Effect of Spacing on Growth performance and Nutrient Quality of Moringa (*Moringa stenopetala*) under the Semi-Arid conditions of Nigeria

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Abstract: **Moringa is a treasured plantdue to its exceptionally high nutritional content and drought-tolerant in the tropics and subtropics. A study was conducted to investigate the effect of spacing on Growth performance and Nutrient quality of Moringa (*Moringa stenopetala*) under the semi-arid conditions of Sokoto, Nigeria. Completely Randomized Design (CRD) was used and replicated three times. Data collected were subjected to Analysis of Variance (ANOVA) and significant differences exist among the means, Duncan's Multiple Range Test (DMRT) will be used to separate the mean values. Results from this study revealed that spacing had no significant influence on number of leaves (NL), plant height (PH) and collar diameter (CD) except for number of branches (NB) with 6 NB each at 15 x 15 cm and 20 cm x 20 cm. The study further reveals an increase in leaf area index (LAI) with the values of 1.00 cmand 1.03 cmat 15 cm x 20 cm and 20 cm x 30 cm, root-shoot ratio of 2.53 cm and 2.50 cm at 15 cm x 15 cm and 15 cm x 20 cm respectively. Biomass accumulation were also higher with the values of 39.57 g and 5.9 g for fresh and dry weight both at 15x15 cm plant spacing. However, 20x20 cm plant spacing had indicated higher concentrations of both micro nutrients (Mg, Na, P, S) and macro nutrients (Cr, Fe, Mn and Sr). Therefore, *Moringa stenopetala* proved to have a good growth performance at a medium plant spacing and could provide nutritional needs of not only human but also livestock in semi-arid region of Nigeria.**

Keywords: **Plant spacing", Growth performance", Macronutrients", Micronutrients", Moringa", *Moringa stenopetala"***

I. INTRODUCTION

Moringa has attracted a lot of attention worldwide due to its highly nutritious and medicinal properties with great agricultural, industrial and domestic uses (Fahey, 2005; Fuglie, 2005) especially in arid and semi-arid environment. This tree has the potential to improve nutrition, boost food security and foster rural development (Hsu, 2006). Moringa pods, seedsand leaves contained highly important phytochemicals than you find in Oranges, Carrots, Bananas, Spinach and Onions(Rockwood, 2013). Senegal and Benin use Moringa products for the treatment of malnourished children (Kasolo, 2010). Moringa Pods are used for the treatment of digestive problems and the leavesare also added in different diets due to its low calorific value (Oduro, 2008). Essential Minerals(such as Calcium, Iron and Zinc) for human proper growth and development were reported to be richer in Moringa than in Milk, Beef and Spinach ((Barminas, 1998 and Fuglie, 1999).

Different spacing and nutritional composition of Moringa tree was extensively investigated. However, there were inconsistency in their respective findings which may be attributed to different conditions such as various Biological, Climatic, Soil and Management regimes (Sriskandarajah, 1987; Ivory, 1990; Gutteridge and MacArthur, 1998; Newton, 2007; Christopher, 2013; Mabapa, 20 17; Balakumbahan *et al*., 2020). Similarly, Biomass accumulation is an important indicator of crop final product and plant performance andwas considered a key trait in plant breeding, agricultural improvement and ecological applications (Chen *et al*., 2018).

For intensive Moringa cultivation to be sustainable, optimum plant spacing is required putting into considerations all other factors that will affect its overall productivity. The optimum density in sandy, well drained and fertile soils was found to be 1.33 million plants per hectare with spacing of 5 x 15cm. However, effective management (watering and fertilization) is necessary in order to provide the optimum level of nutrients needed to reduce competition among the individual plantswith closest spacing for minerals and other nutrients requirements (Amaglo *et al*., 2006)Thus, there is a need for information to establish the best agronomic practices for cultivation and utilization in the semi-arid region of sub-saharan Africa. Therefore, the present study was aimed at investigating the appropriate plant spacing required for *Moringa stenopetala* growth, yield and mineral composition with special reference to semi-arid conditions.

II. MATERIALS AND METHODS

Study Area

A study was carried out on theeffect of spacing on Growth performance and Nutrient quality of Moringa (*Moringa stenopetala*) under the semi-arid conditions of Sokoto, Nigeria. The research was done at Faculty of Agriculture Research farm of Usmanu Danfodiyo University, Sokoto, located between latitudes $11^0$6`N and $13^0$9`N and longitudes $3^0$7`E and $6^0$9`E (Mamman*et al*., 2000).The location has an altitude of 281 (meters) above sea level with average daily maximum temperature (35 to 37°C), and two predominant seasons prevail – the rainy season (500-700mm/annum) usually falling between the months of June and September and the dry season (October and ends in May). The vegetation of the area is characterized by sparse, widely spaced trees (5-9m height) and dominated by shrubs and grasses. The combination of natural and human activities, including droughts, persistent deforestation and continuous encroachment of the natural vegetation are some of the basic features of the area (Shinkafi, 2000).

Experimental Design and Treatments

The experimental design of this study was laid out in a Completely Randomized Design(CRD) with 4 plant spacing (treatments) of 15 x 15 cm, 15 x 20 cm, 20 x 20 cm, and 20 x 30 cm replicated three (3) times.

Land Preparation and Silvicultural Practices

The land was prepared manually (20 cm depth), immediately after land preparation mechanical harrowing and levelling was also done. Three main blocks of 8.7 m x 8.7 mwere established. Sixteen main plots of 1.8 m x 1.8 m with 0.5 m space between treatments were also established within each of the main blocks. In each main plot, sub-plot factors (plant spacing) were randomly assigned.

Seeds of the study species were obtained from International Crop Research Institute for Semi-Arid Tropics (ICRISAT, Niger Republic). Planting stations were marked in each plot and planted with the different plant spacing adopted for this study. The experimental units were irrigated once daily during the trial period. Recommended fertilizer rate of NPK 45:15:30 kg per hectare was also applied at planting (Namesi *et al*., 2010). Two weeks after plant emergence, seedlings were thinned to one healthy plant per station to reduce competition.Weeding was done manually as at when due using hand hoe to reduce competition as weeds compete with plants for growth factors. Harvesting was started at four (4) weeks after complete germination, seedlings were uniformly pinched back and all the foliage were removed. Ten (10) plants were selected from the net plot of 0.8 m x 0.8 m randomly for harvesting.

Field Data Collection

Data collection commenced two weeks after seedlings were uniformly pinched back. Growth parameters (Number of leaves, Number of branches, Plant height and Collar diameter) per seedlings were measured fortnightly for eight (8) weeks. Number of leaves and branches were counted manually, Plant height was measured with a meter rule and Collar diameter with Vernier caliper. Leaf area index, Root-shoot ratio and Biomass (Seedlings fresh and dry weight) were assessed at 8wks through destructive sampling (Aderounmu, 2010). Leaf Area Index (LAI) and Root-shoot ratio were determined using the formula described by Remison (1997). Seedlings were sampled and separated into leaves, stem and roots. Fresh weight of leaves, stem and roots were measured using an electronic weighing balance (S Metter 500) thereafter they were oven dried at 60^0C for 72 hours to a constant weight for dry matter measurements (Namesi *et al*., 2010).

Nutrient Determination

The dried leaves were milled into powder using Grinder, sieved through 1 mm mesh and stored in well-dried plastic containers and taken to the laboratory for nutritional composition determination using the Association of Official Agricultural Chemists (AOAC, 2005) procedures. Similarly, atomic absorption method as described by Aslam *et al*. (2005) was used to determine some mineralsincluding P, K, Ca, Mg, Mn, and Zn.

Data Analysis

Data was analyzed using Analysis of Variance (ANOVA) and where significant differences exist among the means, Duncan's Multiple Range Test was used to separate the mean values using SPSS package (Version 20).

III. RESULTS AND DISCUSSION

Effect of Plant Spacing on Growth Performance

The findings of this study showed no significant differences in all the growth parameters measured except forNBthat recorded statistically higher numbers (6) at 15x15 cm and 20x20 cm plant spacing respectively (Table 1).This might be due to minimum competition by the plants at early stage forlight, nutrients, water and space,as such no differential effect would be observed. Walker, (2007) reported a similar resultthat showed no significant effect on crown diameter at early growth stagein a research conducted on some fodder tree species productivity at eastern Botswana.

Table 1: Effect of spacing on growth parameters of the study species

Growth Parameters	Spacing (cm)				Sig	SEM
	15x15	15x20	20x20	20x30		
NL	51.00	68.00	60.00	41.00	Ns	10.937
NB	6.00^a	5.00^b	6.00^a	5.00^b	*	0.511
PH(cm)	16.83	20.32	15.46	14.92	Ns	2.249
CD(mm)	0.47	0.53	0.56	0.60	Ns	0.039

Means followed by the same letter(s) within a row are not significantly different ($p<0.05$)

NL- Number of leaves; NB- Number of branches; PH- Plant Height; CD- Collar diameter

Effect of Spacing on Leaf Area Index (LAI), Root-Shoot Ratio and Biomass Accumulation

Results of our study have indicated significant effects of plant spacing on LAI, root-shoot and biomass accumulation (Table 2). The LAI had shown that 15x20 cm and 20x30 cm have demonstrated higher LAI in comparison with other plant spacing of 15x15 cm and 20 x30 cm respectively. Our findings have demonstrated that the greater the number of plants per unit ground area the higher the dry biomass accumulation. Amagloet *al*. (2006) indicated a significant effect (P<0.05) of spacing on the leaf and shoot yield of moringa. Similarly, Mabapa*et al*. (2017) have reported an increase in biomass accumulation due to higher planting density in their research on the effect of planting density on the leaf yield and quality of *Moringa oleifera*. These results are in agreement with findings from this study that recorded higher leaf biomassat plant spacing of 15 × 15 cm (39.57g fresh- 5.97g dry) compared to wider plant spacing (20x20 and 20x30 cm) that gave 14.60g and 1.70g for fresh and dry weight respectively.

Furthermore, Goss (2012), have reported an increase in plant dry matter accumulation with an increase in planting density. These agrees with the findings of the present study that recorded an increase in biomass yield with an increase in the number of plants per unit ground area. On the contrary, Ella *et al*. (1989) reported a decrease in biomass yield due to greater number of plants per unit ground area as a result of competition.

Table 2: Effect of spacing on leaf area index, root-shoot ratio and biomass accumulation

Plant Spacing (cm)	Leaf Area Index (cm)	Root-shoot (cm)	Biomass	
			Fresh (g)	Dry (g)
15x15	0.87^{bc}	2.50^{a}	39.57^{a}	5.97^{a}
15x20	1.03^{a}	2.53^{a}	28.17^{ab}	3.50^{ab}
20x20	0.73^{c}	1.40^{b}	14.60^{c}	1.67^{c}
20x30	1.00^{a}	1.67^{b}	17.10^{c}	1.70^{c}
SEM	0.082	0.279	10.652	2.879

Means followed by the same letter(s) within a column are not significantly different (p<0.05)

Effect of Spacing on Nutritional Composition

The findings of this study revealed significant influence of plant spacing on macro-nutrients of *M. stenopetala* (Table 3), however Ca and K showed no significant difference. The level of macro-nutrients as observed from the most abundant to the least abundant was K>Ca>S>Mg>P>Na. Plant spacing showed no significant influence on most of the micro-nutrients except for Cr, Fe, Mn, Mo and Sr that showed significant differences. The concentration trend of micro-nutrient from the most abundant to the least abundant was Fe>Si>Al>Mn>Sr>Zn>B> Cu> Ba>Mo>Ni>Cr. This result agrees withNewton *et al*. (2006), who reported significant effect on the leaf mineral composition of moringa asinfluencedby plan spacing. In the present study, an increase on the chemical composition of moringa leaves was observed due to an increase in plant spacing. Moringa planted ona wider spacing gave higher amount of macro nutrients as compared with the narrow ones (Table 3). In a study conducted by El-Morsy (2009) reported decrease in mineral content due to greater number of plants recorded per unit ground area. This could be as a result of competition by the plantsfor the uptake of nutrients. However, Basra *et al*. (2015) reported that, an increase in plant spacing decreasesthe chemical composition of moringa leaves. The results agree with Nouman *et al*. (2013), who indicated richness in nutrients of moringa that are more important in milk and meat production essentials for livestock feeds.

Factors such as concentration of minerals in the soil, availability to the plants, edaphic and climatic factors as well as the plant developmental stages could also determine the concentration of mineral elements in the plants (Sánchez, 2006; Lukhele, 2003). However, Nouman*et al*. (2013), Moyo*et al*. (2011), and Sánchez *et al*. (2006) recorded no significant effect on the leaf'schemical composition of moringa due to planting density.

Table 3: Effect of Spacing on Nutritional Composition of *M. stenopetala*

Nutrients (mg/kg)	Spacing (cm)				Sig	SEM
	15x15	15x20	20x20	20x30		
Macro-nutrients						
Ca	6265.98	5938.93	6191.59	5948.56	ns	129.265
K	14692.03	15504.77	15685.89	14528.44	ns	481.483
Mg	4026.63^{b}	4253.91^{ab}	4357.89^{a}	4216.99^{ab}	*	106.433
Na	596.81^{b}	566.37^{b}	752.25^{a}	587.08^{b}	*	48.964
P	3204.93^{b}	4134.71^{a}	4176.74^{a}	3873.61^{a}	*	211.359
S	4528.53^{b}	5305.15^{ab}	5703.01^{a}	4883.71^{ab}	*	365.503
Micro-nutrients						
Al	68.26	63.48	79.01	62.54	ns	7.021
B	16.65	17.23	18.46	16.49	ns	0.842
Ba	5.79	6.63	7.47	5.80	ns	0.052
Cr	0.57^{b}	0.53^{b}	0.82^{a}	0.44^{bc}	*	0.080
Cu	10.73	10.80	12.28	15.71	ns	1.745
Fe	170.64^{ab}	174.34^{ab}	208.50^{a}	150.45^{b}	*	15.898
Mn	40.87^{ab}	41.74^{ab}	46.82^{a}	36.98^{b}	*	2.714
Mo	1.14^{c}	2.04^{a}	1.58^{b}	1.74^{ab}	*	0.152
Ni	0.89	1.41	1.08	3.68	ns	1.353
Si	75.41	80.96	79.81	77.18	ns	7.266
Sr	25.66^{b}	33.01^{a}	32.67^{a}	29.83^{a}	*	1.391
Zn	22.34	29.27	31.78	37.82	ns	6.216

Means followed by the same letter(s) within a row are not significantly different (p<0.05)

IV. CONCLUSION

The results of the study showed that plant spacing influence *M. stenopetala* growth, biomass accumulation and nutritional quality. Plant spacing of 15x20 cm produce plants with higher LAI (1.03 cm) and root-shoot ratio (2.53 cm) while15 cm x 15 cm gave a higher biomass accumulation with the values of 39.57 g and 5.97 g of fresh and dry weight respectively. However, 20 x20 cm plant spacing had indicated higher macronutrients (Mg, Na, P and S) and micronutrients (Cr, Fe, Mn and Sr) concentrations.

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