High yield in moringa for lowland areas was obtained from the Bogor accession

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Abstract. Moringa (Moringa oleifera Lam.) is one of the non-wood forest products. Every part of the Moringa plant can be used as a source of food, medicines, and feed. The purpose of this study was to obtain information regarding the growth and production of several Moringa accessions from Indonesia with different leaves harvesting intervals. The study was conducted in January-June 2016 at the Experimental Garden Sawah Baru, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Dramaga. Experiments were arranged in a Randomized Complete Block Design (RCBD) split-plot with 3 replications. The main plot was the accession with 7 different accessions and the subplot was harvesting interval with two levels, namely 5 and 7 weeks. Accessions used were from Lhokseumawe, Bogor, Solo, Banyuwangi, Tabanan, Central Halmahera, and Palu. Results showed the interaction between Bogor accession of 7-week harvesting intervals had the best ratio of harvested leaflets per harvested leaves. Bogor accession had the best growth and production in the number of leaves and weight of harvested branches. Interval harvesting of 7 weeks delivered the best growth and yields. The use of Bogor accession with 7 weeks harvesting interval is advisable to apply for intensive Moringa cultivation in Bogor or other wet lowlands.

1. Introduction

Moringa (Moringa oleifera Lam.) is one of the non-wood forest products. Every part of the Moringa plant has many benefits for mankind. The young leaves and fruit of the Moringa plant are usually consumed as a vegetable, while the bark and roots are used as herbal medicine. Moringa seed powder can be used as a natural water purifier that is very effective [1,2,3,4].

Moringa leaves contain beneficial compounds include nutrients (calories, protein, carbohydrates, fat, fiber, Ca, Fe, Mg, P, and Zn), vitamins (A, B, B1, B2, B3, C, and E), and essential amino acids (arginine, histidine, lysine, tryptophan, phenylalanine, methionine, threonine, leucine, isoleucine, and valine) [5]. In Southern Africa fresh or dried moringa leaves have been consumed widely to improve the nutritional status and alleviate the problem of malnutrition [6].

Moringa is considered an indigenous vegetable in Indonesia, only some areas such as Nusa Tenggara, Southeast Sulawesi, Central Java, and Bali that the people have been accustomed to consuming moringa [7]. Unfortunately, Indonesian people are not accustomed yet to intensively cultivate the moringa plant, which is only used as a border or shading plant.

Moringa has a high source of diversity based on growth, production, and quality due to differences in the origin of Moringa [8]. Moringa production is also influenced by the cultivation techniques applied. Pruning promotes the growth of Moringa branches [5]. Harvesting intervals affect the production of...
fresh leaves and dry leaves of moringa. The harvesting interval of 40 days produced the highest biomass but the harvesting interval of 35 days produced the highest nutritional and protein content compared to harvesting intervals of 30 and 40 days [9]. Other research concluded harvesting interval of 75 days produced high nutrient content [10]. Interval of 8 weeks of harvesting gave the best results on fresh and dry weight leaves and stems per year, and also optimum chemical composition compared to harvesting intervals of 4 and 6 weeks [11]. Harvesting moringa plants at intervals of 30 days provided optimum yields [12]. However, these studies were not conducted in Indonesia and did not use Indonesian accessions. The lack of research regarding moringa production in Indonesia causes its low production in the country.

To produce fresh leaves as vegetables, the method and timing of harvesting leaves from Moringa plants must be considered to obtain the best quality and quantity of leaves and prevent yield loss. Based on this, it is necessary to study the effect of different harvesting intervals on the growth and production of several accessions of moringa from Indonesia.

2. Materials and Methods

This research was conducted at Sawah Baru experimental field, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University (IPB), Darmaga, Bogor from January to June 2016, with altitude 250 m above sea level. Weighing yield was conducted at Postharvest Laboratory, Department of Agronomy and Horticulture, while soil analysis was conducted at Calibration Laboratory, Department of Agronomy and Horticulture.

The experiment was arranged in a Randomized Complete Block Design (RCBD) split-plot with 3 replications. The main plot was the accession with 7 different accessions and the subplot was harvesting interval with two levels, namely 5 and 7 weeks. Accession used were accession from (Lhokseumawe (Aceh), Bogor (West Java), Solo (Central Java), Banyuwangi (East Java), Tabanan (Bali), Palu (South Sulawesi) and Central Halmahera (North Maluku)).

Moringa seeds were collected from seven different locations in Indonesia. Moringa seeds were sown in the nursery using polybags and planted when seedlings were already 3 weeks old. Soil tillage was done one week before planting. Manure rate of 20 t.ha⁻¹, lime 2 tons.ha⁻¹ were added during tillage. Fertilizer application consist of 521 kg N.ha⁻¹, 44 kg P.ha⁻¹ and 731 kg K.ha⁻¹ [13]. Application of Urea fertilizer (N source fertilizer) was applied 3x i.e. 50% at planting, 25% when the plant was 4 WAT, and 25% was applied shortly after the second harvest, while the SP-36 (P source fertilizer) and KCl (K source fertilizer) were applied directly during planting. Moringa seedlings were planted using 0.5 m x 0.5 m spacing.

Harvesting time started when plant age was 10 weeks after transplant (WAT). This was done because, at 5 WAT, all plants were pruned to trigger the formation of branches. Pruning has been done on the main stem of the moringa plant, at 5 WAT. Moringa pruning was done by cut the moringa mainstem at 20 cm from the base [10]. The harvest was done according to the treatment given, i.e. at intervals of 5 and 7 weeks after pruning by cutting the branches that formed at 5 cm from the base of the branch using scissors. Observations were made on all plant populations planted.

Data were analyzed using ANOVA to determine the effect of each treatment. Significant effects were further tested using DMRT at α=5% [14]. Data that has coefficient of variability >30% were transformed using $(x)^{1/2}$ or $(x + 0.5)^{1/2}$ [15].

3. Results and Discussions

Moringa seedlings that have been transplanted into the field were pruned at 5 weeks after planting, to break apical dominance and induce the formation of lateral shoots which later became branches. Furthermore, each branch of the plant was harvested according to the treatment (at 5 and 7 weeks after pruning), by cutting the branch using scissors and leaving 5 cm long from the base of each branch. Moringa plants will produce more leaves with longer harvesting intervals used [16].
Table 1. Interaction of moringa accessions with harvest interval on number of leaves variable

| Accessions       | Harvest intervals | 1st harvest | 2nd harvest |
|------------------|-------------------|-------------|-------------|
|                  | 5 weeks           | 7 weeks     | 5 weeks     | 7 weeks     |
| Tabanan          | 16.5<sup>bcd</sup> | 14.6<sup>de</sup> | 23.8<sup>bcd</sup> | 25.5<sup>bcd</sup> |
| Bogor            | 25.4<sup>a</sup>  | 17.8<sup>bcd</sup> | 29.4<sup>ab</sup> | 29.4<sup>ab</sup> |
| Banyuwangi       | 14.3<sup>de</sup> | 11.2<sup>e</sup> | 18.6<sup>cd</sup> | 30.0<sup>ab</sup> |
| Lhokseumawe      | 20.6<sup>b</sup>  | 15.3<sup>cde</sup> | 19.8<sup>cd</sup> | 30.7<sup>ab</sup> |
| Central Halmahera| 16.9<sup>bcd</sup> | 18.8<sup>bcd</sup> | 21.8<sup>bcd</sup> | 28.0<sup>bc</sup> |
| Palu             | 15.7<sup>bcd</sup> | 16.7<sup>bcd</sup> | 16.3<sup>d</sup> | 38.2<sup>a</sup> |
| Solo             | 20.1<sup>b</sup>  | 15.3<sup>cde</sup> | 20.0<sup>cd</sup> | 18.7<sup>cd</sup> |

Note: Values followed by the same letter at the same harvest period are not significantly different according to DMRT at α=5%.

Different harvest intervals showed different yields on different moringa accessions. Bogor accession at 5 weeks harvest interval produced the highest number of leaves at first harvest, but at second harvest, Bogor, Banyuwangi, Lhokseumawe and Palu accessions at 7 weeks harvest interval produced the higher number of leaves than other accessions. In the second harvest, the average leaves number that can be harvested at 7 weeks interval was more than those harvested at a 5-week interval (Table 1). However, visually the leaflets of moringa leaves harvested at 7-week intervals began to turn yellow, so that not all of the harvested leaves were suitable for consumption.

Table 2. Interaction of moringa accessions with harvest interval on branches weight and ratio of leaflet weight per number of leaves variables at the 2<sup>nd</sup> harvest

| Accessions       | Harvest intervals | 5 weeks | 7 weeks | 5 weeks | 7 weeks |
|------------------|-------------------|---------|---------|---------|---------|
|                  | 5 weeks           | Branches weight (g) | Ratio of leaflet weight per number of leaves |
| Tabanan          | 9.33<sup>f</sup>  | 47.60<sup>ad</sup> | 0.56<sup>f</sup> | 1.08<sup>def</sup> |
| Bogor            | 49.79<sup>cd</sup>| 191.25<sup>*</sup> | 1.71<sup>bcd</sup> | 3.37<sup>*</sup> |
| Banyuwangi       | 18.69<sup>ef</sup>| 90.08<sup>b</sup> | 1.35<sup>def</sup> | 2.13<sup>b</sup> |
| Lhokseumawe      | 10.86<sup>f</sup> | 88.42<sup>bc</sup> | 0.85<sup>ef</sup> | 1.85<sup>bc</sup> |
| Central Halmahera| 31.40<sup>def</sup>| 72.53<sup>bc</sup> | 1.64<sup>bde</sup> | 2.01<sup>bc</sup> |
| Palu             | 25.74<sup>def</sup>| 150.25<sup>+</sup> | 1.80<sup>bcd</sup> | 2.50<sup>b</sup> |
| Solo             | 14.93<sup>ef</sup>| 34.86<sup>de</sup> | 0.99<sup>def</sup> | 1.75<sup>bcd</sup> |

Note: Values followed by the same letter at the same harvest period are not significantly different according to DMRT at α=5%.

#: data transformed by (x)<sup>1/2</sup>

Bogor and Palu accessions at 7 weeks harvesting interval had the highest branch weight at the second harvest. Ratio leaflet weight per number of leaves harvested from Bogor accessions at 7 weeks harvest intervals was 384.11% higher than those at 5 weeks harvest interval, while leaflet weight per number of leaves harvested from Bogor accessions at 7 weeks harvest intervals was 583.72% higher than those at 5 weeks harvest interval (Table 2). The highest ratio of fresh weight of leaflets per number of harvested leaves was obtained by Bogor accessions at 7 weeks harvesting interval for the second harvest period. This ratio indicates that the fresh weight of each tripinnate leaf from Bogor accession at 7 weeks harvesting interval is higher than other accessions harvested at harvest intervals of 5 or 7 weeks of the second harvest (Table 2).
The Bogor accession had more harvested branches than the Central Halmahera accession, but statistically the same with the Tabanan, Banyuwangi, Lhokseumawe, Palu, and Solo accessions during the first harvest. The accessions of Bogor and Palu had longer harvesting branches than accessions of Tabanan, Banyuwangi, Lhokseumawe, Central Halmahera, and Solo. Bogor accessions had the highest number of leaves at the first harvest but did not differ from the number of leaves from Lhokseumawe, Central Halmahera, and Solo accessions, while Tabanan and Palu had a smaller number of leaves (Table 3).

Harvesting interval affects branch length and the number of Moringa leaves. Harvesting intervals of 7 weeks gave the longest branch length at the first and second harvests. The highest number of leaves in the first harvest was obtained at a harvesting interval of 5 weeks, but in the second harvest, the highest number of leaves was obtained at a harvesting interval of 7 weeks (Table 3). The harvesting interval of 7 weeks had more old leaves (yellow leaves) and experienced leaf loss at 1 week before harvest or 6 weeks after harvest and when harvesting. Moringa leaves will fall off after approximately 1 month from the time they first appeared, after which new leaves will grow [17].

The Bogor accession had the highest fresh weight of biomass, branch, and leaflets, but statistically had the same yield as Palu accession except for the fresh weight of the branches at the first harvest. The weight of the harvest in the second harvest was much higher than in the first harvest. The fresh weight of Bogor accession Biomass at the second harvest is 347.20% times heavier than in the first harvest (Table 4). The more often Moringa plants are harvested by pruning, the more branches are formed so that more leaves grow [5]. Each accession of Moringa has different leaflets weights due to the influence of morpho-anatomy, especially leaf cell walls due to different climatic conditions in the area of origin of each accession [18].

The harvesting interval of 7 weeks had the highest wet weight of biomass, branch, and leaflets in the first and second harvests. The harvesting interval of 7 weeks was 140% than the harvesting interval of 5 weeks and gave a higher fresh weight of leaflets 194.80% in the first harvest and 228.16% times in the second harvest (Table 4). These results are in line with the results of previous studies on Moringa plants that longer harvesting intervals lead to increased yields [9,10,11,12,16].

Harvesting with a longer time interval causes the proportion of stems and leaves to increase as the carbohydrate content of photosynthesis increases to form cell walls [19]. In addition, harvesting intervals
that are too short would cause a decrease in photosynthetic ability and inhibit assimilation of nutrients and reduce carbohydrate reserves used in plant growth [5].

Table 4. Fresh harvest weight of moringa biomass, branches, and leaflets

| Treatments       | Harvest | Harvest | Harvest | Harvest |
|------------------|---------|---------|---------|---------|
|                  | Biomass | Branches | Leaflets |         |
| Accessions       | 1st     | 2nd     | 1st     | 2nd     |
| Tabanan          | 15.79   | 48.81   | 6.68    | 28.46   | 9.11    | 20.35   |
| Bogor            | 56.35^a | 195.65^a | 27.81^b | 120.52^a | 28.54^a | 75.13^a |
| Banyuwangi       | 23.64^bc | 70.04^cd | 10.51^bcd | 36.54^cd | 13.13^bcd | 33.50^ed |
| Lhokseumawe      | 28.67^abc | 86.70^d | 13.11^abed | 49.60^d | 15.56^abed | 37.06^ed |
| Central Halmahera| 23.08^bc | 98.24^bc | 10.01^cd | 51.97^bc | 13.06^cd | 46.28^bc |
| Palu             | 53.95^a | 149.70^ab | 28.02^a | 88.00^b | 25.93^ab | 61.71^ab |
| Solo             | 49.38^ab | 54.14^d | 26.18^ab | 26.89^d | 23.20^abc | 27.25^d |

Harvest intervals

|                  | 5 weeks | 7 weeks |
|------------------|---------|---------|
| Biomass          | 22.47^b | 54.70^a |
| Branches         | 51.94^b | 163.39^a |
| Leaflets         | 9.20^b  | 28.85^a |

Note:
Values followed by the same letter at the same treatment and column are not significantly different according to DMRT at α=5%

#: data transformed by (x)^1/2

The ratio of the fresh weight of leaflets per number of branches and the ratio of the fresh weight of leaflets per number of leaves was the highest in the first harvest owned by Palu accessions and statistically not different from the Bogor and Solo accessions. This indicated that Palu accession in the first harvest had the highest fresh weight of leaflets on each branch and each tripinnate leaf harvested, but not different from Bogor and Solo accessions. In the second harvest, the ratio of the fresh weight of leaflets per number of branches and the ratio of the fresh weight of shoots per number of leaves was the highest for the Bogor accessions and statistically not different from the Palu and Central Halmahera accessions. This indicates that the Bogor accession in the second harvest had the highest fresh weight of leaflets on each branch and on each tripinnate leaf harvested, but it was not different from the Palu and Central Halmahera accessions (Table 5).

The ratio of the fresh weight of young leaves per fresh weight of biomass in Banyuwangi and Central Halmahera accessions was higher but had the same ratio as Tabanan, Bogor, Lhokseumawe, and Solo accessions in the first harvest. The ratio of the fresh weight of leaflet per fresh weight of the second harvest biomass in Banyuwangi and Solo accessions, but the ratio of the fresh weight of leaflets per fresh weight of biomass was lowest in Bogor accessions. This indicates that the proportion of leaves in the Banyuwangi and Solo accessions was higher than the proportion of branches or twigs, while in the Bogor accessions the proportion of branches was higher than the proportion of leaves (Table 5). Although the proportion of leaves in the Bogor accession was lower than the proportion of branches, the growth of the Bogor accessions was faster so that the weight of the biomass, branches, and leaflets was higher than that of the other accessions (Table 4). The Bogor accession in the second harvest had a ratio of the fresh weight of leaflets per fresh weight of biomass of 0.42, which means that every 1 kg of biomass weight in Bogor accession consisted of 0.58 kg of branches and 0.42 kg of leaves (Table 5). Each branch and leaf tripinnate contained a higher fresh weight of leaflets at harvesting intervals of 7 weeks. The fresh weight content of the branch was higher than the fresh weight content of the leaflets in each biomass at a harvesting interval of 7 weeks (Table 5). This is due to the new shoots growing so that nutrients are used to dominantly form leaves on new shoots and cause the wet weight of the leaflets...
to be higher than the branches [19]. Meanwhile, when leaf development takes longer, the results of photosynthesis in leaves, are higher so that more cellulose is formed which is used to form cell walls, and the proportion of stems increases in elephant grass plants.

Table 5. Ratio between moringa harvest variables

| Treatments         | Harvest              | 1st   | 2nd   | 1st   | 2nd   |
|--------------------|----------------------|-------|-------|-------|-------|
|                    | LW/NB #              |       |       |       |       |
| Accessions         |                      |       |       |       |       |
| Tabanan            |                      | 2.59d | 3.34e | 0.57c | 0.82d |
| Bogor              |                      | 8.49ab| 17.38a| 1.42ab| 2.54a |
| Banyuwangi         |                      | 4.60bcd| 7.96cd| 1.03abc| 1.54bcd |
| Lhokseumawe        |                      | 4.64bcd| 8.00d | 0.91bc| 1.35cd |
| Central Halmahera  |                      | 4.65bcd| 12.78abc| 0.72c| 1.82abc |
| Palu               |                      | 9.13a | 13.70ab| 1.59a| 2.15ab |
| Solo               |                      | 8.02abc| 8.44bcd| 1.41ab| 1.45bcd |
| Harvest intervals  |                      |       |       |       |       |
| 5 weeks            |                      | 3.99b | 7.19b | 0.72b | 1.32b |
| 7 weeks            |                      | 8.92a | 14.55a| 1.60a| 2.15a |
| Accessions         |                      |       |       |       |       |
| Tabanan            |                      | 0.43  | 0.52  | 0.57ab| 0.48b |
| Bogor              |                      | 0.44  | 0.58  | 0.56ab| 0.42c |
| Banyuwangi         |                      | 0.42  | 0.47  | 0.58a | 0.53a |
| Lhokseumawe        |                      | 0.43  | 0.53  | 0.57ab| 0.47b |
| Central Halmahera  |                      | 0.41  | 0.51  | 0.58a | 0.49ab |
| Palu               |                      | 0.50  | 0.54  | 0.50b | 0.46b |
| Solo               |                      | 0.48  | 0.48  | 0.52ab| 0.52a |
| Harvest intervals  |                      |       |       |       |       |
| 5 weeks            |                      | 0.40b | 0.45b | 0.60a | 0.55a |
| 7 weeks            |                      | 0.50a | 0.59a | 0.50b | 0.41b |

Note: Values followed by the same letter at the same treatment and variable are not significantly different according to DMRT at $\alpha=5\%$.

#: data transformed by $(x)^{1/2}$.

LW/NB: ratio of leaflet fresh weight per number of branches harvested.
LW/NL: ratio of leaflet fresh weight per number of leaves harvested.
BW/BiW: ratio of branches fresh weight per biomass fresh weight.
LW/BiW: ratio of leaflet fresh weight per biomass fresh weight.

4. Conclusion

Bogor accessions at the harvesting interval of 7 weeks had the highest ratio of the wet weight of leaflets per number of harvested leaves. Moringa planting in Bogor or its surroundings should use Bogor accession with harvesting intervals of 7 weeks.

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