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*Full Length Research Paper*

# A study of the initial establishment of multi - purpose moringa (*Moringa oleifera* Lam) at various plant densities, their effect on biomass accumulation and leaf yield when grown as vegetable

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**A field study was carried out to evaluate the effect of different plant spacing on growth, biomass accumulation and initial establishment of *Moringa oleifera* multi-purpose tree. This was a one factor experiment comprising of five different plant spacing carried out in randomised design (RCBD) in three blocks at the University of Zimbabwe, Crop Science Department. The main objective of this study was to determine the most ideal plant spacing for increased biomass accumulation. The net plot was 3 × 3 m. Leaf harvests were done periodically at three week intervals by harvesting three side branches and fresh and dry matter biomass was taken in grams per plant/plot. The results indicated that high plant populations/unit area with closer spacing, produced higher biomass yields, robust rooting and longer stems, but with smaller stem diameters. Whilst on the other hand, low plant populations resulted in higher individual plant growth as evidenced by the thicker stem diameters produced. Therefore for increased biomass and leaf production, it is recommended that closer plant spacing be used if the plant is intended for vegetable and forage utilization. However, if the plants are to be utilized for fuel, leaf processing, pod and seed production, wider plant spacing are recommended for increased individual plant growth.**

**Key words:** *Moringa oleifera,* biomass accumulation, population density, initial establishment.

## INTRODUCTION

Moringa, a multi-purpose tree (MPTS) has gained a lot of publicity because of its many varied uses, which range from the medicinal applications, industrial, sanitary to the nutritional. Moringa has very high nutritional properties that would be useful as a food supplement, especially in those marginalized communities. Besides its nutritional and medicinal applications, *M. oleifera* is very useful as an alley crop in the agro-forestry industry Dash and Gupta (2009) to reduce soil erosion and improve soil conservation. Besides Moringa oleifera being processed into a medicine, it contains acetone which can be prepared into a herbal formulation which is an effective anti-malaria bioagent (Patel et al., 2010). This technology is being extensively utilized in India. Given the over-use of synthetic medications, increasing cost of acquiring prophylactic and therapeutic drugs, plants of ethnomedicinal properties are being highly acclaimed and their importance being noted and *M. oleifera* is one such crop (Singh et al., 2010). Such trees have the potential to be a source of new drugs (Singh et al., 2010). According to further studies *M. oleifera* can be used as an important browser for goats in the drier ecological areas of Zimbabwe, Sri Lanka and Indonesia, which are important sources of meat, milk, manure, income etc in these climatically marginalized households (Sereshine and Marapana, 2011). It is also an effective water clarifier using the seed, thus providing millions of people with clean drinking water along the Nile River (Yarahmadi et al., 2009). In view of these diversified significant applications of Moringa oleifera and its impact on improved livelihoods and health, it is crucial that proper and viable agronomic practices for increased productivity of *M. oleifera* be identified and established.

Mahn et al. (2005) studied different spacing of Moringa on sulfate acidic soils and the results suggest that Moringa can develop on the sulfate acid soil but the young plant did not adapt well to water logged conditions and biomass harvests of up to 52 tonnes/ha were achieved. There is need therefore to establish how the tree will perform and adapt to local Zimbabwean conditions which are drier, warmer and with soils which are predominantly sandy and inherently low in nitrogen and phosphorus.

Numerous studies have been conducted on other MPTS. For example *Gliricidia* leaf biomass (DM) production under a range of climatic and edaphic conditions, various management regimes and different variables such as establishment methods, plant spacing, plant density, harvesting frequency and intensity, indicated that the values (DM production) attained varied (Wong and Sharudin, 1986; Sriskandarajah, 1987; Atta-Krah and Sumberg, 1987; Ivory, 1990; Gutteridge and MacArthur, 1998) . Ella et al. (1989) revealed that as plant spacing was reduced, biomass yield per plant decreased owing to competition. However, total forage yield/unit area increased, giving the highest leaf yields at the highest density tested. In addition, studies on Sesbania spacing and population density indicated lower stem diameters and increased height at high densities but increased biomass as plant population increased (Dutt and Pathania, 1986; Zsuffa, 1984).

Further studies with leucaena plant densities and eucalyptus, indicated the mean total biomass differed significantly between species; *Melia azedarach* accumulated the maximum biomass (14.9 t/ha), which was 24% higher than *Leucaena. leucocephala* and 43% higher than that of *Eucalyptus tereticonis.* Eucalyptus varied the most in biomass over the population densities tested. Total biomass in all species increased as population density increased, although gains from 15000 to 20000 plants/ha were non-significant (Mishra et al., 1992). Higher plant growth rates were observed Ella et al. (1989) in the higher plant populations than in the lower plant populations. Leaf area index (LAI) was also higher for the high plant density than the lower plant density (Mih et al., 2008). All these other observations are supportive of the findings of this study with *M. oleifera.*

## MATERIALS AND METHODS

### Study site

The experiment was carried out at the University of Zimbabwe Crop Science Department fields, in Plot 10 located in Mount Pleasant area, which is found in Natural Region II with an annual rainfall of 600 to 1000 mm, an altitude of 1500 mm above sea level and average temperatures of 20 to 30°C. The soils comprise mainly of red clayey soils.

### Experimental design

A randomised complete block design (RCBD) in three blocks was used. The experiment was a one factor experiment with five plant population densities which were:

1) 12 346 plants/ha spaced at 0.9 × 0.9 m
2) 24 692 plants/ha spaced at 0.65 × 0.65 m
3) 49 384 plants/ha spaced at 0.45 × 0.45 m
4) 98 764 plants/ha spaced at 0.35 × 0.35 m
5) 197 528 plants/ha spaced at 0.25 × 0.25 m

Plot area was 4 × 4 m with a net plot area of 3 × 3 m. The following parameters were used for data collection: plant height measurements and stem diameter at 15 cm DBH at base height were taken at three weekly intervals and leaf harvests (three leaves were harvested per plant) at three weekly intervals. At the end of the trial, the whole plant biomass was taken separately as above and below ground parts. The data was subjected to analysis of variance (ANOVA) and mean separation was done using Fisher's protected least significant difference method (LSD). The analyses were done using Genstat 6 Release 3.22 for windows statistical computer package.

## RESULTS

### Effect of population density on above ground whole plant biomass

Increasing population density had the effect of increasing the plant dry matter weight of Moringa ($p<0.05$) (Table 1). The highest treatment mean was for the largest plant density per given area (197 528 plants $ha^{-1}$) which produced a plant dry matter of 174.42 g. This was however, not significantly different ($p<0.05$) from the mean achieved for the second highest population density (98 764 plants $ha^{-1}$) which yielded 100.98 g.

### Effect of population density on below ground plant biomass

The results showed significant differences ($p<0.05$) for both plant fresh-weight and dry matter, with the highest mean for both parameters being for the highest population density (197 528 plants $ha^{-1}$) (Table 2). The second highest population density mean was however, not significantly different from the other population densities at $p<0.05$. The highest mean (793.1 g) plant dry matter, for the highest plant density (197 528 plants $ha^{-1}$), was significantly different ($p<0.05$) from all the other treatment means.

### Effect of population density on leaf biomass yields

The highest population density (197 528 plants $ha^{-1}$) and the second highest population density (98 764 plants $ha^{-1}$) produced the highest leaf dry matter and leaf fresh-weight figures (Table 3). The lowest plant density (12 346

**Table 1.** Effect of population density on above - ground plant dry - matter (g/pot) obtained at crop science department, July to August 2007.

| Population (plants/ha) | Mean (DM g/plot) |
|---|---|
| 197 528 | 174.42[a#] |
| 98 764 | 100.98[ab] |
| 49 384 | 68.07[b] |
| 24 692 | 41.33[b] |
| 12346 | 31.82[b] |
| P value | 0.037 |
| SED | 46.5 |
| $LSD_{0.05}$ | 96.7 |
| Significance | * |

# Means followed by the same letter are not significantly different at $P \leq 0.05$; * Significant at $p<0.05$; SED Standard errors of differences between means; $LSD_{0.05}$ Least significant differences of means (5% level).

**Table 2.** Effect of population density on root fresh weight (g/plot) and root dry matter (g/plot) obtained from crop science department, July to August 2007.

| Population (plants/ha) | Meanfresh weight (g/pot) | Mean dry (g/pot) |
|---|---|---|
| 197 528 | 3300[a#] | 793.1[a] |
| 98 764 | 2012[ab] | 415.5[b] |
| 49 384 | 1167[b] | 255.9[b] |
| 24 692 | 696[b] | 160.5[b] |
| 12 346 | 579[b] | 133.3[b] |
| P value | 0.019 | 0.002 |
| SED | 832.9 | 157.2 |
| $LSD_{0.05}$ | 1722.9 | 325.1 |
| Significance | * | * |

**#,** Means followed by the same letter are not significantly different at $P \leq 0.05$; *, Significant at $p<0.05$; SED, Standard errors of differences between means; $LSD_{0.05}$ Least significant differences of means (5% level).

**Table 3.** Effect of population density on leafy dry matter (g/plot) and leaf fresh weight (g/plot) obtained from the crop science department, July to August 2007.

| Population (plants/ha) | Leaf dry matter (g/pot) | Leaf fresh weight (g/pot) |
|---|---|---|
| 197 528 | 82.82[a] | 404.0[a#] |
| 98 764 | 42.72[b] | 205.5[b] |
| 49 384 | 22.49[bc] | 106.8[bc] |
| 24 692 | 11.22[c] | 52.9[c] |
| 12 346 | 6.37[c] | 28.7[c] |
| P value | <.001 | <.001 |
| SED | 11.59 | 59.3 |
| $LSD_{0.05}$ | 23.10 | 118.2 |
| Significance | *** | *** |

**#,** Means followed by the same letter are not significant at $P \leq 0.05$; ***Significant at $p<0.001$; SED Significant errors of differences between means; $LSD_{0.05}$ Least significant differences of means (5% level).

plants $ha^{-1}$) produced the lowest leaf fresh-weight and leaf dry matter (Table 3). The highest means were obtained at the highest plant density, 82.82 g for dry-matter and 404 g for the fresh-weight. In both cases,

**Table 4.** Effect of population density on stem diameter (mm) obtained from the crop science department site, July to August 2007.

| Population (plants/ha) | Stem diameter (mm/plant) |
|---|---|
| 197 528 | 4.947[b#] |
| 98 764 | 5.020[b] |
| 49 384 | 5.053[b] |
| 24 692 | 4.502[c] |
| 12 346 | 5.234[a] |
| P value | <.001 |
| SED | 0.1138 |
| $LSD_{0.05}$ | 0.2230 |
| Significance | *** |

# Means followed by the same letter are not significant at P ≤ 0.05; ***Significant at p<0.001; SED Standard errors of differences between means; $LSD_{0.05}$ Least significant differences of means (5% level).

**Table 5.** Effect of population density on stem-length (mm) obtained from crop science department, July to August 2007.

| Population (plants/ha) | Stem length (mm/plant) |
|---|---|
| 197 528 | 122.36[a#] |
| 98 764 | 121.32[a] |
| 49 384 | 118.28[b] |
| 24 692 | 102.06[c] |
| 12 346 | 122.44[a] |
| P value | <.001 |
| SED | 2.828 |
| $LSD_{0.05}$ | 5.544 |
| Significance | *** |

# Means followed by the same letter are not significant at P ≤ 0.05; ***Significant at p<0.001; SED Standard errors of differences between means; LSD0.05 Least significant differences of means (5% level).

these means were significantly different (p<0.05) from the other treatment means.

### Effect of population density on stem-length and stem diameter

Population density reduced the stem diameters at high populations while increasing them at low densities (Tables 4 and 5). The results obtained indicated significant differences (p<0.05) among the plant population densities for both stem-length and stem diameter. The treatment with the highest mean for stem diameter (5.234 mm/plant) was the lowest plant population density (12 346 plants $ha^{-1}$), and this was significantly different (p<0.05) from the rest of the other treatment means.

Conversely the stem-length increased at high density treatments (Table 5). The third largest population (49 384 plants/hectare) produced the highest (p<0.05) stem length of 118 mm.

## DISCUSSION

Since an increase in the plant population density gave an increase in the biomass produced for both below ground (root) and above ground plant organs and low plant densities produced low root biomass, this suggests that the plants in low densities had adequate growth resources (moisture and nutrients), and roots did not have to expand in search of these resources. Studies done on other multi-purpose trees indicate that increases in plant population density results in an increase in the growth of the plants with resources being utilized when roots and stems entangle and when each plant competes with its neighbour (Squire, 1990). In production systems were suitable plant densities are used, the plants efficiently utilize soil and environmental conditions, and the inter-or-intra-specific competition is reduced (Sadeghi et al., 2009). Further studies Sadeghi et al. (2009) have indicated that the number of plants in a given unit area significantly influence yield of a given crop where closer row spacing resulted in increased yields/plant.

Furthermore, high root biomass produced at high plant densities suggest the development of a deep, extensive rooting system Squire (1990), capable of penetrating deeper into the soil profile thus improving soil nutrient absorption and the possibility of reaching deep soil moisture. An extensively developed rooting system results in plants which are more capable of withstanding adverse environmental conditions (dry spells, fluctuating water availability) and better able to anchor firmly into the soil. High plant biomass production implies more foliage which in turn improves radiation capture hence increased plant yields. Studies Sadeghi et al. (2009) have revealed that there exists a positive correlation between above ground biomass and seed yield, an increase in above ground biomass resulted in an increase in seed yield. However only under optimum plant density do plants show efficiency in utilization of available water, light and nutrients, once the plant density is too high competition between plants occurs, which interferes with economic productivity of the plants (Sadeghi et al., 2009). These same studies Sadeghi et al. (2009) indicated increased biomass trend patterns as the plant density increased. Other studies Damtew et al. (2011) have indicated an increase in the leaf area index (LAI) with increase in plant population density, this is attributed to the occurrence of a greater number of plants/unit area. This increased LAI then implies an increased rate of capture of photosyntheticaly active radiation (PAR) as more leaves are exposed to sunlight radiation, thus increasing photosynthesis. Other studies Mih et al. (2008) are also indicative of higher growth rates, coupled with higher

LAIs of plants at high plant density compared to low plant density. These studies Mih et al. (2008) further concluded that plant density and spacing greatly influences growth and yield of plants, with high competition occurring between plants when intra-row spacing is low, showing etiolating, which further supports findings in this study were the stem lengths were longer, with thinner stem diameters in the high plant density in comparison to the low plant density.

Therefore, the most ideal density for improved initial seedling establishment are the high plant population densities per hectare which encourage robust, deep and extensive root development. Since the study showed that lowest plant populations produced the highest stem diameters, the implications are that, if the aim is specifically seed and firewood production, then low populations are most ideal as they result in faster and greater individual plant growth with larger stem diameters, and consequently higher seed yields. This attribute is supported by studies Patidar et al. (2011) which indicated that individual plant growth is greatly influenced by the environmental conditions in which it grows as these affect its physiology and the radiant flux capture (light). This is a major variable that is unique in the way it interacts and reacts to various environments, which factors in turn determine the intensity, color, duration and direction of interception achieved by each individual plant (Patidar et al., 2011). Thus these studies revealed that the different row spacing and nitrogen combinations affected the protein and nitrogen contents of each individual plant, with maximum contents of nitrogen, protein, phosphorus and potassium being observed in the wider spacing Patidar et al. (2011)] which is indicative of lower plant density/unit area. These findings are supportive of the observed increased individual plant growth due to the presence of adequate amounts of plant nutrients for plant uptake triggering rapid cell expansion and growth resulting in greater individual plant growth. The other observation of longer stem heights in the higher plant population is supported by other studies Damtew et al. (2011) which recorded the highest plant height in the highest plant population (49 383 plants$^{-ha}$) compared to the lower plant population [6,944 plants$^{-ha}$] which recorded the lowest stem height.

## Conclusion

Population density influences Moringa growth and biomass accumulation. High plant densities produce higher plant biomass yields and longer stems, but smaller stem diameters. Conversely, lower plant densities produce lower plant biomass yield per given area, but produce higher individual plant growth as indicated by the thicker stem diameters produced. The other conclusion was that, high plant densities or plant populations resulted in an increase in root biomass.

## REFERENCES


Atta-Krah AN, Sumberg JE (1987). Studies with Gliricidia *sepium* for crop/livestock production systems in West Africa. In: Withington, D., Glover, N and Brewbaker, J. L (Eds), *Gliricidia sepium (*Jacq) Walp :) *Management and improvement.* Proceedings of a workshop at CATIE, Turriable, Costa Rica. NFTA Special Publication 87-01, pp. 31-43.

Damtew Z, Tesfaye B, Bisrat D (2011). Leaf, Essential Oil and Artemisinin Yield of Artemisia (*Artemisia annuna* L.) As Influenced by Harvesting Age and Plant Population Density. World Journal of Agricultural Sciences 7(4): 404 -412, 2011. ISSN 1817-3047. IDOSI Publications, 2011.

Dash S, Gupta N (2009). Effect of Inorganic, Organic and Biofertilizer on Growth of Hybrid *Moringa oleifera* (PKM 1). Acad. J. Plant Sci., 2(3): 220-221. ISSN 1995-8986. IDOSI Publications, 2009.

Dutt AK, Pathania U (1986). Effect of different spacing on growth and wood production in *S. sesban. Nitrogen Fixing Tree Research Reports* 4: 13.6. Ella, A., Jacobsen, C., Stur, and Blair, G. 1989. Effect of plant density and cutting frequency on the productivity of four tree legumes. Tropical Grasslands, 23: 28-34.

Gutteridge RC, MacArthur S (1998). Productivity of *Gliricidia sepium* in sub- tropical environment. Tropical Agric., 65: 275-276.

Ivory DA (1990). Major characteristics, agronomic features and nutritional value of shrubs and tree fodders. In: Devendra, C. (Ed). *Shrubs and Tree Fodders for Farm Animals.* Proceedings of a workshop in Denspasar, Indonesia, 24-29 July 1989, pp. 22-38.

Mahn LH, Dung NNX, Ngoi PT (2005). Introduction and evaluation of *Moringa oleifera* for biomass production and as feed for goats in the Mekong Delta. Cantho University Cantho, Vietnam.

Mih M, Acha AN, Nebane CLN (2008). Growth and Productivity of *Vernonia hymenolipis*. A. Rich. Under different Plant Densities and Spacing Configurations. World J. Agric. Sci., 4(2): 178 -182. ISSN 1817-3047. IDOSI Publications, 2008.

Mishra VK, Sharma A, Verma KS (1992). In: Leucaena Res Rpts - p. 34.

Patel JP, Bharat G, Patel K (2010). Evaluation of *invitro* Schizonticidal Properties of Acetone Extract of some Indian Medicinal Plants. Advances in Biological Research 4 (5): 253-258, 2010. ISSN 1992-0067. IDOSI Publications.

Patidar S, Gontia AS, Upadhyay A, Nayak PS (2011). Biochemical Constituents in Kalmegh (*Andrographis paniculata* Nees.) Under Various Row Spacing's and Nitrogen Levels. World Appl. Sci. J., 15(8): 1095-1099, 2011. ISSN 1818-4952. IDOSI Publications.

Sadeghi S, Rahnavard A, Ashraf ZY (2009). Study Importance of Sowing Date and Plant Density Affect on Black Cumin (*Cuminum carvi*) Yield. Botany Res. Int., 2(2): 94-98. ISSN 1995-8951. IDOSI Publications, 2009.

Sereshine T, Marapana RAUJ (2011). Goat Farming Systems in the Southern Province of Sri Lanka: Feeding and Management Strategies. World J. Agric. Sci. 7(4): 383-390, 2011. ISSN 1817-3047. IDOSI Publications, 2011.

Singh PK, Kumar V, Tiwari RK, Sharma A, Rao CV, Singh RH (2010). Medico-Ethnobotany of Chatara' Block of District Sonebhadara, Uttar Pradesh, India. Advances Biol. Res., 4(1): 65-80. ISSN 1992-0067. IDOSI Publications.

Squire GR (1990). The Physiology of Tropical Crop Production. CAB International Wallingford, UK.

Sriskandarajah N (1987). Forage yield from *Gliricidia sepium* in Papua New Guinea. Nitrogen Fixing Tree Res. Reports, 5: 49-50.

Wong CC, Sharudin MAM (1986). Forage Productivity of three forage shrubs in Malaysia. MARDI Res. Bulletin, 14: 178-188.

Yarahmadi M, Hossieni M, Bina B, Mahmoudian MH, Naimabadie A, Shahsavani A (2009). Application of Moringa Oleifera Seed Extract and Polyaluminum Chloride in Water Treatment. World Appl. Sci. J., 7(8): 962-967, 2009. ISSN 1818-4952. IDOSI Publications.

Zsuffa (1984). In: Forage tree legumes in tropical agriculture, Gutteridge and Shelton (Eds).1994. CAB International.UK.