height variations, suggesting that seasonal factors influenced density impacts.

Leaf production showed a distinct response to plant density. In 2023, at 4 WAP, holes with 2 and 3 seeds yielded more leaves, producing 7.5 to 7.8 leaves, while those with 1 seed yielded 6.6 leaves. In 2024, plant spacing affected the number of leaves, where 75 cm by 45 cm achieved the maximum value of 6.3, while 75 cm by 25 cm recorded the minimum value of 5.3. In 2023, leaf area reached a maximum of 193.5 cm² with 2 seeds per hole, and spacing had no significant impact on leaf area in both years. This suggests that the density of planting holes was more crucial than the distance between them for initial leaf growth.

Stem thickness was consistently affected by the number of seeds, with one seed per hole resulting in the greatest thickness at 4 and 8 WAP across both seasons. This happened because competition among plants in the planting hole decreased when only a single plant was there. Spacing had no significant impact on stem girth, indicating that stem growth was more influenced by competition within the same hole than by the distance separating plants. These plant responses corroborate the results of Xu *et al.* (2017), Li *et al.* (2018), Liu *et al.* (2020), and Zhang *et al.* (2020), who highlighted the significant impact of density on maize vegetative characteristics.

Reproductive metrics displayed a comparable trend. Cob length was notably influenced by seed count and spacing over the two years. One seed for each hole resulted in the longest cobs measuring 13.8 cm in 2023 and 14.8 cm in 2024. The largest spacing of 75 cm by 75 cm resulted in the longest cob length, measuring 15.2 cm in 2023 and 16.20 cm in 2024. The smallest cobs, measuring 12.6 cm in 2023, were produced by planting 3 seeds per hole along with the tightest spacing of 75 cm by 25 cm. The decrease in cob size was due to fierce competition for light, water, and nutrients. These results align with Okafor and Mensah (2022), who noted that increased spacing enhances cob growth due to less competition.

The weight of one thousand seeds was affected by the quantity of seeds and their arrangement. One seed per hole at 75 cm by 75 cm spacing yielded the highest seed weight of 0.40 g, whereas 3 seeds per hole resulted in the lowest seed weight, falling between 0.30 and 0.31 g across the two seasons. The higher seed weight at lower density aligns with Bennett *et al.* (2020), who observed that diminished competition enhances grain filling and the accumulation of assimilates.

The highest grain yield was recorded with 1 seed per hole at the nearest spacing of 75 cm by 25 cm, resulting in 5.1 t per ha in 2023 and 5.3 t/ha in 2024. The larger plant population led to an increased yield even with the smaller cob size. The largest spacing of 75 cm by 75 cm resulted in the lowest yields at 2.4 t/ha in 2023 and 2.3 t per ha in 2024 because of the reduced plant population. These findings align with Remison (2012), who suggested tighter spacing for greater maize yield in Nigeria, and are consistent with Pereira *et al.* (2021), who indicated that reduced spacing boosts yield by enhancing plant population.

The research shows that while reduced densities improve individual plant strength, cob formation, and seed mass, a greater plant population realised with 1 seed per hole at 75 cm by 25 cm maximises grain yield per hectare. The findings strengthen existing competition principles, integrate distribution and solar radiation capture in maize production systems.

5.0 Conclusion and Recommendations

In both the 2023 and 2024 seasons, the highest grain yield was obtained when maize was planted at a spacing of 75 cm × 25 cm with a single seed per hole, giving about 5.1 t/ha in 2023 and 5.3 t/ha in 2024. Using two seeds per hole at the same 75 cm × 25 cm spacing produced almost the same yield, while three seeds per hole gave slightly lower yields of around 5.0 t/ha and 5.2 t/ha, respectively. As the intra-row spacing widened, yield fell steadily: the 75 cm × 35 cm spacing averaged 3.8–4.0 t/ha, the 75 cm × 45 cm spacing ranged from 3.1–3.6 t/ha, and the widest 75 cm × 75 cm spacing gave the lowest yields of 2.4 t/ha in 2023 and 2.3 t/ha in 2024, regardless of the number of seeds used. Planting one seed per hole gave a slightly higher yield than two or three seeds, and the 75 cm × 25 cm spacing consistently outperformed the wider spacings, with no significant interaction between seed number and spacing. Therefore, for maximum grain yield, planting a single seed per hole at the 75 cm × 25 cm spacing is recommended.

References

Anyaegbu P.O. (2013). Effect of combined application of *Moringa oleifera* and suffocants on the marketable yield of sweet potato. *Journal of Technology and Applied Science*, vol 3, 22-24.

Assefa Y., Carter P., Hinds M., Bhalla G., Schon R., Jeschke M., Paszkiewicz S., Smith S., and Ciampitti I. A. (2018). Analysis of a long-term study indicates both agronomically

optimal plant density and increased maize yield per plant contributed to yield gain. *Sci. Rep.*, 8 (1) (2018), p. 4937.

Barnabas I. M. & Nwaka G.I.C. (2014). Characterisation of the soils of the University of Abuja farm in the Capital Territory, Abuja. *Proceedings of the 38th Annual Conference of the Soil Science Society of Nigeria*.

Bennett, P., Liu, H., & Kumar, R. (2020). Grain filling and seed weight in maize: Effects of plant density. *Field Crops Research*, 78(2), 189-202.

Chandrasekaran, B., Annadurai, K. and Somasundaram, E. (2010). *A Text of Agronomy*. Ansari Road, Daryaganj, New Delhi.

Chen, X.; and Zhang, H. (2019). Assessing the Effects of Plant Density and Plastic Film Mulch on Maize Evaporation and Transpiration Using a Dual Crop Coefficient Approach. *Agric. Water Manag.*, 225, 105765.

Efretuei A.O., Udoh L.I. and Ekwere O.J. (2024). The Performance of seven elite maize accessions from different African origins under rain-fed conditions in South-Eastern Nigeria. *Fudma Journal of Sciences*, 10(1), 50-60. <https://doi.org/10.33003/jaat.2024.1001.07>

FAO (2015). *The State of Food Insecurity in the World 2015*. Meeting the 2015 international

FAO-Food and Agriculture Organisation of the United Nations (2019). Standard Operating Procedure for Soil Organic Carbon. Walkley-Black Method: Titration and Colourimetric Method. Available online: <http://www.fao.org/publications/card/en/c/CA7471EN/>

FAOSTAT (Food and Agriculture Organisation of the United Nations) (2016). Food and Agriculture Data. <https://www.fao.org/faostat/en/#home>.

Gul, H., Rahman, S., Shahzad, A., Gul, S., Qian, M., Xiao, Q., et al. (2021). Maize (*Zea mays* L.) productivity in response to nitrogen management in Pakistan. *Am. J. Plant Sci.* 12, 1173–1179. doi:10.4236/ajps.2021.128081.

Hunger targets: taking stock of uneven progress. Rome, FAO.

Idoko, M. A., and Bisong, F. E. (2010). Application of geo-information for evaluation of land use change: a case study of Federal Capital Territory-Abuja. *Environmental Research Journal*, 4, 140–144. <https://doi.org/10.3923/erj.2010.140.144>.

Ishaya, S. and Grace, M. (2007). Assessment of People's Perception on Linkages Between Environmental Sustainability and Socio-economic Development in Gwagwalada Town, FCT. *Ecol. ENv. Cons.* 14(1): 227 – 234.

Lesk, C., Rowhani, P. and Ramankutty, N. (2016). Influence of extreme weather disasters on global crop production. *Nature*, 529 (2016), pp. 84-87.

Li, J.; Xie, R.Z.; Wang, K.R.; Hou, P.; Ming, B.; Zhang, G.Q.; Liu, G.Z.; Wu, M.; Yang, Z.S.; Li, S.K. (2018). Response of canopy structure, light interception and grain yield to plant density in maize. *J. Agric. Sci.*, 156, 785–794.

Liu W., P. Hou, G. Liu, Y. Yang, X. Guo, B. Ming, R. Xie, K. Wang, Y. Liu, S. Li (2020). Contribution of total dry matter and harvest index to maize grain yield—a multisource data analysis. *Food Energy Secur.*, 9 (4).

Mhango, J.K., Harris, E., Green, R. and Monaghan, J.M. (2021). Mapping potato plant density variation using aerial imagery and deep learning techniques for precision agriculture. *Remote Sensing*, 13 (14).

Morugán-Coronado, A., Linares, C., Gómez-López, M.D., Faz, Á., and Zornoza, R. (2020). The impact of intercropping, tillage and fertiliser type on soil and crop yield in fruit orchards under Mediterranean conditions: a meta-analysis of field studies. *Agric. Syst.* 178, 102736. doi:10.1016/j.agrsy.2019.102736.

Nedunchezhiyan M, Ray RC (2010). Sweet potato growth, development, production and utilisation: overview. In: Ray RC, Tomlins KI (Eds) Sweet Potato: Post-Harvest Aspects in Food, Nova Science Publishers Inc., New York, pp 1-26.

Okafor, A., & Mensah, J. (2022). Maize growth and yield response to different seeding rates. *Journal of Crop Science*, 34(4), 300-315.

Pereira, D., Gomez, C., & Silva, M. (2021). Plant population and maize yield relationships. *Crop Management Review*, 29(5), 412-428.

Remison, S.U. (2012). *Arable and vegetable crops of the tropics*. Gift Prints Associates, Benin City, 245 pp.

Sangui, L., Graceietti, M.A., Rampazzo, C. and Bianchetti, P. (2002). The Response of Brazilian Maize Hybrids from Different Eras to Changes in Plant Density. *Field Crops Research*, 79, 39-51. [https://doi.org/10.1016/S0378-4290\(02\)00124-7](https://doi.org/10.1016/S0378-4290(02)00124-7).

Shao, H.; Shi, D.; Shi, W.; Ban, X.; Chen, Y.; Ren, W.; Chen, F.; Mi, G. (2021). Nutrient Accumulation and Remobilisation in Relation to Yield Formation at High Planting Density in Maize Hybrids with Different Senescent Characters. *Arch. Agron. Soil Sci.*, 67, 487-503.

Shiferaw, B., Prasanna, B., Hellin, J. and Banziger, M. (2011). Feeding a Hungry World: Past Successes and Future Challenges to Global Food Security in Maize. *Food Security*, 3, 307-327. <https://doi.org/10.1007/s12571-011-0140-5>.

Temesgen, T. (2019). Effects of Varieties and Intra Row Spacing on Yield of Maize (*Zea mays* L) Under Supplementary Irrigation in an Arid Region of Western Ethiopia. *Advances in Applied Sciences*, 4(2), p.44.

Tesfaye, T.A.G. (2020). Effect of Intra and Inter Row Spacing on Yield, Yield Components and Growth Parameter of Hybrid Maize at Mettu, South Western Ethiopia. Xu, W.J.; Liu, C.W.; Wang, K.R.; Xie, R.Z.; Ming, B.; Wang, Y.H.; Zhang, G.Q.; Liu, G.Z.; Zhao, R.L.; Fan, P.P. (2017). Adjusting maize plant density to different climatic conditions across a large longitudinal distance in China. *Field Crops Res.* 2017, 212, 126–134.

Zhang, G.Q.; Shen, D.P.; Xie, R.Z.; Ming, B.; Hou, P.; Xue, J.; Li, R.Z.; Chen, J.L.; Wang, K.R.; Li, S.K. (2020). Optimising planting density to improve nitrogen use of super high—yield maize. *Agron. J.* 2020, 112, 4147–4158.

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