Effect of Plant Population Density on Growth and Leaf Yield of *Moringa Oleifera* Lam.

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ABSTRACT

Moringa *(Moringa oleifera),* a fast growing tree that originated from India is extensively promoted worldwide for nutrition supplement as it is rich in protein, minerals and vitamins. Currently, studies on Moringa seem to be focusing more on its nutritional and medicinal values, than its agronomy as a cultivated crop. Hence, this study was conducted to assess the influence of different plant population density on growth and leaf yield of Moringa for sustainable dry matter production. The experiment was established at the nursery of the Department of Agronomy, University of Ilorin, Nigeria. It was a Completely Randomized Design which comprised three plant populations: 1,000,000 plant/ha, 250000 plants/ha and 111,111 plants/ha replicated thrice. Data were collected on the following: emergence percentage, plant height, number of branches, stem girth, number of leaflets, leaf fresh weight, leaf dry matter, shoot fresh weight and shoot dry matter. Results showed significant treatment effect on parameters evaluated at $p<0.05$. Emergence percentage, number of leaflets, fresh leaf weight and dry leaf weight were highest at 250 000 plants/ha while mean stem girth and stem weight were highest at 111,111plants/ha. Hence, the population density of 250,000 plants/ha could be considered the optimum for sustainable growth and high leaf yield in an intensive mono-cropping system.

Keywords: Plant population density, Leaf dry matter, Moringa, growth, plant spacing.

INTRODUCTION

Moringa (*Moringa oleifera* Lam.), a small, fast growing deciduous tree belongs to the monogenic family-Moringaceae. It is native to Northern India, Pakistan and Nepal but has become naturalized well beyond its native range, including many countries of Southeast Asia, the Arabian peninsula, Tropical Africa, Central America, the Caribbean and Tropical America (Francis *et al*., 1991). Over the years, interest had been shown on Moringa for its nutritional and medicinal uses. It is extensively promoted worldwide for nutrition supplementation as it is rich in protein (5-10%), minerals (iron and calcium) and vitamins (Vitamin C and Carotene) (Church World Service, 2000). In comparison, gram for gram with other fruits and vegetables, Moringa has more beta-carotene than carrots (*Dancus carota*), more protein than peas (*Pisum sativa*), more vitamin C than oranges (*Citrus spp*), and more iron than spinach (*Spinocea oleracea*) (Palada and Chang, 2003).

The World Declaration and the Plan of Action on Nutrition, adopted by 159 countries, at the International Conference on Nutrition organized by the United Nation's Food and Agriculture Organization and World Health Organization in 1992, adopted the inclusion of

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Moringa in diets as a sustainable food-based strategy aimed at combating micronutrient malnutrition (particularly for populations deficient in vitamin A and iron) (WHO, 1992). It is also rich in health promoting phytochemicals such as carotenoids, phenolics (chlorogenic acids) and flavonoids (quercitin and kaempherol glycosides) (Foidl, *et al.*, 2001; Becker and Siddhuraju, 2003; Bennett *et al.,* 2003). Moringa, when being processed contains acetone which can be prepared into herbal formulation found to be an effective anti-malaria bioagent (Patel *et al*., 2010).

Aside its nutritional and medicinal applications, Moringa was found to be very useful as alley crop in agro-forestry industry (Dash and Gupta, 2009) as it could reduce soil erosion and improve soil conservation. Moringa seed contains ben oil used in making perfumes, soap and can also be used as wood preservative and machinery and watch lubricant (Fuglie, 1999). It is an important water clarifier, using the seeds greatly assisted in providing millions of people with clean and drinkable water along the River Nile (Yarahmadi *et al*., 2009).

In regions where large scale production is practiced, Moringa receives little or no attention in terms of its' agronomic requirements for optimum land use and leaf yield. Increasing production to meet the current growing demand of the crop requires that more land be put into its' cultivation. This may be expensive and difficult to achieve due to competing uses of available cultivable land for food and other uses. Hence the need to determine the extent to which plant spacing and plant population could be reduced to achieve optimum performance of the crop without overstressing the need for inter plant competition.

Different plant spacing was found to have varying effect on leaf yield, plant height and stem girth of Moringa under various planting system. Plant spacing coupled with soil composition (level of organic matter), water availability, soil type and water holding capacity determine the optimum leaf yield of the crop (Amaglo *et al*., 2006). Reyes-Sanchez *et al*., (2006) reported an average dry matter yield of 18tons ha^{-1} of Moringa grown at a population of 750,000 plants /ha. However, Foild *et al*. (2001) found that increase in leaf green matter yield could be achieved from 5 to 44tons /ha at 350,000 and 16,000000 plants /ha respectively, but there was high mortality rate at such high density. Foidl, *et al.*, (2001) reported that when Moringa was cultivated as a sole crop with different spacing under different ecological zones, there is possibility of obtaining different yields due to changes in climatic factors such as rainfall, temperature, humidity and edaphic factors. He suggested that a spacing of 10 x10 cm is preferable for the production of green matter under intensive sole cropping farming system in a sandy, well drained fertile soil. Hence, it is important to quantify the optimum plant density to obtain optimum quantity of Moringa leaf yield in different circumstances. Therefore, this study was carried out with the aim of evaluating the effect of varying population density on vegetative growth and leaf yield of Moringa for sustainable production under southern Guinea savanna ecology.

MATERIALS AND METHODS

The study was carried out at the nursery pavilion of the Department of Agronomy, Faculty of Agriculture, University of Ilorin, Ilorin, Nigeria. It is a southern Guinea Savanna Ecological zone of Nigeria located on latitude 8’ 30 N and longitude 4’ 32E characterized by a bimodal rainfall pattern and about 307m above the sea level. The site contains sandy-loam soil.

The experiment was a Completely Randomized Design, with three treatments replicated three times. Treatment 1 (P_1) was Moringa planted at 10 x 10 cm (a population of 1,000,000 plants/ha), Treatment 2 (P_2) was Moringa planted at 20 x 20cm (population of 250,000 plants/ha), Treatment 3 (P_3) was Moringa planted at 30 x

30cm (population of 111,111 plants/ha).

The land was cleared manually to remove existing vegetation and soil worked thoroughly to remove pebbles and hard objects. The site was demarcated into nine plots of 2m x 2m prepared as raised beds with an alley of 1m between beds. Weeding was controlled manually as at when due. Plants were adequately irrigated throughout the period of observation. Leaf defoliator (mainly grass hopper) was controlled using Cypermethrin (10%EC) at the rate of 0.12g/kg active ingredient. Poultry manure at the rate of 5tons/ hectare was applied two weeks before planting and NPK 20-10-10 at the rate of 500kg/ha. Data on growth parameters were collected as follow: Emergence percentage, plant height, stem girth, number of branches/plant and number of leaflets/plant were evaluated during the first 60 days after sowing. Cutting commenced thereafter so that the seedlings could have good root development. First cutting was done 60 days after sowing (DAS) and every 30 days subsequently. Stem fresh and dry weight, leaf fresh and dry weight, leaf yield per plant were taken at each harvest (60, 90, and 120 DAS). All data collected were subjected to analysis of variance (ANOVA) using Genstat Release 4th edition. Significance means were separated using least significance difference (LSD) at 5% probability.

RESULTS AND DISCUSSION

The results showed the effect of plant population density on percentage emergence of Moringa plant (table 1). It was observed that during the first ten days after planting, P3 (111,111 plants/ha) had the highest emergence percentage (42.9%) while the lowest emergence percentage (20.4%) was observed from P1 (1,000,000 plants/ha). Subsequently, between 15 and 25 DAS there were significant treatment differences ($p<0.05$) in the percentage emergence of Moringa with P2 (250,000 plants/ha) having the highest value all through (69.3%). The mean plant height increased with time, showing significant treatment differences ($p<0.05$) between the 4th and 6th weeks after sowing (WAS) (table 2). At 4th weeks after sowing, there was a high significant effect of plant density on mean plant height ($p<0.001$) with P1 (1,000,000 plants /ha) having the highest increase in plant height (16.2cm) while the least height (11.7cm) was obtained from P2 (250,000 plants /ha). Also at 6th WAS the mean plant height was found to be significantly different ($p<0.05$) with the highest population (1,000,000 plants /ha) still having the highest increase in mean plant height.

However, there was no significant treatment difference in mean plant height among plant population from 8th WAS. According to Lyons, (1968), increasing plant density accelerates the rate of plant growth hence the increased heights in closer spacing at initial stage. The table 3 showed the main effect of plant population density on mean number of branches per plant of Moringa. The mean number of branches per plant was found to increase with age of plant. At the early stage (4WAS), no significant treatment difference was observed in mean number of branches/plant at different plant population density. Significant treatment differences were observed among the different plant populations from the 6th WAS with the highest mean number of branches (10.7) found in P2 (250,000 plants /ha). Also, stem girth was found to increase generally with time for all the treatments and was significantly different ($p<0.05$) from 6th and 8th WAS. However, there was no significant difference in mean stem girth among the plant population densities at 4th WAS. P3 (111,111) which had the lowest plant population recorded the highest stem girth (6.63cm) while the highest population (P1) had the lowest stem girth (4.0cm) (table 3). This may be due to the fact that there wasn't much competition for space within the plant. This agrees with report of Janick (1972) which stated that increasing competition is similar to decreasing the concentration of growth factors. Thus the closely spaced plants have decreased growth factors such as space and access to water which may lead to a higher competition for growth factors among individual plants. Consequently, the least plant population was found to have the thickest stem size while the most densely populated plants had the smallest stem girth.

The main effect of population density on mean number of leaves of Moringa was shown on table 4. The mean number of leaves produced per plant increases generally with time and this was significantly different among the treatments from 8th weeks after sowing. P1 had the highest increment in leaf number /plant from 4th to 8th WAS. P1 had the highest mean leaf number at 8th WAS which was significantly different ($p<0.05$) from the other treatments. This corresponds with the findings of Amaglo *et al*., (2006). Leaf fresh and dry weight /plant were significantly affected by plant populations at the first cutting at 60 DAS (table 5). P1 had the highest leaf fresh and dry weight while P3 had the least. However, a sharp decline in leaf fresh weight was observed from 90 DAS for P1(1,000,000 plants/ha) being the most populated while P2 and P3 - the medium and least populated respectively had substantial increment in fresh and dry leaf weight by 120DAS though there was no significant treatment differences at $p< 0.05$.

orman (1992) and Foidl *et al*., (2001) indicated that increasing plant density does not affect individual plants if the plant density is below the level at which competition occurs between plants. However, when the plant density is too high and there is competition between plants, yield decreases. Therefore, yield per plant decreases as total biomass production per unit area increases with increased planting density.

There was significant treatment difference at $p< 0.05$ in stem fresh and dry weight per plant at first cutting 60 DAS (table 6). It was observed that P1 had the highest fresh and dry stem weight while P3 had the least. Thereafter, there was no significant difference between treatments at 90DAS and 120DAS. Consequently, stem yield generally decline at 90DAS for all the treatments. At 120DAS stem fresh and dry weight per plant increases substantially for P3 only.

Table 1:Effect of plant population density on emergence percentage of *Moringa oleifera*.

	Emergence Percentage (%)			
Plant Population/ha	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**
1,000,000	20.4[b]	34.2[b]	38.4[b]	40.4[b]
250,000	41.1[a]	56.8[a]	63.3[a]	69.3[a]
111,111	42.9[a]	58.3[a]	63.1[a]	63.1[a]
S.E.D	7.97	8.69	6.69	6.86
L.S.D (0.05)	19.5	21.2	16.4	16.8

*Means followed by different letters in the same column are significantly different at 0.05 probability level by LSD.

DAS - days after sowing SED- Standard error

Table 2: Effect of population density on mean plant height of *Moringa oleifera.*

PLANT HEIGHT (cm)			
Plant Population /ha	**4WAS**	**6WAS**	**8WAS**
1,000,000	16.22[a]	38.5[a]	91.1
250,000	11.74[c]	34.6[b]	87.4
111,111	13.18[b]	27.3[c]	86.0
SED	0.57	1.27	3.71
LSD (0.05)	1.40	3.12	ns

Means followed by different letters in the same column are significantly different at 0.05 probability level by LSD

n.s - not significant WAS - weeks after sowing SED- Standard error

Table 3: Effect of plant population density on mean number of branches and stem girth (cm) of *Moringa oleifera*.

	Mean number of branches/plant			**Mean stem girth /plant**		
Plant Population /ha	**4 WAS**	**6WAS**	**8WAS**	**4WAS**	**6WAS**	**8WAS**
1, 000 000	8.0	10.0[b]	11.7[b]	1.64	2.63[c]	4.00[c]
250,000	8.1	10.7[a]	12.9[a]	1.55	2.90[b]	5.37[b]
111,111	8.2	9.3[b]	12.0[b]	1.69	2.93[a]	6.63[a]
Lsd (0.05)	n.s	0.94	0.81	n.s	0.15	0.81

Means followed by different letters in the column are significantly different at 0.05 level of probability by L.S.D n.s - not significant WAS = weeks after planting

Table 4: Effect of plant population density on mean number of leaves /plant of *Moringa oleifera.*

	Mean number of leaves/plant		
Plant Population /ha	**4WAS**	**6WAS**	**8WAS**
1, 000 000	73.9	284.0	3332.0[a]
250,000	65.9	281.0	3101.0[b]
111,111	68.2	182.0	2954.0[b]
SED	3.18	49.4	90.4
Lsd (0.05)	n.s	n.s	221.1

Means followed by different letters in the same column are significantly different at 0.05 probability level by LSD.

n.s not significant WAS weeks after sowing SED- standard error

Table 5: Effect of plant population density on mean leaf fresh and dry weight /plant of *Moringa oleifera.*

	Leaf fresh weight/plant (g)			leaf dry weight /plant (g)		
Plant Population /ha	**60DAS**	**90DAS**	**120DAS**	**60DAS**	**90DAS**	**120DAS**
1, 000 000	1357.0[a]	870.0	743.0	283.0[a]	241.0	214.0
250,000	968.0[b]	725.0	917.0	238.0[b]	191.0	267.0
111,111	693.0[c]	733.0	937.0	180.0[c]	198.0	260.0
SED	191.2	153.7	189.0	40.9	46.5	48.0
Lsd (0.05)	467.8	n.s	n.s	100.2	n.s	n.s

Means followed by different letters in the same column are significantly different at 0.05 probability level by LSD. n.s not significant DAS- days after sowing SED-standard error

Table 6: Effect of plant population density on mean stem fresh and dry weight of *Moringa oleifera* L.

	Mean stem fresh weight (g)			Mean stem dry weight (g)		
Plant Population /ha	**60DAS**	**90DAS**	**120DAS**	**60DAS**	**90DAS**	**120DAS**
1, 000 000	1715[a]	1030	923	338 [a]	282	167
250,000	1268[b]	883	1183	237[b]	232	230
111,111	917[c]	907	1217	155[c]	230	247
SED	259.2	215.4	259.6	46.0	52.4	53.7
Lsd (0.05)	634.2	Ns	Ns	112.5	ns	ns

Means followed by different letters in the same column are significantly different at 0.05 probability level by LSD. n.s not significant DAS- days after sowing SED- standard error

CONCLUSION

The results from this experiments showed that the effect of population density on parameters evaluated was significant ($p<0.05$). Emergence percentage, number of leaflets, fresh and dry leaf weight were found to be highest at plant population of 250,000 plants/ha while mean stem girth was highest at the least plant population. Thus, it could be concluded that if the objective is to harvest the green leaf, plant population of 250,000 plants /ha which is probably the optimum plant density might be adequate for sustainable production of Moringa in the study area.

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تأثير الكثافة النباتية على نمو وانتاجية أوراق شجرة المورينغا (*Moringa oleifera*)

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ملخص

يتم الترويج للمورينغا، وهي شجرة سريعة النمو نشأت أصلاً في الهند، على نطاق واسع في جميع أنحاء العالم لقيمتها كمكملات غذائية، وذلك لغناها بالبروتين والمعادن والفيتامينات. الحالية، يبدو أن الدراسات على المورينغا تقوم بالتركيز على القيمة الغذائية والطبية لهذه الشجرة أكثر من القيمة الزراعية لها بوصفها أحد المحاصيل المزروعة. وبناء على ذلك، أجريت هذه الدراسة لتقييم تأثير كثافات نباتية مختلفة على نمو وانتاجية أوراق المورينغا بهدف الانتاج المستدام للمادة الجافة. تم القيام بالتجربة في مشتل قسم الزراعة، جامعة ايلورين، نيجيريا. وكان تصميم التجربة كامل العشوائية وضم ثلاث كثافات نباتية : 1000000 نبات / هكتار، 250000 نبات / هكتار، و111111 نبات / هكتار، تم تكرارها ثلاث مرات. وقد تم جمع البيانات على النحو التالي: نسبة ظهور النباتات، ارتفاع النبات، عدد الفروع، محيط الساق ، عدد الوريقات، الوزن الطري للورقة، الوزن الجاف للورقة، الوزن الخضري الطري، الوزن الخضري الجاف. و أظهرت النتائج فروقات (P< 0.05) معنوية في المعايير المقاسة. وسجلت نسبة ظهور النبات ، وعدد الوريقات والأوزان الطرية والجافة للأوراق أعلى المستويات عند (250000 نبات/ هكتار) ، بينما سجل متوسط محيط ووزن الساق أعلى المستويات عند (111111 نبات/ هكتار)، و بالتالي يمكن اعتبار الكثافة النباتية (250000 نبات/ هكتار) هي الكثافة الأمثل لتحقيق النمو المستدام والنتاج الورقي العالي في النظام الزراعي الأحادي المكثف.

الكلمات الدالة: الكثافة النباتية، وزن الورقة الجاف، المورينغا، النمو، المباعدة بين النباتات.

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