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Influence of Maize (*Zea mays* L.) Density on Morpho-Physiological and Yield Parameters in Bali, North West Region of Cameroon

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Authors' contributions

This work was carried out in collaboration between all authors. Authors TIK and DKN designed the study. Author TDA performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author DKN managed the analyses of the study. Authors TIK and TDA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study was to investigate the morpho-physiological and yield response of maize (*Zea mays* L.) variety as influenced by different plant density in Bali Nyonga, North West Region of Cameroon. The fives treatments (intra-row spacing) were: Treatment 1 (T_1 = 15 cm ≈ 95200 plants/ha), Treatment 2 (T_2 = 20 cm ≈ 71400 plants/ha), Treatment 3 (T_3 = 25 cm ≈ 57100 plants/ha), Treatment 4 (T_4 = 30 cm ≈ 47600 plants/ha) and Treatment 5 (T_5 = 35 cm ≈ 40100 plants/ha). The treatments were arranged in a Randomized Complete Block Design. Commercial NPK (20:10:10) fertilizer was used twice in the course of the study. This experiment was done in Bali Nyonga, a village located in Bali sub- Division, North West Region of Cameroon. This research was conducted in 2014 from March to July. There were four blocks, each with a surface area of

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38.2 m^2. Each block was divided into five raised beds. Each bed measured 300 cm x 40 cm. The peak of each bed was separated from the adjacent bed by 70 cm. The blocks were separated by a gap of 1.5 m. Each bed contained a treatment (intra-row spacing). Maize seed were sown per the intra-row spacing on the 20th on March 2014 after two consecutive heavy rain falls. Two fertilizer applications were made in the experiment; on the day of sowing and four weeks after emergence. Data was collected on physiological, morphological and yield parameters. SPSS ver. 23 was used for all analysis. Results indicated that different intra-row spacing influenced morpho-physiological (plant emergence, plant height, stem diameter, senescence, lodging leaf area index, plant vigour), and yield (number and weight of cobs at harvest) parameters of maize. The highest plant emergence and plant height was recorded from treatment 1 (P = .05). There was an inverse proportion between plant density stem diameter, plant vigour and leaf area index (P = .05). The number of cobs increased with plant density. The highest mean number of cobs at harvest was 12.8 for treatment 1 (P = .05). The highest mean weight of cobs harvested was from treatment 3 and treatment 2 (P = .05). There was also a strong regression (R^2 = 0.792, P < .043). From the findings of this experiment maize density significantly influenced agronomic and yield parameters of maize. Farmers are recommended to use treatment 3 and treatment 2 for optimal growth and yield.

Keywords: Agronomic; Cameroon; density; intra-row; morpho-physiological; yield.

1. INTRODUCTION

In Cameroon, like many developing nations, the agricultural sector contributes a large proportion of the GDP, employing about two-thirds of the population [1]. In the area of crop production, maize stands out as one of the most important cereal cultivated in Cameroon [2] for direct consumption, animal feed production and for the brewery industry [3]. Not until the late 1980s when the prices of the two major exporting cash crops (cocoa and coffee) dropped drastically, maize was largely considered by the populace as a crop whose existence was subsistence; grown principally for home consumption. Since then, the demand for maize has reached soaring heights. Farmers in the pursuit to meet this ever-growing domestic and international demand are facing many challenges and setbacks, both biotic and abiotic [4]. Achiri, et al. [2] has reported many challenges facing maize farmers in the North West region of Cameroon; maize density, soil fertility, labour and unstable market prices are a few amongst many.

Plant density is the prime component for obtaining maximum yield which is described by intra and inter row spacing [5]. Roekel and Coulter [6] determined a close tie between maize yield and plant population. Maize density is reported to have a direct influence on phenology of maize [7], canopy morphology of maize [8,9], nitrogen use efficiency [10], water use efficiency [11,12] and grain yield [13,14]. Maize density is an agronomic component that has consistently received keen attention and research in maize agro-ecosystem especially with the release of new varieties and hybrids [15]. In the last decades, research on this subject has concentrated on about 50000 to 150000 plants/ha [16-20] in combination with different agronomic practices such as soil fertility regimes, types of variety and irrigation systems.

In this study, we investigated the effect of maize density on physiological, morphological and yield parameters in Bali Nyonga, NWR Cameroon, in order to improve overall agronomic practices in the maize agro-ecosystem in Cameroon.

2. MATERIALS AND METHODS

2.1 Experimental Site

This experiment was conducted in Bali Nyonga, a village located in Bali sub- Division, North West Region of Cameroon. Bali is rich with antiques that date back to colonial days in Cameroon. Bali lies west of Bamenda, the Capital City of North West Region and it has a population of about 30,375 inhabitants [21]. The geographical coordinates of Bali are 5053 ‘0’ North, 10 ’0’ Fast with a humid tropical climate. Annual rainfall ranges between 5.8mm to 10.4 mm with average temperatures between 17.0 °C - 27.0 °C. The principal activity of the inhabitants was agriculture: chief crops grown included maize, beans, potatoes and vegetables. This research was conducted in 2014 from March to July. Site and soil preparation took place in March; planting in late March harvesting took place in July. Average humidity was 72.2%.

2.2 Experimental Design, Field Layout and Cultural Practices

A piece of land measuring 20 m x 15 m was cleared with a machete and soil preparation started 2 days later. With the help of a hoe, raised beds were made with the weed debris buried under the beds. Each bed measured 300cm x 40cm. The peak of each bed was separated from the adjacent bed by 70 cm. The blocks were separated by a gap of 1.5 m. The experimental treatments (intra-row spacing) were: Treatment 1 (T_1 = 15 cm ≈ 95200 plants/ha), Treatment 2 (T_2 = 20 cm ≈ 71400 plants/ha), Treatment 3 (T_3 = 25 cm ≈ 57100 plants/ha), Treatment 4 (T_4 = 30 cm ≈ 47600 plants/ha) and Treatment 5 (T_5 = 35 cm ≈ 40100 plants/ha). Each of these treatments was replicated five times. These different planting distances guaranteed different plant densities per hectare. The treatments were distributed in the experimental field in randomized complete block design (RCBD). There were five blocks each containing five raised beds. Each bed had maize planted with a particular plant distance, one treatment per bed. The maize variety planted was “coca”, which has an orange colour. The variety was selected because it is an acid tolerant variety as most soil in the North West is acidic. Maize seed were sown on the 20th on March 2014 after two consecutive heavy rain falls. The field was rain fed for the rest of the study. Two fertilizer (NPK: 20:10:10) applications were made in the experiment; on the day of sowing and four weeks after emergence. On the day of sowing, the fertilizer was applied in shallow trenches then mix with soil and the maize seed 3 cm deep. The maize was thinned to 1 plant/hole two weeks after germination. Five weeks after germination, the second application of fertilizer (4 g/stand) was made: fertilizer was applied in a ring manner around and 4 cm away from the plant. No control measure of insect, disease and weed was applied since they were inconsequential. However, hand weeding, and hoeing was done when necessity in all blocks. Plant spacing and fertilizer application was done based on farmer’s practice.

2.3 Data Collection

Data was collected on the vegetative stage and at harvest. Data was collected on agronomic (plant emergence, plant height, stem diameter, leaf area index, plant vigour, senescence, lodging) and yield (number of cobs at harvest, weight of cobs harvested) parameters.

Plant emergence: The number of plant emerging was counted 5 days after planting (DAP). All emerged plants were counted.

Plant height (cm) was measured from ground level to the collar of the upper leaf with developed leaf sheath using a meter rule on the 30th of June (3.5 months after sowing). Four plants were sampled from each block.

Stem diameter (cm): was measured at tasseling (2.5 months after planting). The circumstance (s) was measured at 2/3 the plant height and using the relationship given below to estimate the stem diameter (d) d = $\frac{C}{\pi}$ where π ≈3.14. Sampling for the stem diameter was done in the same manner as that of plant height.

Leaf Area Index (LAI): The plant was divided into three equal quadrants along the plant length and a mature leaf in the middle quadrant was used to obtain LAI: LAI= LWK (where L= Length of leaf, W = Width of leaf. K = constant ≈ 0.75) [2,22]. Sampling for LAI was done in the same manner as that of plant height.

Plant vigour plant: Plant vigour was estimated using a three coded scale standard: Poor (1), Average (3) and Good (5). Plant vigour measurements were made on the 30th of June. Sampling for plant vigour was done in the same manner as that of plant height.

Senescence was collected 75 days after planting.

The number of plants lodged was counted after tasseling.

2.4 Data Analysis

Analysis of variance (ANOVA) was used to evaluate the means for differences. Duncan’s Multiple Range Test (DMRT) was used to separate the means. All analysis was done with the use of statistical package for social sciences SPSS ver. 23 and the probability level was 0.05. Where necessary Microsoft Excel (2007) was used to produced bar charts. A regression analysis was done to evaluate the relation between row spacing and number and weight of harvested cobs was evaluated.

3. RESULTS AND DISCUSSION

3.1 ANOVA Table

Table 1 shows the Analysis of variance (ANOVA) for the agronomic and yield parameters in this study. The Blocking effect did not significantly (P > .05) influenced any measured parameter in this study. Thus the Blocking effect was omitted in the ANOVA analysis in order to increase the error degree of freedom (df) consequently increasing the reliability of the analyses by increasing the error effect. The effect of maize row distance was significant (P = .05) for all agronomic parameters except for plant height (P = .317) and weight of cobs (P = .139). NPK also significantly (P = .001) influenced the yield parameter (weight of harvested maize kg).

3.2 Seed Emergence

The number of plant emerged was significantly different ($F_{4,20}$ = 96.361, P < .0001) for the different treatments. The number of seeds emerged was highest (31.40) from treatment 1 (95200 plants/ha), followed by that of treatment 2 (71400 plants/ha) at 26.40. The least seed emerged (16.0) was recorded from treatment 5 (40100 plants/ha) (Table 2). No other study in literature has evaluated the effect of maize density on the seed density. We posit here that the reason for this discrepancy in seed emergence may not have directly resulted from intra-row spacing effect, rather from the fact that fewer seeds were planted in treatments with higher densities. This probably is the reason why the number of seed emerging in treatment 1 (95200 plants/ha) is twice the number of seeds emerging from treatment 5 (40100 plants/ha) (Table 2).

3.3 Plant Height (cm)

In this study, mean plant height was not significantly ($F_{4,20}$ = 1.262, P = .317) influenced by intra-row spacing (Table 2). The mean plant height ranged from 202.86 cm to 181.64 cm. The highest plant height (2020.86 cm) was observed from treatment 1 (95200 plants/ha) followed by 195.80 cm and 194.44 from treatment 2 (71400 plants/ha) and treatment 3 (57100 plants/ha). In a similar study conducted by [23] in South West Nigeria concluded that, plant density did not significantly influenced plant height. However, plant height increased with increased plant density. Although the plant height was not statistically significantly different from each other in our study and in [17], the trends in these researches are consistent with the findings of [18,20] wherein, intra-row spacing significantly influenced plant height. In [20], the highest plant height (245.25 cm) was observed from the highest plant density (88888 plants/ha), very similar to our findings.

The reason for this observation is explained by [24,25] who posited that overcrowding leads to increasing competition for light; a vital component for photosynthesis, thus leading to increasing heights of the plants. Not only did Rafiq, et al. and Sherifi, et al. [26,27] agreed with Boomsma, et al. and Sangakkara, et al. [24,25] but went further to say that maize plant height is influenced by maize variety. Thus, we can conclude that there is a direct proportional relationship between plant height and plant density.

3.4 Stem Diameter

The stem diameter was significantly ($F_{4,20}$ = .201, P = .002) influenced by intra-row spacing. The mean stem diameter ranged from 1.74 cm to 2.16 cm. The smallest stem diameter was 1.74 cm, recorded from treatment 1 (95200 plants/ha). The highest stem diameter was 2.16 cm, recorded from treatment 5 (40100 plants/ha). As can be seen in Table 2, there is an inverse proportional relationship between stem diameter and maize density. Our results are in concordance with that of PD15. In Adeniyan [17], the highest stem diameter was 2.78 cm, obtained from maize density of 53335 plants/ha and the least stem diameter was 1.87 cm from maize density of 106670 plants/ha. Amanullah, et al. [22] and Ashraf, et al. [28] concluded that plant density generally influenced agronomic characteristics of maize. They further argue that plants in lower density areas do not have consequential competition, as a result, can develop tougher and thicker stalks.

3.5 Plant Vigour

Farmers were randomly selected to rate the plant vigour based on a three coded scale. Our analysis revealed that plant vigour was significantly ($F_{4,20}$ = 13.667, P < .0001) influenced by intr-row density. The highest plant vigour was 3.72, recorded from treatment 5 (40100 plants/ha) and the smallest plant vigour was 1.80, recorded from treatment 1

(95200 plants/ha) (Table 2). There was an inverse proportional relationship between plant vigour and maize density; the plant vigour steadily increased with decreasing maize density. Plant vigour actually measures the visual appraisal of the toughness and thickness of the plant. This finding can be explained by the claims of [22,28].

Table 1. ANONA analyses for maize morpho-physiological and yield parameters

Parameter	Source of variation	Degree of freedom (df)	Sum of squares	Means squares	F	Sig.
Plant Emergence	Between groups	4	747.760	186.940	96.361	.000
	Within groups	20	38.80	1.94		
	Total	24	786.560			
Plant Height (cm)	Between groups	4	1173.246	293.311	1.262	.317
	Within groups	20	4647.148	231.357		
	Total	24	5820.394			
Stem diameter (cm)	Between groups	4	0.803	0.201	6.465	.002
	Within groups	20	0.621	0.031		
	Total	24	1.424			
Plant vigour	Between groups	4	13.382	3.346	13.667	.000
	Within groups	20	4.896	0.245		
	Total	24	18.278			
Senescence	Between groups	4	33.840	8.46	6.409	.002
	Within groups	20	26.40	1.32		
	Total	24	60.24			
Lodging	Between groups	4	13.6	3.40	3.696	.021
	Within groups	20	18.4	.92		
	Total	24	32			
LAI	Between groups	4	82603.870	20650.968	7.506	.001
	Within groups	20	55027.821	2751.391		
	Total	24	137631.691			
Number of maize cobs	Between groups	4	58.160	14.54	3.429	.027
	Within groups	20	84.80	4.240		
	Total	24	142.96			
Cob weight (kg)	Between groups	4	.850	.213	1.965	.139
	Within groups	20	2.164	.108		
	Total	24	3.014			

Table 2. Morpho-physiological parameters as influenced by intra-row spacing

	Morpho-physiological parameters						
Row spacing (cm)	**Plant emergence**	**Plant height**	**Stem diameter**	**Plant vigour**	**Senescence**	**Lodging**	**LAI**
15	31.40±1.03a	202.86±7.44a	1.74±0.08a	1.80±0.22a	4.2 0± 0.37a	3.0±0.63a	419.4±16.0a
20	26.40±0.24b	195.80±6.21a	1.75±0.08a	2.52±0.15b	3.60±0.81a	1.0±0.44b	425.3±37.67a
25	20.60±0.6c	194.44±6.75a	2.05±0.06b	3.28±0.23c	1.8±0.58b	1.6±0.24b	503.5±23.98b
30	19.40±.024c	181.64 ±7.93a	2.10±0.07b	3.64±0.27c	1.8±0.37b	1.4±0.40b	522.04±14.72b
35	16.0±0.63d	194.34±.5.49a	2.16±0.10b	3.72±0.23c	1.20±0.20b	1.0±0.32b	568.50±16.88b

Means in the same column with the same letter(s) are not significantly different (α = .05). Means were separated with the Duncan's Multiple Range Test (DMRT)

3.6 Senescence

The number of plants experiencing senescence at the point of record was significantly influenced ($F_{4,\ 20}$ = 6.409, P = .002) maize density. The senescence value ranged from 1.20 to 4.2 (Table 2). The highest senescence value was 4.2, recorded from treatment 1 (95200 plants/ha) and the least value was 1.20, recorded from treatment 5 (40100 plants/ha). Our results show that there was an inverse proportional relationship between senescence and maize density. It is also reported by [29] that increasing plant density can accelerate leaf senescence in maize. The early senescence observed from high density plants can be explained by the high stresses on the plant, such as competition for nutrient, light, water and space [24]. According to Esechie, [30], these stressors decrease the overall physiology of the plants, consequently leading to early senescence.

3.7 Lodging

The number of plants lodged at the time of record was significantly ($F_{4, 20}$ = 3.696, P = .021) influenced by plant density. The mean number of plants lodged ranged from 1.0 to 3.0 (Table 2). The highest number of plants lodged was 3.0, recorded from treatments 1 (95200 plants/ha) and the smallest number of plants lodged was 1.0 from treatment 2 (71400 plants/ha) and treatment 5 (40100 plants/ha). The number of plants lodged was not significantly different for treatment 2 (71400 plants/ha), treatment 3 (57100 plants/ha), treatment 4 (47600 plants/ha) and treatment 5 (40100 plants/ha), nevertheless was significantly different from treatment 1 (95200 plants/ha). Our result is on par with those of [31]. In line with the explanation of [28,31], the overcrowding or high density plants have smaller diameter, and weak morphological parameters such as roots and stalks. These weaknesses preclude high density plants from resistance to wind and other chaotic environmental factors.

3.8 Leaf Area Index (LAI)

The LAI like many other morphological parameters, was significantly ($F_{4,\ 20}$ = 7.506, P = .01) influenced by maize plant density. The LAI ranged from 419.40 to 568.50 (Table 2). Our results reveal that there was an inverse proportional relation between LAI and maize density. There was a constant increase in LAI with decreased maize density. Our findings are markedly contrary to those of [16,20], who recorded an increasing LAI with increasing plant density. They argue that LAI increased with plant density due to more leaf area occupied per unit ground area purposefully for maximum light interception. Their work is also supported by Saberali [32]. Worthy of note is that these researches calculated LAI per unit area occupied by the plants. However, in our study, LAI was calculated based on length and width. Our result is similar to that recorded by Tetio-Kagho and Gardner [29]

3.9 Number of Cobs Harvested and Weight of Harvested Cobs (Kg)

The number of cobs at harvest was significantly ($F_{4,\ 20}$ = 3.429, P = .027) influenced by maize density. The number of cobs increased with plant density (Fig. 1). The highest mean number of cobs at harvest was 12.8 for treatment 1 (95200 plants/ha) and 8.8 for treatment 4 (47600 plants/ha). Our study is on par with those of [16-18]. This pattern can be explained by the fact there are many cobs per hectare at high density stands. Research has shown that although there are many cobs per hectare at high density stands, the number of cobs per plant reduces with increasing plant density [16,33].

Interestingly the weight of cobs harvested was not significantly different based on plant density (Fig. 2). The highest cob weight was recorded from treatment 3 (57100 plants/ha). In spite of the fact that there were many cobs in high density stands, that did not translate into higher weight. Our result is in line with that of [17]. Zamir, et al. [33] posited that competition in high plant density stands reduces the supply of nitrogen, photosynthesis and water to the growing ears. The little difference in or lack thereof in weight of harvested cob is also reported by Maddonni and Otegui [34], who argue that kernel weight may not be significantly influenced by plant densities, thus justifying to an extent our findings. It is also reported that as plant population increases, kernel weight is more stable than other yield parameter [18,35].

3.10 Regression of Number and Weight of Cobs Harvested and Plant Density

Our results shows a strong negative regression between row-spacing and number of cobs harvested (Fig. 3). This implies that number of cobs at harvest increases with decreasing plant densities.

However, this was not the same with weight of cobs at harvest; a negative regression was noticed between row-spacing and weight of harvested cobs (Fig. 4).

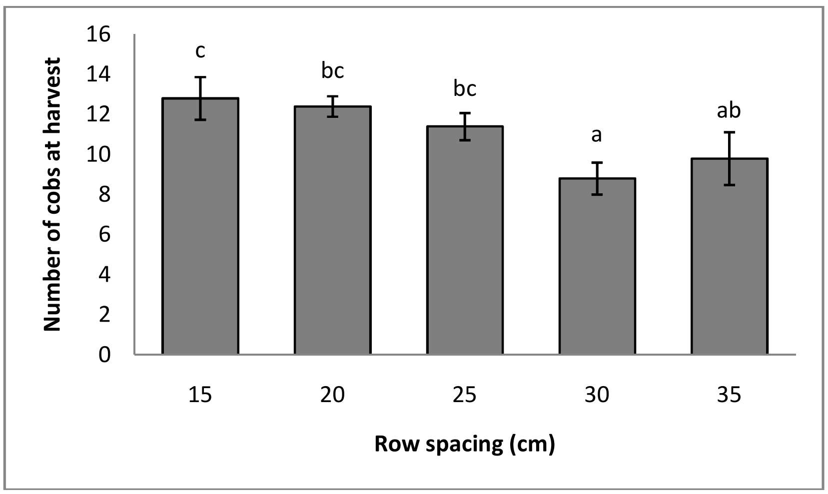

Fig. 1. Number of cobs harvested (mean bars with the same letter(s) are not significantly different (α = .05). Means were separated by DMRT

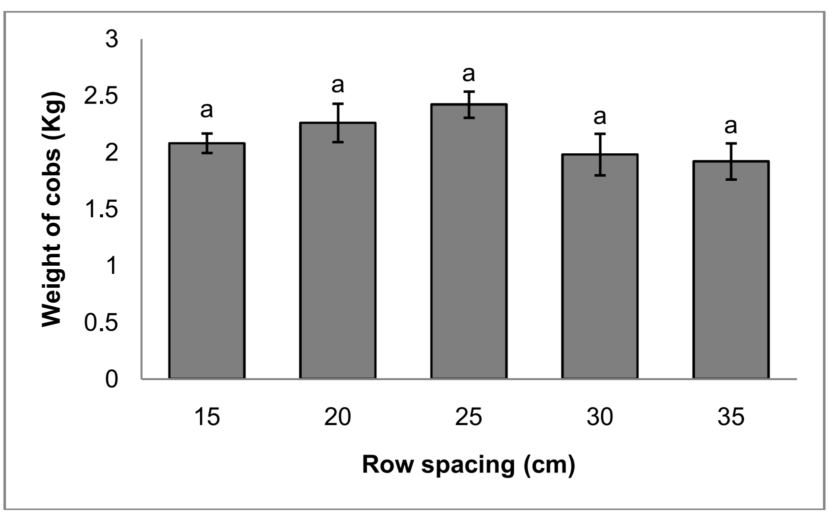

Fig. 2. Weight (Kg) of harvested cobs (mean bars with the same letter(s) are not significantly different (α = .05). Means were separated by DMRT

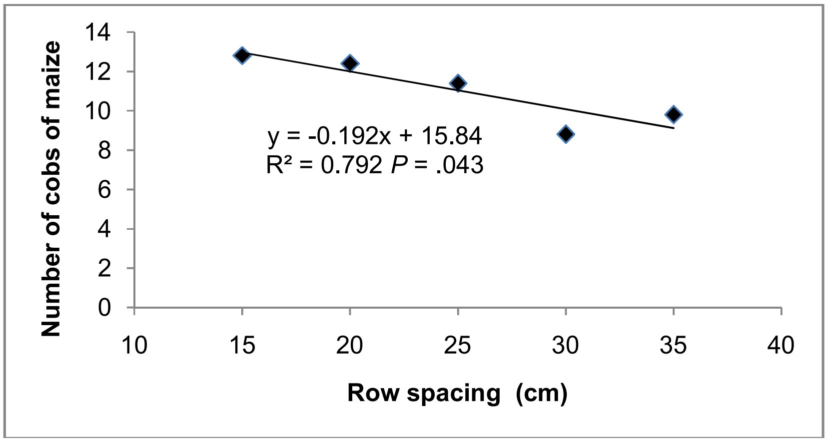

Fig. 3. Regression analysis of number of cobs harvested and intra-row spacing

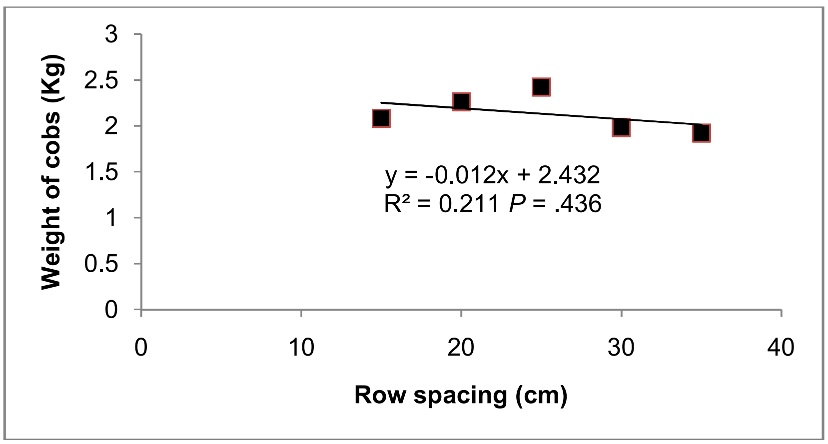

Fig. 4. Regression analysis of weight of cobs harvested and intra-row spacing

4. CONCLUSION

Our study, like many others has concluded that truly, maize plant density is an important agronomic component which influences both morphological and yield parameters. Therefore, based on farmers' objectives, appropriate intra-row spacing is needed for optimal utilization of scarce resources such as light, water, nutrient and space. In reference to the farmers in Bali Nyonga, NWR Cameroon, whose principal objective is yield, we recommend plant density of treatment 2 (71400 plants/ha) and Treatment 3 (57100 plants/ha). At these densities, the farmers obtain high yields and high plant tissue biomass as justified in LAI, vigour, and stem diameter, which could be part of fodder.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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