The growth and yield of *Moringa oleifera* Lam. as affected by plant spacing and cutting interval

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**Abstract.** *Moringa* (*Moringa oleifera* Lam.) is a multipurpose plant with high nutritional composition and for its use in bioactive compounds. A field study was carried out to investigate the the growth and of *Moringa* as affected by different plant spacing and cutting interval. The study was carried out in research field of the Laboratory of Ecology and Plant Production, Agriculture Department, Faculty of Animal and Agricultural Sciences Diponegoro University, Semarang. A split-plot experimental design was set up with plant spacing as main plot factor and cutting interval as sub plot factor. The *Moringa* plants were observed at three plant spacings: 50 cm x 10 cm; 40 cm x 12.5 cm; and 20 cm x 25 cm, and cutting intervals (60 and 90 day after planting (dap), with three times replications. Parameters evaluated were plant height, stem diameter, fresh matter yield and dry matter yield. Separately, plant spacing and cutting interval significantly affected the plant height, stem diameter, fresh matter yield and dry matter yield. There were no interaction result between those two treatments on parameters observed. In conclusion, for gaining maximum growth and yield production, *moringa* should be established as food and fodder purpose at plant spacing of (20 cm × 25 cm) with optimum cutting interval of 90 dap.

1. **Introduction**

*Moringa* (*Moringa oleifera* Lam.) is commonly known as fast growing agricultural plants with high nutritional composition and for its use in bioactive compounds [1] [2] [3]. It grows in many tropical and subtropical regions. In addition, it tolerant to adverse environmental and climatic conditions where many agricultural crops would not survive [4]. Nouman et al. [5] reported that *moringa* can be grown under adverse environmental conditions in hot, humid, and dry tropical and subtropical regions. An exception is areas that experience waterlogging. Interestingly, the plant can produce substantial nutritional quality even under marginal conditions.

The main advantages of *Moringa* include human nutrition (leaves, seeds, flowers), alley cropping (biomass production for biodiesel and fertilising), animal forage (leaves and treated seepod-cake), biogas (from leaves), domestic cleaning agent (crushed leaves), blue dye (wood), fencing (living trees), fertiliser (seed-cake), foliar nutrient (juice expressed from the leaves), green manure (from leaves) [6] [7] [8]. Due to its enormous uses and function, it potential to be developed. Several agronomic practices may effects on overall growth and yield of *Moringa*, such as cultivar selection, plant spacing, cutting interval, fertilizer management, and timely irrigation.

Optimum management practices for *Moringa* are not clear. Plant spacing management has a direct effect on available light and nutrition, plant population, and canopy development, which ultimately affects weed growth, photosynthetic capacity, growth and dry matter yield [9] [10] [11]. Plant spacing affect the plant density. Higher plant density limits individual plant growth while lower plant density is the wastage of resources therefore, optimum plant density is important for achieving higher yield.
per unit area [12]. There are few studies on the effects of plant spacing on moringa production. Adegun et al. [13] obtained highest fodder yields of moringa from plants spaced at 30x40 cm compared to higher spacing in south-western Nigeria.

Another agronomic practices for increasing plant growth and yield is cutting interval management. Several plants performed maximum growth due to the cutting management. Precise cutting management is essential for high production, quality of forage species [15] [16]. Cutting interval also triggering the continuous regrowth of Moringa. In other hand, high cutting frequency reduces growth and development, whereas long intervals between harvests lead to accumulation of fiber and reduction in quality [16].

The maximum growth and yield as affected by several kind of plant spacing and cutting interval and its interaction effect on Moringa are unknown. Therefore, taking all these aspects in consideration, the present study was conducted to evaluate the growth of *Moringa oleifera* Lam. as affected by plant spacing and cutting interval

2. Materials and Methods
A field study was conducted at the experiment field (Lat. 110°16'20"- 110°30'29"N and Long. 6°55'34" - 7°07'04" E, altitude approximately 125 m above mean sea level) and laboratory of plant ecology and production, agriculture department, faculty of animal and agriculture sciences, Diponegoro university. Daily agroclimate parameters were recorded by automatically weather system (AWS) located nearby the field area. The average annual rainfall varies from 450 mm to 500 mm. The mean daily maximum and minimum temperatures during the growing season of Moringa are ranged between 29.8 to 37.9°C and 15.6 to 26.7°C, respectively. Similarly, mean daily relative humidity ranged between 46 to 92%.

2.1 Research materials
The materials used in the experiments were 30 days after sowing (DAS)-moringa seedlings and cow manure. The tools used were hoes, digital scales, and oven.

2.2 Crop establishment and experimental design
Moringa seedlings were planted in the 700 m² field. The experiment field were divided into 27 plots, each plot is 3 x 2 m in size with 2 m in space between each plot. Three level of plant spacings (50 cm x 10 cm; 40 cm x 12.5 cm; and 20 cm x 25 cm) and and cutting intervals (30 dap, 60 dap, and 90 dap) were arranged during experiment as plant treatments with three times replications. The cutting height was 15 cm above the ground surface. The experimental design used in this study was split plot; with the plant spacings as main plot and cutting intervals as sub plot.

2.3 Observed parameters and statistical analysis
Parameters evaluated were plant height, stem diameter, fresh matter yield and dry matter yield. The plant height and stem diameter were observed at 90 dap, while fresh matter yield and dry matter yield data were recorded at 90 dap. The data obtained were processed by using SAS program according to variance analysis to show the effects of treatment on the observed parameters and continued with Duncan's Multiple Area Test to see differences between treatments [17].

3. Results and Discussion
3.1 Plant growth responses as affected by plant spacing and cutting interval management
3.1.1 Stem diameter. Various plant spacing and cutting interval separately, showed significant effect on stem diameter of Moringa. However, the interaction between those treatment had not significant effect on it. Appropriate plant spacing and cutting interval management significantly improved the stem diameter. Among plant spacing arrangement, 20 x 25 cm spacing generated the largest stem diameter. While, differential responses of stem diameter also generated by various cutting interval management. The largest stem diameter was performed by cutting the aerial part of moringa at 90 dap (Table 1). Similar report showed that plant spacing related with population density reduced the stem diameters at high populations while increasing them at low densities [18].
Table 1. Stem diameter of Moringa plants at 90 dap due to plant spacing and cutting interval

| Plant spacings | Cutting intervals (DAP) | 30 | 60 | 90 | Mean |
|----------------|-------------------------|----|----|----|------|
| 50 x 10 cm     | 2.1                     | 2.52 | 2.73 | 2.45<sup>b</sup> |
| 40 x 12.5 cm   | 2.46                    | 2.2  | 2.58 | 2.39<sup>b</sup> |
| 20 x 25 cm     | 2.8                     | 3.1  | 3.17 | 3.02<sup>a</sup> |
| Mean           | 2.45<sup>c</sup>        | 2.61<sup>bc</sup> | 2.82<sup>a</sup> |

* Mean values followed by same letter within column did not differ significantly according to Duncan’s multiple range tests (P < 0.05).

Stem diameter variation is composed of two parts: one is due to the growth of cambium and living bark cells in terms of cell division and enlargement; the other is driven by the water potential gradient of plant [19]. Plant spacing and cutting management effects the stem diameter may due to those treatment related with the growth regulation of cambium. Proper light, nutrition, and water resources might provided by appropriate plant spacing. In other hand, plant cutting might related with the sink-source interaction. Longest interval of cutting generated largest stem diameter in Moringa plants.

3.1.2 Plant height. Plant height is an important factor which helps in the determination of growth. Several kind of plant spacing arrangement and cutting interval significantly effect the Moringa plant height. Interaction between those two factor had no significant on plant height. The highest plant hight was performed by arranging plant spacing 50 x 10 cm, however this result were not significant different with those 20 x 25 cm spacing. Separately, among cutting interval treatment, cutting the aerial part of Moringa at 30 dap performed the highest plant height (Table 2).

Table 2. Plant height of Moringa plants at 90 dap due to plant spacing and cutting interval

| Plant spacings | Cutting intervals (DAP) | 30 | 60 | 90 | Mean |
|----------------|-------------------------|----|----|----|------|
| 50 x 10 cm     | 98.5                    | 97  | 90.2 | 95.2<sup>a</sup> |
| 40 x 12.5 cm   | 102                     | 94.4 | 87.8 | 94.7<sup>b</sup> |
| 20 x 25 cm     | 97.5                    | 96.1 | 91.6 | 95.1<sup>a</sup> |
| Mean           | 99.3<sup>a</sup>        | 95.8<sup>b</sup> | 89.9<sup>c</sup> |

* Mean values followed by same letter within column did not differ significantly according to Duncan’s multiple range tests (P < 0.05).

Previous report on maize plants indicated that the effect of plant population and spacing on plant height was significant [20] [21]. The plants become taller as the plant density increased [20]. In production systems which plant densities are used, the plants efficiently used and adapted with soil and various environmental conditions, and the inter-or-intra-specific competition is reduced [22]. 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 [23].

3.2 Fresh and dry matter yield as affected by plant spacing and cutting interval management

Various plant spacing arrangements and cutting interval management significantly effects the fresh matter yield of Moringa plant. However there was no interaction between those two treatment on fresh matter yield parameter. Under 20 x 25 cm plant spacing. Moringa plants produce the highest fresh matter yield as high as 59.2 g plant<sup>-1</sup>. While, by cutting plants at 90 dap generated the highest fresh matter yield as high as 62.07 g plant<sup>-1</sup> (Table 3).
Table 3. Fresh matter yield accumulation of Moringa plants at 90 dap due to plant spacing and cutting interval

| Plant spacings | Cutting intervals (DAP) | Mean       |
|----------------|-------------------------|------------|
|                | 30                      | 60         | 90         |
| 50 x 10 cm     | 53.3                    | 57.5       | 62.7       | 57.8b       |
| 40 x 12.5 cm   | 57.1                    | 56         | 60.5       | 57.9b       |
| 20 x 25 cm     | 58.4                    | 56.2       | 63         | 59.2a       |
| Mean           | 56.3b                   | 56.6b      | 62.1a      |             |

* Mean values followed by same letter within column did not differ significantly according to Duncan’s multiple range tests (P < 0.05).

Table 4. Dry matter yield accumulation of Moringa plants at 90 dap due to plant spacing and cutting interval

| Plant spacings | Cutting intervals (DAP) | Mean       |
|----------------|-------------------------|------------|
|                | 30                      | 60         | 90         |
| 50 x 10 cm     | 24                      | 25.8       | 27.7       | 25.8b       |
| 40 x 12.5 cm   | 25.1                    | 23.6       | 27.2       | 25.3b       |
| 20 x 25 cm     | 26.7                    | 24         | 28.6       | 26.4a       |
| Mean           | 25.3b                   | 24.5b      | 27.8a      |             |

* Mean values followed by same letter within column did not differ significantly according to Duncan’s multiple range tests (P < 0.05).

Different plant spacing arrangement and cutting interval had significant effect on dry matter yield of Moringa plant. Interaction between those two treatment had no significant on dry matter parameter. Under 20 x 25 cm plant spacing, Moringa plants produce the highest dry matter yield as high as 26.43 g plant\(^{-1}\). While, by cutting plants at 90 dap generated the highest dry matter yield as high as 27.83 g plant\(^{-1}\) (Table 4).

Plant spacing contributed to the light, water and nutrition uptake. Moreover, it directly effects on shoots, roots and canopy development, which ultimately affects photosynthetic capacity, growth, fresh and dry matter yield. A high planting density was effective on yield if the inter-row spacing was narrow. When the planting density is increased, the single plant yield potential is reduced. The lower single plant yield potential is balanced by the higher plant population [24] [25]. The number of plants in a given unit area significantly influence yield of a given crop where closer row spacing resulted in increased growth and yields/plant. 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 [22].

Improvement of fresh dry matter also generated by cutting treatment. Similar result performed by Gadzirayi et al., cutting interval lead the continuous shoots re-growth [26]. It may due to the regulation of auxin and cytokinin ratio. Another finding revealed that the appropriate cutting management stimulated shoot growing and canopy size in Guava plant [27]. Planting density and frequency of cutting have been identified as critical management practices that affect biomass yield and growth quality [28] [29] [30].

4. Conclusion
It was concluded that various plant spacings arrangement and cutting interval management affected the growth and yield of Moringa plants. Under 20 x 25 cm plant spacing and 90 dap cutting interval, showed the highest stem diameter, fresh and dry matter yield. Hence, might be used as recomendation of agronomic techniques in Moringa.
Acknowledgement
This research was financially supported by a research grant from The Diponegoro University DIPA (SK Dean FPP UNDIP No 43/UN7.5.5/PP/2019). The authors are thankful to Dean of Animal and Agricultural Sciences Faculty for the research facility.

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