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Effect of Plant Spacing on Growth and Leaf Biomass Production of *Moringa stenopetala* bac in Arba Minch Zuriya woreda, Southern Ethiopia

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Abstract

Moringa stenopetala is indigenous multipurpose tree to Southern Ethiopia grown as a backyard crop and park land agroforestry for various uses. To meet the growing demands of the tree leaf biomass as a vegetable, growers need to increase their production by adopting improved management techniques. This study was initiated to determine the optimum spacing required for improved growth and higher biomass production. Six planting spacing treatments (0.5 m*0.5 m, 1 m*1 m, 1 m*1.5 m, 2 m*2 m, 2 m*2.5 m and 3 m*3 m) were used in randomized complete block design with three replications. Data was collected on survival, root collar diameter, plant height, and branch number, and crown width, diameter at breast height and leaf biomass. All studied parameters showed significant differences (P<0.05) among treatments. Narrower spacing revealed significantly lower survival and higher plant height. The wider spacing produced significantly higher (P<0.05) root collar diameter, crown width, diameter at breast height and branch number per plant than plants of the closer spacing. Similarly, highest fresh leaf yield was recorded in wider spacing per plant. Besides the estimation of fresh leaf biomass collection per tree, the estimation was also done at hectare level. Accordingly the highest and lowest fresh leaf biomass was recorded on 2 m × 2 m spacing (3110 kg ha^{-1}) and 3 m × 3 m spacing (1800 kg ha^{-1}) respectively. Thus, 2 m × 2 m was proved to be optimum with desired number of stems per hectare to product the highest leaf and branch biomass.

Keywords: Fresh leaf biomass; Growth parameters; Spacing; Wood biomass

Introduction

Moringa (*Moringa stenopetala*, Bac.) belonging to the family *Moringaceae* is a softwood Multipurpose Tree (MPT), that grows throughout the tropics with significant economic importance, as it has vital nutritional, industrial, and medicinal applications **[1]**. *Moringa stenopetala* was domesticated in the East African lowlands and is indigenous to Southern Ethiopia. The cultivation of *Moringa stenopetala* in Ethiopia occurs mainly as a backyard crop and park land agroforestry in the zones and special districts such as Konso, Gamo, Gofa, Derashe, South Omo, Kaffa, Sheka, Bench Maji, Wolaita, Dawaro, Bale, Borena, Sidama, Burji and Amaro **[2]**. Its cultivation is suitable in well-drained soils at altitudes of 900 m-1200 m. The species is quite drought resistant. In southern Ethiopia, it has been found in areas of mean annual rainfalls ranging from 500 mm-1400 mm. The potential growing area fall in a rainfall range from 300 mm-1400 mm per year with soil reaction of 6-7. Cold temperatures are limiting factors for the cultivation of the species in Ethiopia because it does not tolerate frost.

In Southern Ethiopia it has been grown for various uses particularly important as human food because the leaves, which have high nutritional value **[3,4]**, appear towards the end of the dry season when few other sources of green vegetables are available. The leaves contain high amounts of essential aminoacids and vitamins A and C. Because of its multiple uses and ease of propagation and ability to perform well under harsh environments, its acreage as a cultivated crop is on the increase, as is the demand for its products **[5]**. *Moringa* has attracted enormous attention of ethnobotanists and plant genetic resource conservationists due to its widespread use in agriculture and medicine. The genus *Moringa* consists of 13 species **[1]** of which only *Moringa oleifera* has been accorded research and development attention.

Farmers in Southern Ethiopia have been managing the plant traditionally but could not adequately address the ever increasing demand of *Moringa* products as they only integrate the tree in agricultural landscapes being as a tree. Improving the productivity of the tree through intensive management could be an appropriate option to meet market demands. Therefore, evaluation and demonstration of different improved management practices could be crucial to enhance the productivity of the plant. Hence, this study was initiated to determine the optimum spacing required for improved production of *Moringa stenopetala*.

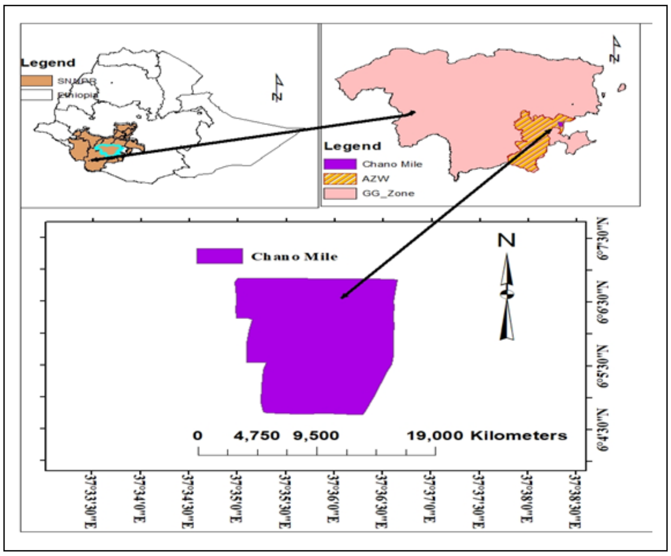

Figure 1: Some other soil physcio-chemical characteristics of the study site and the ratings.

Materials and Methods

Location and climate of experimental site

The study was conducted at Chano Mille substation from 1st October 2016 to 30th September 2019. The study site is found in Arba Minch zuria District of Gamo zone, Southern Ethiopia. The study area is geographically located at 6°5′30″ N, 37°35′0″ E with an altitudinal range of 1200 m above sea level. Meteorological records reveal that rainfall pattern in Arba Minch Zuria is bimodal with mean annual rainfall ranges between 1100 mm - 1600 mm, whereas the minimum and maximum air temperature varying between 17 and 35°C. The soil of the study site is characterized by clay loam texture and landscape of gentle slope. Some other soil physcio-chemical characteristics of the study site and the ratings are presented in the Table 1. The rating was done with the help of publication by **[6]** **(Figure 1)** **(Table 1)**.

Soil parameters	Mean values ± SD	Rating
pH	7.31 ± 0.13	Neutral
Available phosphorus (ppm)	21.9 ± 8.66	Medium
Organic carbon (%)	1.57 ± 0.05	Medium
Total nitrogen (%)	0.22 ± 0.02	Medium
Bulk density (gm/cm3)	1.32 ± 0.01	-
Particle density (gm/cm3)	2.15 ± 0.16	-

Table 1: Some soil characteristics of the study site; SD: Standard Deviation.

Land preparation, seed sowing and seedling transplanting

The land had previously been cropped with *Cassava* (*Manihot esculenta*). A total land area of 55 m × 33 m was used for the study. This was sub-divided into three blocks (Blocks I, II and III) from which soil samples were taken at one depths (0 cm -40 cm) for analysis of nutrient levels. The field was ploughed, harrowed and leveled. Seeds of *Moringa* were collected from Arba Minch area and raised at Arba Minch University nursery site by polythene tubes. Seeds were germinated within ten (10) days of sowing and the seedlings were transplanted after 60 days of nursery life and planted in September 2017 using the same number of seedling (20). The six (6) treatments were randomly distributed in each of the three blocksand plots were separated from each other by 3 meter walkways with a boarder of 0.50 cm × 0.50 cm created around the treatment plots. During the course of the study, the plots were well maintained by weeding and watering when required and application of compost after the first two months of growth at a rate of 1.5 tons per hectare to arrest declining yields.

Study Design and Setting

The design of the experiment was Randomized Complete Block Design (RCBD) with three replications. Six planting arrangements were considered as experimental treatments: (1) 0.5 m × 0.5 m, (2) 1 m × 1 m, (3) 1 m × 1.5 m, (4) 2 m × 2 m, (5) 2 m × 2.5 m and (6) 3 m × 3 m. The following data: Survival, Root Collar Diameter (RCD), Plant Height (HT), Branch Number (BN), Crown Width (CW), Diameter at Breast Height (DBH), fresh leaf biomass (FLB) and fresh wood biomass (FWB) were collected at ages of 6, 12, 18, 24 ,30 and 36 months after planting from six inner trees. The fresh weight of shoots harvested per plot was taken and weighted. The leaf was dried under shade and dry weight of each sample per plot was recorded using sensitive balance.

Data Collection

Six (6) inner row plants were selected and marked for all agronomic parameters from each plot. The fresh and dry weight of shoots harvested per plot was determined using a weighing scale in the field. The dry weight of each sample was then recorded using an electric beam balance after shade drying of the samples. The height of the trees was measured by using measuring tape. Caliper was used to measure Diameter at Breast Height (DBH) and Root Collar Diameter (RCD). Data on Survival Rate (SR) and Branch Number (BN) was taken by counting the number of trees per plot and the number branches per tree respectively.

Data Analysis

Analysis of Variance (ANOVA) was employed to analyze all response variables and means were separated by Duncan's Multiple Range Test (DMRT) at 5% probability level.

Results and Discussion

Survival rate and growth performance

Growth performance in terms of tree Survival Rate (SR), Plant Height (PH), Root Collar Diameter (RCD), Diameter at Breast Height (DBH), Crown Width (CW) and Branch Number (BN) for different spacing treatments planted at Chano mile site is presented in Table 2. The mean Plant Height (PH) showed significant differences (P<0.05). The plant spacing (1 m × 1 m) gave the highest plant height (3.13 m) followed by the plant spacing 0.5 m × 0.5 m (2.78 m) while the wider spacing (3 m × 3 m) demonstrated the lowest plant height. According to Lyons (1968) increasing plant density accelerates the rate of plant growth hence the increased heights in closer spacing.

The Survival Rate (SR) of the trees in each of the treatments showed significant difference (P<0.05). Three wider spacing treatments; 3 m × 3 m, 2 m × 2.5 m and 2 m × 2 m recorded significantly higher rate of survival (99.44%, 97.78% and 98.33%) respectively than the rest three narrower treatments **(Table 2)**. At narrower spacing, the competition for essential growth factors like water, nutrients and sunlight was so intense that, in some of the inner row plants, lower branches and leaves died, which could result in lower survival rate. The effect of increasing competition is similar to decreasing the concentration of growth factors **[7]**. It was also observed that a large number of plants died during the period between December 2017 and March 2018. This period also coincided with the dry season where the plants were monitored monthly. This decline may be attributed to the decrease in growth factors and the increased competition between individual plants leading to the death of many plants from the closest spacing relative to the other treatments. It also indicates that very good field management (watering and fertilization) is necessary in order to provide the optimum level of nutrients needed to reduce competition among the individual plants. This will then greatly reduce the death of plants and ensure sustainability in the long run.

Treatment	SR (%)	FLB (gm)	DLW (gm)	RCD	DBH (cm)	Ht (m)	CW (m)	BN	FWB (Kg)
0.5 m x 0.5 m	44.11d	173.0b	52.4b	4.02c	1.78d	2.78ab	0.68c	3.11c	1.34d
1 m x 1 m	59.00c	515.9b	158.1b	6.54b	2.63bcd	3.13a	1.18 b	7.66c	5.58cd
1 mx 1.5 m	86.11b	538.9b	144.4b	5.99b	2.352cd	2.58bc	1.19b	6.31c	3.22d
2 m x 2 m	98.33a	1270.0a	372a	9.09a	3.64a	2.31bcd	1.91a	15.10b	15.92ab
2 m x 2.5 m	97.78a	1222.0a	336.1a	8.24a	3.06abc	2.24cd	1.90 a	16.38b	11.47bc
3 m x 3 m	99.44a	1640.1a	429a	8.87a	3.42ab	2.06d	2.02 a	24.72a	18.78a
LSD (5%)	3.85	561.8	140.4	1	0.88	0.49	0.27	6.4	6.3
CV (%)	4.6	38.7	58.9	14.7	32.7	20.5	18.2	28.9	36.6

Table 2: Effect of spacing on leaf production and growth of *M. stenopetala* in Arba Minch Zuria (Chano Mille), Southern Ethiopia. SR: Survival Rate; FLB: Fresh Leaf Biomass; DLW: Dry Leaf Biomass; RCD: Root Collar Diameter; DBH: Diameter at Breast Height; BN: Number of Branch; HT: Height of Tree; CW: Width of Tree Crown; FWB: Fresh Wood Biomass; LSD: Least Significant Difference and CV: Coefficient of Variation. Means showing different letters are significantly different in a column at a 5% probability level.

There was significant statistical difference in crown width (P<0.05). The observed data showed that the wider spacing (3 m × 3 m, 2 m × 2.5 m and 2 m × 2 m) gave the highest (2.02 m, 1.90 m and 1.91 m) crown width respectively than the closer spacing. On the other hand the closer spacing (0.5 m × 0.5 m, 1 m × 1 m and 1 m × 1.5 m) recorded significantly lower (0.68 m, 1.18 m and 1.19 m) crown width respectively. Diameter at Breast Height (DBH) of the treatments was significantly varied among treatments (P<0.05).The 2 m × 2 m spacing recoded significantly higher DBH (3.64 cm) than 0.5 m × 0.5 m (1.78 cm), 1 m × 1 m

(2.63 cm) and 1 m × 1.5 m (2.35 cm) spacing. The wider spacing (3 m × 3 m) recorded highest branch number (24.72) followed by 2 m × 2.5 m (16.38) and 2 m × 2 m (15.10). The wider spacing produced higher Root Collar Diameter (RCD) per plant and this was significantly different (P<0.05) than plants of the closer spacing throughout the study period. Plant spacing of 2 m × 2 m, 3 m × 3 m and 2 m × 2.5 m recoded higher RCD (9.09 cm, 8.87 cm and 8.24 cm) respectively **(Table 2)**.

Significantly higher growth parameters observed in terms of Root Collar Diameter (RCD), Diameter at Breast Height (DBH), Crown Width (CW) and Branch Number (BN) at wider spacing could be due low competition of growth factors. Janick reported that increasing competition is similar to decreasing the concentration of growth factors. This explains why the widely spaced plants showed the thickest stems and the closely spaced plants the smallest stems **[7]**.

Fresh and dry leaf biomass

The statistical test indicated in the above table that there was significant difference (p ≤ 0.05) in fresh leaf biomass among treatments, with a highest mean value recorded in wider spacing. Treatment spacing 3 m × 3 m , 2 m × 2.5 m and 2 m × 2 m was significantly higher (1640.1 gm, 1222 gm and 1270 gm per tree respectively) than the rest three closer spacing. There are however studies that have not shown spacing effects on biomass of *Moringa* . On the other hand, reports by Norman and **[8]** 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. Yield per plant decreases as total biomass production per unit area increases with increased planting density.

Similarly, the fresh wood biomass was significantly higher in wider spacing than closer spacing (p ≤ 0.05). Accordingly, treatment 3 m × 3 m and 2 m × 2 m recorded significantly higher mean value (18.78 kg and 15.92 kg per tree respectively) than treatment 1 m × 1.5 m (3.22 kg), 1 m × 1 m (5.58 kg) and 0.5 m × 0.5 m (1.34 kg). This fresh wood biomass was collected during pollarding trees at 1.5 m height above ground at age of 24 months of planting which was aimed to increase leaf biomass harvested per tree.

Fresh leaf biomass production by age and hectare

The trend of leaf biomass collected revealed that as age of tree and spacing increases the fresh leaf biomass was increased and vice versa. That means there were no significant increments on fresh leaf biomass collected on treatments of closer spacing **(Figure 2)**. Besides the estimation of fresh leaf biomass collection per tree, the estimation was also done at hectare level. Accordingly the highest and lowest fresh leaf biomass was recorded on 2 m × 2 m spacing (3110 kg^{-1}) and 3 m × 3 m spacing (1800 kg^{-1}) respectively **(Figure 3)**.

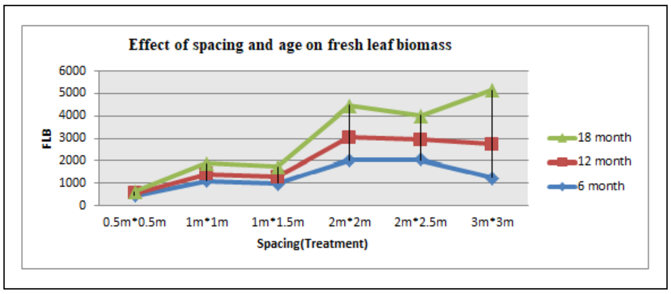

Figure 2: The trend of fresh leaf biomass collected through age.

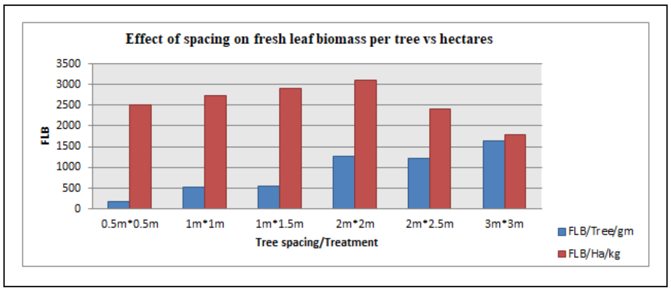

Figure 3: Fresh Leaf Biomass (FLB) production. FLB/tree/gm= Fresh Leaf Biomass (in gram) per tree, FLB/ha/kg= Fresh Leaf Biomass in Kilogram per hectare.

Conclusion and Recommendation

The results of the study showed that spacing had a detrimental effect on the growth and leaf yield of *Moringa stenopetala* significantly. A pronounced effect was observed on leaf production as well as on survival rate, plant height, root collar diameter, diameter at breast height branch number. The optimum plant spacing which resulted higher leaf production per hectare was found to be 2 m × 2 m followed by 1 m × 1.5 m. Therefore, farmers in the study area could adopt 2 m × 2 m planting arrangement for improved production of *Moringa stenopetala*. Since the period of this study was short, further progeny should be undertaken for a longer period to obtain definitive recommendations on spacing.

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