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RESEARCH ARTICLE

Optimizing the plant spacing for the maximum yield of pigeon pea monoculture in Delta State of Nigeria

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ABSTRACT

Pigeon pea [*Cajanus cajan* (L.) Millsp.] is an important crop worldwide, usually sown in the mixed cropping system. However, the sole cropping system is constrained mainly by high weed infestation caused by under population and low productivity due to overcrowding. It is necessary to optimize the appropriate crop spacing to fully maximize the potential of pigeon pea in a sole cropping system. In the 2019 and 2020 planting seasons, two varieties of Pigeon pea: ICP88038 and ICP6971 seeds planted at Ogbagu Ogume community communal farm settlement of Nigeria at three different spacing: 30 × 45, 30 × 60 and 45 × 45 cm at a seed rate of 7.41, 5.56 and 4.93 kg ha^{-1}, respectively. The experiment was a 2 by 3 factorial in a randomized complete block design with three replicates. The result showed that the 45 × 45 cm spacing produced significantly taller plants in 2019 (12.22±0.41) and 2020 (12.55±0.99), highest number of leaves in 2019 (11.50±0.67) and 2020 (9.83±0.96), number of pods in 2019 (138.33±12.01) and 2020 (153.17±23.43), dry pod weight in 2019 (3.57±0.27) and 2020 (3.76±0.39) and dry grain yield (t ha^{-1}) in 2019 (1.78±0.14) and 2020 (1.76±0.21). However, the genotypic effect on the parameters was insignificant.

Keywords: Pigeon pea; Farming system; Monocropping; Plant spacing; Genotypes

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INTRODUCTION

Pigeon pea (*Cajanus cajan* (L.) Millsp.) is a leguminous crop predominantly cultivated in Asia, Africa and Latin America (Sandya and Singh, 2018). It is mainly grown for its high protein (about 25%), micro and macronutrients and essential amino acid contents (Saxena and Nadarajan, 2010). Pigeon pea cultivation has gain popularity worldwide due to its wide range of adaptation to different climatic conditions (Ayenan et al., 2017) and its usage in soil reclamation through the fallow system (Musokwa and Mafongoya, 2021).

Pigeon pea can be sown in a mixed cropping system or as a sole crop. However, the monoculture system is usually constrained by the high weed infestation due to the space availability that is not covered (Sandya and Singh, 2018) leading to about 80% yield loss (Padmaja et al., 2013). However, reducing the plant spacing of pigeon pea to ensure there is little or no space for weeds to thrive might lead to an intra-species competition between the plants for light, water, and nutrient, affecting productivity.

To fully maximize the productivity of pigeon pea plants sown in a sole system, the appropriate plant spacing needs to be investigated and optimized, considering the effect of overcrowding and under-population. Therefore, present study was aimed to establish the best plant spacing for pigeon pea cultivation in the Ogbagu Ogume community of Nigeria.

MATERIALS AND METHODS

Experimental site and season

The experiment was conducted at Ogbagu Ogume community farm settlement located at Latitude 5.7652˚N and Longitude 6.3341˚E in 2019 and 2020 planting seasons.

Soil and climatic conditions

The community is located in the rainforest agroecological zone. The soil is rich in organic matters which is the sole means of nutrient enrichment as the farmers practices land follow system.

Treatments and Design

The treatments comprise of (1) two varieties of Pigeon pea: ICP88038 and ICP6971 sourced from the International Institute of Tropical Agriculture, IITA, Ibadan, and (2) three different plants spacing: 30 × 45 cm, 30 × 60 cm and 45 × 45 cm. The experiment was a 2 (varieties) × 3 (spacing) factorials in a randomized complete block design with 3 replicates.

Crop husbandry

The fallowed farm settlement was cleared, stumped, burned and packed, while one pigeon pea seed per hole were sown in three different spacing: 30 × 45 cm, 30 × 60 cm and 45 × 45 cm with seed rate of 7.41, 5.56 and 4.93 $kgha^{-1}$, respectively. The plots were planted at the rainy season to take advantage of rainfall as practiced by the farming community. Weeding was done manually with the aid of hoe monthly till harvest.

Data collection and statistical analysis

Data were collected on the plant height using tape rule, number of leaves and leaf area at 3, 6 and 9 weeks after planting, days to 50% flowering, number of pods per plant, dry pod weight (100 pods per treatment), dry grain yield (t ha^{-1}) at 15% moisture content and days to maturity. Data collected were analyzed using ANOVA (SAS 9.0 version) while genotypic and treatment means were separated using LSD at $P \leq 0.05$.

RESULTS

Effect of spacing on growth and yield parameters of pigeon pea

Results obtained showed that in 2019, the tallest plant (12.22±0.41) was observed in the 45 × 45 cm spacing which was 10% and 35% taller than the plants in 30 × 60 cm and 30 × 45 cm, respectively. It also followed same trend in 2020 where the plants produced in the 45 × 45 cm spacing (12.55±0.99) was 27% and 44% taller than the ones in 30 × 60 cm and 30 × 45 cm, respectively (Table 1). Also, in 2019, the number of leaves produced in the 45 × 45 cm spacing (11.50±0.67) was 26% higher than the ones produced in the 30 × 45 cm spacing. However, the difference between the 45 × 45 cm and 30 × 60 cm spacing was insignificant (Table 2). Then the leaf area observed in the plants raised in the 45 × 45 cm (20.67±1.67) in 2019 was 35% larger than the 30 × 45 cm, while in 2020, it (26.83±2.85) was 59% larger than the leaf area of the plants raised in the 30 × 45 cm spacing (Table 3).

In the 2019 planting season, the number of days taken by the genotypes to reach 50% flowering in the 45 cm × 45 cm plant spacing (88±3.22) was significantly shorter than those sown with 30 cm × 45 cm (104±3.22) and 30 × 60 cm (108±3.22) spacing respectively. However, in 2020, those sown

with 45 cm × 45 cm spacing (91±3.99) was only significantly shorter than the 30 cm × 45 cm (106±3.99) spacing. In 2019, the plant spacing was insignificant in the number of days to maturity. However, in 2020, the plants grown with a spacing of 45 cm × 45 cm (141±9.25) matured significantly earlier than those sown with a spacing of 30 cm × 45 cm (152±9.25) (Table 4).

In both 2019 and 2020 planting seasons, the number of pods produced was insignificant among the three spacing. However, the weight of dried 100 pods produced in the 45 × 45 cm spacing (3.57±0.27) was 35% heavier than the pod weight obtained in the 30 × 45 cm spacing, while in 2020, the dry pod weight obtained in the 45 × 45 cm spacing (3.76±0.39) was 37% heavier than the dry pod weight obtained in the 30 × 60 cm spacing. Also in 2019, the highest dry grain yield was obtained in the 45 × 45 cm spacing (1.78±0.14), and this was 26% heavier than the dry grai yield harvested from the 30 × 45 cm spacing. However, in 2020, the dry grain yield was insignificant among the proceeds from the spacing (Table 5).

Table 1. Effect of spacing on the plant height of pigeon pea grown in Ogbagu Ogume community

	Three weeks		Six weeks		Nine weeks	
Treatments	2019	2020	2019	2020	2019	2020
30 cm × 45 cm	2.15^{a}	1.83^{a}	5.50^{b}	4.83^{a}	8.00^{b}	7.00^{b}
30 cm × 60 cm	2.23^{a}	2.35^{a}	6.67^{a}	5.83^{a}	11.00^{a}	9.17^{b}
45 cm × 45 cm	2.35^{a}	2.30^{a}	5.90^{ab}	6.45^{a}	12.22^{a}	12.55^{a}
LSD (0.05)	0.42	0.69	0.99	2.12	1.26	3.04
SE	0.14	0.22	0.32	0.69	0.41	0.99

Means with the same letter(s) down the group are not significantly different from each other at 5% significance level, LSD=Least significance difference and SE= Standard error.

Table 2. Effect of spacing on the number of leaves produced by pigeon pea plants grown in Ogbagu Ogume community

	Three weeks		Six weeks		Nine weeks	
Treatments/ Genotypes	2019	2020	2019	2020	2019	2020
30 cm × 45 cm	2.67^{a}	2.33^{a}	5.17^{a}	4.67^{a}	8.50^{b}	7.50^{a}
30 cm × 60 cm	2.50^{a}	3.00^{a}	5.00^{a}	5.67^{a}	9.83^{ab}	8.50^{a}
45 cm × 45 cm	2.83^{a}	2.67^{a}	5.17^{a}	5.50^{a}	11.50^{a}	9.83^{a}
LSD (0.05)	0.66	1.03	0.84	2.01	2.08	2.97
SE	0.14	0.33	0.27	0.65	0.67	0.96

Means with the same letter(s) down the group are not significantly different from each other at 5% significance level, LSD=Least significance difference and SE= Standard error.

Table 3. Effect of spacing on the leave area of pigeon pea plants grown in Ogbagu Ogume community

Treatments/ Genotypes	Three weeks		Six weeks		Nine weeks	
	2019	2020	2019	2020	2019	2020
30 cm × 45 cm	5.00^{a}	4.17^{a}	9.83^{a}	9.17^{a}	13.50^{b}	11.00^{b}
30 cm × 60 cm	4.00^{a}	5.00^{a}	9.83^{a}	14.33^{a}	16.17^{ab}	19.67^{ab}
45 cm × 45 cm	4.83^{a}	5.33^{a}	10.33^{a}	13.83^{a}	20.67^{a}	26.83^{a}
LSD (0.05)	1.15	1.83	3.35	5.4	5.16	8.79
SE	0.37	0.59	1.09	1.75	1.67	2.85

Means with the same letter(s) down the group are not significantly different from each other at 5% significance level, LSD=Least significance difference and SE= Standard error.

Table 4. Effect of spacing on the number of days to 50% flowering of pigeon pea plants grown in Ogbagu Ogume community

	Days to 50 % flowering		Days to maturity	
Spacing	2019	2020	2019	2020
30 cm × 45 cm	104[a]	106[a]	151[a]	152[a]
30 cm × 60 cm	108[a]	103[ab]	153[a]	144[ab]
45 cm × 45 cm	88[b]	91[b]	144[a]	141[b]
LSD (0.05)	9.91	12.29	10.55	9.25
SE	3.22	3.99	3.42	3

Means with the same letter down the group are not significantly different from each other at 5% significance level. LSD: Least significance difference and SE: Standard error.

Table 5. Effect of spacing on the yield of pigeon pea plants grown in Ogbagu Ogume community

	Number of pods		Dry pod weight (t/ha)		Dry grain yield (t/ha)	
Spacing	2019	2020	2019	2020	2019	2020
30 cm × 45 cm	125.00[a]	120[a]	2.32[b]	3.35[ab]	1.32[b]	1.55[a]
30 cm × 60 cm	133[a]	146[a]	3.35[a]	2.36[b]	1.54[ab]	1.16[a]
45 cm × 45 cm	138[a]	153[a]	3.57[a]	3.76[a]	1.78[a]	1.76[a]
LSD (0.05)	36.99	72.18	0.85	1.2	0.44	0.66
SE	12.01	23.43	0.27	0.39	0.14	0.21

Means with the same letter(s) down the group are not significantly different from each other at 5% significance level, LSD=Least significance difference and SE= Standard error.

Effect of variety on growth and yield parameters of pigeon pea

Results obtained showed that in both 2019 and 2020 planting seasons, there were no significant differences between the genotypes on the plant height and the number of leaves (Table 6 and 7). However, in 2019, the leaf area of ICP6971 (19.22±1.37) was significantly larger (25% more) than the ICP88038 (14.33±1.37), while the difference was insignificant in 2020 (Table 8). On the days to 50% flowering, Days to maturity, number of pods produced, the dry pod weight (t/ha) and the dry grain yield (t/ha), there were no significant differences between the genotypes (Table 9 and 10).

Interaction effect of variety and spacing on growth and yield parameters of pigeon pea

In 2020, the genotype by spacing interaction was significant at 6 weeks after planting (Table 6). Also, in the number of leaves produced in 2020 at 9 weeks after planting was significant due to the interaction between genotype and spacing (Table 7). Then on the days to 50% flowering, the interactive effect of genotype and spacing was also significant (Table 9). However, the number of pods produced by ICP88038 (151±9.8) was 25% more than ICP6971 (113±9.8) (Table 10).

Table 6. Height of two genotypes of pigeon pea grown in Ogbagu Ogume community

	Three weeks		Six weeks		Nine weeks	
Genotypes	2019	2020	2019	2020	2019	2020
ICP88038	2.29[a]	2.24[a]	5.93[a]	6.00[a]	10.57[a]	9.89[a]
ICP6971	2.20[a]	2.08[a]	6.11[a]	5.41[a]	10.24[a]	9.26[a]
LSD (0.05)	0.34	0.56	0.81	1.73	1.03	2.48
SE	0.11	0.18	0.26	0.56	0.33	0.81
Gen × Spacing interaction	0.01[ns]	0.07[ns]	0.17[ns]	2.51[*]	2.17[ns]	2.10[ns]

Means with the same letter(s) down the group are not significantly different from each other at 5% significance level, LSD=Least significance difference and SE= Standard error.

Table 7. Average number of leaves produced by two genotypes of pigeon pea grown in Ogbagu Ogume community

	Three weeks		Six weeks		Nine weeks	
Genotypes	2019	2020	2019	2020	2019	2020
ICP88038	2.56[a]	2.78[a]	5.11[a]	5.33[a]	10.00[a]	9.33[a]
ICP6971	2.78[a]	2.56[a]	5.00[a]	5.22[a]	9.89[a]	7.89[a]
LSD (0.05)	0.54	0.84	0.68	1.64	1.69	2.42
SE	0.18	0.27	0.22	0.53	0.55	0.79
Genotype × Spacing interaction	0.00ns	0.06ns	2.72ns	1.17ns	1.72ns	11.56*

Means with the same letter(s) down the group are not significantly different from each other at 5% significance level, LSD=Least significance difference and SE= Standard error

Table 8. Leaf area of two genotypes of pigeon pea grown in Ogbagu Ogume community

	Three weeks		Six weeks		Nine weeks	
Genotypes	2019	2020	2019	2020	2019	2020
ICP88038	4.78[a]	5.22[a]	9.22[a]	14.00[a]	14.33[b]	19.67[a]
ICP6971	4.44[a]	4.44[a]	10.78[a]	10.89[a]	19.22[a]	18.33[a]
LSD (0.05)	0.94	1.49	2.74	4.41	4.21	7.17
SE	0.3	0.48	0.89	1.43	1.37	2.33
Genotype × Spacing interaction	0.39ns	0.17ns	6.50ns	13.39ns	22.39ns	32.06ns

Means with the same letter(s) down the group are not significantly different from each other at 5% significance level, LSD=Least significance difference and SE= Standard error.

Table 9. Days to 50% flowering and maturity of two genotypes of pigeon pea plants grown in Ogbagu Ogume community

	Days to 50% flowering		Days to maturity	
Genotypes	2019	2020	2019	2020
ICP88038	99.00[a]	102.00[a]	151.00[a]	147.00[a]
ICP6971	100.00[a]	98.00[a]	147.00[a]	144.00[a]
LSD (0.05)	8.09	10.03	8.61	7.56
SE	2.63	3.26	2.8	2.45
Genotype × Spacing interaction	244.00*	40.00ns	269.00ns	173.00ns

Means with the same letter(s) down the group are not significantly different from each other at 5% significance level, LSD=Least significance difference and SE= Standard error.

Table 10. Number of pods, dry pod weight and grain yield of two genotypes of pigeon pea plants grown in Ogbagu Ogume community

	Number of pods		Dry pod weight (t ha^{-1})		Dry grain yield (t ha^{-1})	
Genotypes	2019	2020	2019	2020	2019	2020
ICP88038	151[a]	123[a]	3.21[a]	3.09[a]	1.56[a]	1.51[a]
ICP6971	113[b]	156[a]	2.94[a]	3.09[a]	1.52[a]	1.47[a]

LSD (0.05)	30.21	58.94	0.69	0.98	0.36	0.54
SE	9.8	19.13	0.22	0.32	0.12	0.17
Genotype × Spacing interaction	289.00ns	908.00ns	0.85ns	1.06ns	0.47ns	0.26ns

Means with the same letter(s) down the group are not significantly different from each other at 5% significance level, LSD=Least significance difference and SE= Standard error.

DISCUSION

Pigeon pea is a crop grown for its diverse uses, ranging from the consumption of the pulses by the local farmers for its nutritive values to its straw and vegetative parts consumed as fodders by animals (ABD EL-Hack et al., 2018). This study showed that the agronomic development of the two pigeon pea genotypes was optimal for all the growth and yield parameters considered at the 45 cm × 45 cm spacing in both 2019 and 2020 planting seasons. The superior performances of the pigeon pea genotypes in the 45 × 45 cm spacing can be attributed to more space available to the plants, which they exploited regarding the nutrient available (Babale et al., 2020), being a fallowed land without an additional amendment.

The appropriate utilization of the available nutrient in the soil by the plants grown in the 45 cm x 45 cm, which had less competition for nutrients was evident in the quick flower development, days to maturity, dry pod and grain weights. The quick development of the pigeon pea genotypes in this spacing could be as a result of more photosynthates made available for the crops as a result of the availability of more leaves produced with large surface area. This improves the chance for photosynthetic activities in the plants (Kshkooll et al., 2020), which is essential for the physiological development. However, the development of the less spaced crops will be constrained by the crop's competition between for the available nutrients.

Due to the availability of more photosynthates in the 45 cm × 45 cm spaced grown crops, there was more robust grain filling in their fruits compared to the less spaced grown plants. However, spacing did not affect the number of pods produced, although the pod sizes differ in favour of the more spaced ones.

The two genotypes used performed equally well regardless of the spacing they were grown. This shows high adaption rate to the Southern Guinea savanna agro-ecological zones where this evaluation's location is situated possibly due to the high nodulation potential of pigeon pea (Adjei-Nsiah et al., 2018), they were classified as an early maturing genotype. Arriving at this classification is made easy when calculated from the days to 50% flowering (Owusu et al., 2018), which this study corroborated with our present study results.

CONCLUSION

Pigeon pea has a tremendous advantage as a crop to the farmers as food crop with varieties of available nutrients, fodder for animal husbandry and soil enrichment crop. However, undermining the economic damage imposed on it by overcrowding the crop is devastating. The more spaced crops at a spacing of 45 × 45 cm gave the best level of agronomic and yield performances in the two planting seasons. Thus, adequate spacing of 45 cm × 45 cm with an improved yield quality in this study is recommended for the sole cultivation of pigeon pea, while in the mixed crop, other crops can be sown in between this spacing for optimum productivity. Also, the two genotypes of pigeon pea used in this study performed equally among the spacing and year, showing their stability to the environment.

DISCLOSURE STATEMENT

The author declares no competing interests

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