Germplasm evaluation and influence of soil type, plant density and pruning height on biomass yield of moringa in central Vietnam

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Abstract

Moringa (*Moringa oleifera* Lam.) is a tree species with known value for food, medicine and water treatment. This study was conducted to: 1) evaluate promising moringa accessions from the World Vegetable Center; 2) select accessions adapted to growing conditions in central Vietnam; and 3) determine the influence of soil types, plant density and pruning height on biomass yield of moringa. The results showed that moringa accession VI08718 is the most adapted for growing in central Vietnam. It gained the highest yield (96.1 g plant^{-1}) and highest mean number of branches at each harvest (3.9 branches). Moringa can grow in any soil type but it gained highest yield in alluvial soil (108.0 g plant^{-1}). Biomass yield of moringa grown in sandy soil and fallow sandy soil was lower than in other soil types. However, improvement of sandy soil and fallow sandy soil resulted in high biomass yield comparable to yield in alluvial soil. Plant density of 160,000 plants ha^{-1} produced the highest yield (8.3 kg plot^{-1}), whereas plants pruned at 55 cm from the soil surface obtained the highest yield (10.3 kg plot^{-1}).

Keywords: moringa, germplasm, Vietnam, adapted, soil type, plant density

INTRODUCTION

Moringa oleifera Lam. is the most widely cultivated species of the monogenic family *Moringaceae* and is grown throughout the tropics and subtropics (Muluvi et al., 1999). It is native to the sub-Himalayan tracts where it is known by several regional names (Fahey, 2005). Many reports have described its nutritional and medicinal properties (Chopra et al., 1956; Verma et al., 1976; Ramachandran et al., 1980; Dahot, 1988; Francis and Liogier, 1991; Palada, 1996; Fahey, 2005; Yang et al., 2006). Although utilized by people in ancient times, *M. oleifera* is now widely cultivated and has become naturalized in many locations in the tropics (Fahey, 2005). In Vietnam, it was originally found to be widely grown in Thanh Hóa, NinhThuận, BìnhThuận, An Giang, and Phú Quốc Island. It was grown along the fence but not for eating until the seed was imported to Vietnam and purposely cultivated. Thus, in central Vietnam as well as in the whole country, very few farmers cultivate this tree on their farms because only few consumers know about moringa and its potential health benefits. This made it difficult to sell moringa products and moringa as vegetable in the open markets or super markets.

This study served three objectives: 1) to evaluate promising moringa accessions from the World Vegetable Center; 2) to identify suitable plant densities and pruning heights for optimum production for the market and for cultivation in home gardens; and 3) to determine the growth and yield of moringa as influenced by soil types in central Vietnam.

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MATERIALS AND METHODS

Moringa accessions

Five *M. oleifera* accessions provided by the World Vegetable Center and one variety collected from Hanoi were used in the study (Table 1). Three accessions came from Thailand, one from Taiwan, and one from the United States. The best moringa accession from the evaluation trial was selected for the other studies involving soil types, pruning height, and plant density.

Table 1. List of moringa accessions used in the evaluation study.

Serial no.	Vegetable/ introduction	Temporary no.	Species	Pedigree/ cultivar name	Origin country
1	VI047492	TOT4100	*Moringa oleifera*	La-Mu	Taiwan
2	VI048590	TOT4880	*Moringa oleifera*	Virgin Islands' drumstick	USA
3	VI048687	TOT4951	*Moringa oleifera*	Marum	Thailand
4	VI048718	TOT4977	*Moringa oleifera*	Marum	Thailand
5	VI048966	TOT5169	*Moringa oleifera*	Marum	Thailand
6			*Moringa oleifera*	Ha Noi	Vietnam

Experimental design

The experiments were laid out in a randomized complete block design (RCBD) with three replications. Five plants were planted in pots (28×25×24 cm) per replication for germplasm evaluation and soil type experiments, while 30 plants were planted in the field per replication for pruning height and plant density experiments.

1. Germplasm evaluation.

Five accessions provided by the World Vegetable Center and one variety collected from Ha Noi, Vietnam, were used as treatments. The seeds were sown directly in the pots containing alluvial soil supplied with 30 g of NPK fertilizer and 300 g of micro-organic fertilizer. The pots were placed in the plastic house for three months for protection against rainfall and low temperature. The plants were then moved to the net house one month before pruning. Due to the limited number of seeds provided by the World Vegetable Center (20 seeds per packet) only 15 seeds were used for each accession in this study and 5 seeds were sown for seed production that will be used for future studies.

Soil type experiment.

The study evaluated five soil types representative of central Vietnam: alluvial soil, sandy soil, fallow sandy soil, light loam soil, and basalt soil were used as five treatments. Two other treatments involved the improvement of sandy soil and fallow sandy soil by placing 300 g of rice husk ashes in the bottom of the potto maintain ideal soil moisture. Four kg of each soil type were used for each pot. All soil types were obtained at a depth of 0.5 m and used to fill the 28×25×24 cm plastic pots. Each pot was supplied with 30 g of NPK fertilizer and 300 g of micro-organic fertilizer. After the seedlings were transplanted, 300 g of rice husk ashes were applied onto the surface of the soil for all treatments.

Plant density experiment.

The study evaluated six plant densities: 400,000 (15×15cm), 300,000 (15×20 cm), 250,000 (20×20 cm), 200,000 (15×30 cm), 160,000 (20×30cm), and 130,000 (25×30 cm) plants ha^{-1}. The plants were transplanted in the net-house with old alluvial soil. The area of each plot was 5 m^2 and total area of the trial was 100 m^2.

Pruning height experiment.

The study evaluated five pruning heights: 45, 55, 65, 75 and 85 cm from ground level.

The plants were transplanted in a net-house with old alluvial soil (udiflavents). Plant density was 160,000 (20×30cm) plants ha^{-1}. The area of each plot was 5 m^2 with a total trial area of 100 m^2.

2. Raising of seedlings.

Moringa seeds were sown in coffee paper cups (large size) containing a 1:1:1 mixture of sand, garden soil and commercial organic fertilizer. These were grown inside a net-house for 8 weeks then transplanted to pots and fields in the net-house. Watering was done whenever necessary. Recommended practices in moringa seedling production were followed as described in AVRDC International Cooperators' Guide: Suggested Cultural Practices for *Moringa*, AVRDC Pub #03-545 (Palada and Chang, 2003).

3. Care of plants.

The seedlings were inspected daily to check if there are pests or diseases infesting and/or infecting them. The population of insect pests was kept low by mechanical means. Two months after planting, all seedlings were pruned 70 cm above the soil surface for germplasm evaluation, soil type and plant density experiments.

4. Time and place of the study.

This study was conducted from November 2013 to September 2015 at the experimental facility of the Faculty of Agronomy, Hue University of Agriculture and Forestry, Vietnam.

5. Data collection.

The following data were collected:

1. Percent germination and plant survival within 120 days after germination for germplasm evaluation.

$$\% \text{ Germination}= \frac{\text{No. of seedlings that emerged}}{\text{No. of seeds sown}} \times 100 \quad (1)$$

$$\% \text{ Survival}= \frac{\text{No. of alive seedlings 1 month after emergence}}{\text{No. of seedlings that emerged}} \times 100 \quad (2)$$

A seed was considered to have emerged when at least 2 cm of its epicotyl was above the soil level. A seedling was considered to have survived if it was alive and healthy one month after emergence.

2. Plant height. This was measured at biweekly intervals from one week after emergence, from the soil level in the pot to the last node.
3. Number of side shoots or branches that developed after pruning.
4. Number of leaf-petioles (branches) developed starting 2 weeks after germination and developed starting 2 weeks after transplanting, measured at weekly intervals.
5. Stem diameter at monthly interval.
6. Leaf yield. Green leaves were snapped off from the stems after pruning and then weighed. Prunings were conducted for 4 times at three weeks interval.
7. Dry matter (%).

RESULTS AND DISCUSSION

Germplasm evaluation

The number of days from sowing to emergence varied within accessions and ranged from 9.3 to 12.3 days (Table 2). Accession Ha Noi from Vietnam was the earliest to emerge and VI07492 from Taiwan was the last. The time for emergence in this study was longer than in the other study (Palada et al., 2012) because the seeds were sown at the end of November

2014 and low temperature caused a delay in the cracking of the seed and plant growth was quite slow.

Table 2. Number of days from sowing to seedling emergence, germination rate and survival rate after germination of moringa accessions.

Accession	Days to emergence	Germination rate (%)	Survival rate (%)					
			14 DAG	21 DAG	35 DAG	49 DAG	90 DAG	120 DAG
Ha Noi	9.3	100	100.0	93.3	93.3	93.3	86.7	86.7
VI08966	10.7	80.0	80.0	80.0	80.0	73.3	73.3	73.3
VI08718	10.7	86.7	86.7	86.7	86.7	86.7	86.7	86.7
VI08590	10.7	86.7	86.7	86.7	80.0	60.0	60.0	60.0
VI07492	12.3	86.7	86.7	86.7	80.0	80.0	80.0	80.0
VI08687	10.7	80.0	80.0	46.7	33.3	26.7	20.0	20.0

DAG: Days after germination.

The overall germination rates of all accessions were high ranging from 80% to 100%. Only accession Ha Noi from Vietnam reached 100%, three accessions had 86.7%, and two accessions had 80%. At 14 days after germination (DAG), several germinated seeds from all accessions were not healthy and died except for accession Ha Noi having 100% healthy seedlings. The growth of healthy seedlings was quite slow in subsequent weeds, but remained stable at90 days after germination. At this time, all seeds that germinated developed into healthy seedlings with 20 to 86.7% survival (Table 2).

Since the rainy season in central Vietnam falls into the months of December to January, the seedlings were placed into the plastic house for three months and moved then out to net house. The survival rate of healthy seedlings was stable at 12 DAG. Data were not recorded for accession VI08687 since only two plants survived.

Moringa leaves were harvested whenever 50% of the plants of each accession reached a height of 100 cm. This occurred at about 120 days after germination. At this time, the number of leaves on the stem of accessions ranged from 24.5 (VI07492) to 28.9 (VI08966) (Table 3). There was no significant difference among accessions, except for VI08966.Accession VI07492 produced the tallest plants (106.5 cm) while accession Ha Noi had the shortest plants (75.8 cm). Plant height was not significantly different among accessions from the World Vegetable Center. Mean stem diameter ranged from 0.81 (Ha Noi) to 1.06 cm (VI08590). Thus, accession Ha Noi had shorter and smaller plants than the accessions received from the World Vegetable Center.

Table 3. Leaf number, plant height, and stem diameter before pruning of moringa accessions.

Accession	Number of leaves	Plant height (cm)	Stem diameter (cm)
Ha Noi	24.9[b]	75.8[b]	0.81 [b]
VI08966	28.9[a]	104.7[a]	1.02 [a]
VI08718	25.9[b]	93.1[a]	1.02 [a]
VI08590	24.7[b]	93.5[a]	1.06 [a]
VI07492	24.5[b]	106.5[a]	0.97 [a]
VI08687	-	-	-
$LSD_{0,05}$	2.08	13.52	0.14

-: data was not recorded.

Values in a column with different upper case letters are significantly different ($P<0.05$).

After the fourth pruning, mean stem diameter ranged from 1.9 (Ha Noi) to 2.2 cm (VI07492) (Table 4). There were no significant differences among accessions. High mean number of branches was recorded for accessions VI08718 (3.9 branches) and VI08590 (2.7 branches). Lowest mean number of branches was observed in the Ha Noi accession (2.1 branches). The length of branches ranged from 26.1 (VI08966) to 18.7 cm (Ha Noi). There were no significant differences in branch length among accessions from the World Vegetable

Center. Accession Ha Noi obtained the highest mean number of leaves per branch (4.9), followed by VI08966 (4.6) and VI08718 (4.6). The lowest mean number of leaves per branch was recorded for VI08590 (4.0).

Table 4. Stem diameter, number of branches, branch length, and number of leaves per branch after pruning of different moringa accessions.

Accession	Stem diameter (cm)	Number of branches	Branch length (cm)	Number of leaves per branch
Ha Noi	1.91 a	2.1 c	18.69 c	4.9 a
VI08966	2.18 a	2.3 bc	26.11 a	4.6 a
VI08718	2.18 a	3.9 a	22.41 b	4.6 a
VI08590	2.18 a	2.7 ab	23.26 ab	4.0 b
VI07492	2.23 a	2.2 c	22.92 ab	4.3 ab
VI08687	-	-	-	-

-: data was not recorded.
Values in a column with different upper case letters are significantly different (P<0.05).

Dry matter content ranged from 22.07 (Ha Noi) to 25.22% (VI07492) (Table 5). Dry matter in this study was similar compared to the results reported by Palada et al. (2012) in which dry matter of 18 moringa accessions provided by the World Vegetable Center ranged from 23.2 to 33.6%. Though accessions VI08718 and VI07492 yielded the highest leaf fresh weight with 96.1 and 96.0 g plant^{-1}, respectively, there were no significant differences in biomass yield among moringa accessions. However, all accessions from the World Vegetable Center had significantly higher fresh biomass yield than the local accession Ha Noi (Table 5).

Table 5. Dry matter and biomass yield of different moringa accessions after pruning.

Accession	% Dry matter	Fresh biomass yield (g plant^{-1})
Ha Noi	22.07 c	66.90 b
VI08966	22.69 c	84.82 a
VI08718	24.43 ab	96.10 a
VI08590	23.08 bc	90.97 a
VI07492	25.22 a	96.01 a
VI08687	-	-

-: data was not recorded.
Values in a column with different upper case letters are significantly different (P<0.05).

Influence of different soil types on biomass yield of moringa

Different soil types did not show any significant difference in the number of leaves per stem before pruning of moringa, except for basalt soil and sandy soil (Table 6). Significant differences in plant height were observed among different soil types. Plants were tallest in alluvial soil (70.2 cm), followed by plants growing in improved sandy soil (62.6 cm). The shortest plants were observed in sandy soil (48.1 cm). This indicates that sandy soil is not suitable for growing moringa but the use of rice husk ash before planting can improve the soil property. Moringa can be added as a component to the cropping systems in Thua Thien Hue as well as in the provinces in central Vietnam, where most of the soils in the area are sandy. Alluvial soil is a fertile soil rich in potassium and highly suitable for agriculture. The result in this study is in agreement with the study undertaken by Ramachandran et al. (1980) who reported better growth of moringa in sandy loam soils. Stem diameter was smallest in sandy soil (0.67 cm) and largest in alluvial soil (0.80 cm). However, there were no significant differences in stem diameter among different soil types (Table 6).

Table 6. Influence of soil types on leaf number, plant height, and stem diameter before pruning of moringa.

Treatment	Number of leaves	Plant height (cm)	Stem diameter (cm)
Light loam soil	17.5 ab	58.8 abc	0.76 a
Basalt soil	19.1 a	49.3 bc	0.68 a
Sandy soil	16.8 b	48.1 c	0.67 a
Fallow sandy soil	18.7 ab	49.1 bc	0.68 a
Alluvial soil	18.0 ab	70.2 a	0.80 a
Improvement of sandy soil	18.6 ab	62.6 a	0.77 a
Improvement of fallow sandy soil	17.4 ab	59.8 ab	0.78 a

Values in a column with different upper case letters are significantly different (P<0.05).

Mean number of leaves per branch ranged from 6.2 to .8.9 (Table 7). Highest number of leaves per branch was observed in alluvial soil and improved sandy soil (8.9 leaves).This was followed by treatments in light loam soil (8.6 leaves), improved fallow sandy soil (8.3 leaves) and fallow sandy soil (8.0 leaves). Mean number of leaves per branch was lowest in sandy soil (6.2 leaves). Different soil types affected branch length significantly. The shortest branches were observed in sandy soil (16.7 cm) and the longest branches were obtained in light loam soil (28.1 cm), followed by plants in alluvial soil (26.1 cm), and improved sandy soil (25.9). Mean number of branches ranged from 4.7 to 3.4. Alluvial and improved sandy soils resulted in the highest number of branches (4.7 branches), followed by sandy soil (4.3 branches). The lowest number of branches was observed in light loam soil (3.4 branches). Soil types did not significantly influence stem diameter, except for the difference observed between light loam soil and alluvial soil with sandy soil. Stem diameter ranged from 1.3 cm (sandy soil) to 1.4 cm (alluvial soil and light loam soil).

Table 7. Influence of soil types on leaf number per branch, branch length, number of branches, and stem diameter after pruning of moringa.

Treatment	Number of leaves per branch	Branch length (cm)	Number of branches	Stem diameter (cm)
Light loam soil	8.56 a	28.11 a	3.4 b	1.43 a
Basalt soil	6.78 bc	20.33 cd	3.7 ab	1.30 ab
Sandy soil	6.22 c	16.67 d	3.9 ab	1.27 b
Fallow sandy soil	8.00 ab	22.89 bc	3.7 ab	1.31 ab
Alluvial soil	8.89 a	26.11 ab	4.7 a	1.43 a
Improvement of sandy soil	8.89 a	25.89 ab	4.3 ab	1.34 ab
Improvement of fallow sandy soil	8.33 a	22.44 bc	3.9 ab	1.38 ab

Values in a column with different upper case letters are significantly different (P<0.05).

Though moringa accessionVI08718 was used in all treatments, significant differences were observed in dry matter content among different soil types (Table 8). Dry matter ranged from 16.3 (sandy soil) to 25.6% (alluvial soil). Significant differences were detected in biomass yield between different soil types. Highest biomass yield of moringa was recorded in alluvial soil with 108.0 g plant^{-1}, followed by the treatment with improved sandy soil (97.7 g plant^{-1}), improved fallow sandy soil (97.4 g plant^{-1}), and light loam soil (95.7 g plant^{-1}). Lowest yield was obtained on basalt soil (62.2 g plant^{-1}) and sandy soil (63.7 g plant^{-1}).

Table 8. Influence of soil types on dry matter and biomass yield of moringa.

Treatment	% Dry matter	Biomass yield (g plant^{-1})
Light loam soil	19.15 ^{bc}	95.73 ^{ab}
Basalt soil	19.00 ^{bc}	62.20 ^{b}
Sandy soil	16.27 ^{c}	63.73 ^{b}
Fallow sandy soil	22.29 ^{ab}	68.40 ^{b}
Alluvial soil	25.65 ^{a}	108.00 ^{a}
Improved sandy soil	22.96 ^{ab}	97.73 ^{ab}
Improved fallow sandy soil	22.37 ^{ab}	97.40 ^{ab}

Values in a column with different upper case letters are significantly different (P<0.05).

Influence of plant density on biomass yield of moringa

Mean number of leaves per branch ranged from 4.7 (400,000 plants ha^{-1}) to 5.4 (160,000 plants ha^{-1}) (Table 9). Branch length was affected significantly by different densities in home gardens. The longest branches were observed at a plant density of 130,000 plants ha^{-1} (45.0 cm) and the shortest ones were detected at a plant density of 400,000 plants ha^{-1} (35.3 cm). Various plant densities significantly affected the number of branches. The number of branches ranged from 4.0 (400,000 plants ha^{-1}) to 4.8 (160,000 plants ha^{-1}). A significant difference was observed in stem diameter among plant densities. The largest stem diameter was obtained with plant densities of 160,000 plants ha^{-1} (2.2 cm), followed by130,000 plants ha^{-1} (2.1 cm). The smallest stem diameter was detected with plant densities of 400,000 plants ha^{-1} (1.9 cm) and 300,000 plants ha^{-1} (1.9 cm).

Table 9. Influence of plant density on leaf number per branch, branch length, number of branches, and stem diameter of moringa.

Treatment (plants ha^{-1})	Plant and row spacing (cm)	No. of leaves branch^{-1}	Branch length (cm)	No. of branches	Stem diameter (cm)
400,000	15×15	4.72 ^{c}	35.34 ^{c}	4.03 ^{c}	1.90^{b}
300,000	15×20	5.29 ^{a}	36.57 ^{c}	4.09 ^{c}	1.92 ^{b}
250,000	20×20	4.93 ^{bc}	43.35 ^{a}	4.45 ^{b}	1.95 ^{b}
200,000	15×30	5.15 ^{ab}	42.00 ^{ab}	4.09 ^{c}	2.08 ^{ab}
160,000	20×30	5.35 ^{a}	38.91 ^{bc}	4.81 ^{a}	2.18 ^{a}
130,000	25×30	5.20 ^{a}	44.96 ^{a}	4.27 ^{bc}	2.11 ^{a}

Values in a column with different upper case letters are significantly different (P<0.05).

Results of leaf biomass are presented in Table 10 indicated no increasing trend in leaf fresh biomass with increasing plant density. Plant density significantly influenced biomass yield. Plant density at 160,000 plants ha^{-1} had significantly higher biomass yield than all other densities. Increasing plant density above or higher than 160,000 plants ha^{-1} did not result in a further increase in biomass yield.

Table 10. Influence of plant density on biomass yield of moringa.

Treatment (plants ha^{-1})	Plant and row spacing (cm)	Biomass yield (kg plot^{-1})
400,000	15×15	6.25 ^{b}
300,000	15×20	6.13 ^{b}
250,000	20×20	6.30 ^{b}
200,000	15×30	6.38 ^{b}
160,000	20×30	8.28 ^{a}
130,000	25×30	6.99 ^{ab}

Values in a column with different upper case letters are significantly different (P<0.05).

Different pruning heights significantly affected the number of leaves per branch. The number of leaves ranged from 5.4 to 7.3 (Table 11). Pruning at 45 cm from soil surface resulted in the lowest number of leaves per branch, whereas the highest number of leaves was observed when plants were pruned at 55 cm, followed by pruning at a height of 75 cm. Branch length ranged from 29.3 cm (pruning at 45 cm) to 44 cm (pruning at 55 cm) and differences were not significant, except for pruning at 45 cm. A pruning height of 85 cm resulted in the highest number of branches (4.4 branches) and the lowest number of branches was obtained at a pruning height of 75 cm (3.7 branches). Significant differences in stem diameter were observed when plants were pruned to various plant heights. The largest stem diameter (1.8 cm) was observed at a pruning height of 75 cm, whereas the smallest stem diameter was detected when plants were pruned at 45 cm (1.5 cm) and 55 cm (1.4 cm).

Table 11. Influence of pruning height on leaf number per branch, branch length, number of branches and stem diameter of moringa.

Height of pruning treatment (cm)	Number of leaves on branch	Branch length (cm)	Number of branches	Stem diameter (cm)
45	5.41 d	29.27 b	4.13 ab	1.47 b
55	7.34 a	44.10 a	4.03 ab	1.44 b
65	6.60 bc	42.31 a	4.18 ab	1.67 a
75	7.09 ab	42.84 a	3.66 b	1.79 a
85	6.34 c	38.71 a	4.42 a	1.61 ab

Values in a column with different upper case letters are significantly different ($P<0.05$).

Different pruning heights showed a significant effect on leaf biomass yield of moringa. Leaf biomass yield ranged from 5.9 to 10.0 kg $plot^{-1}$. Pruning at 55 and 65 cm resulted in the highest biomass yields, followed by pruning heights at 85 and 75 cm. No significant difference was observed among these various pruning heights. Pruning height at 50 cm from soil surface resulted in the lowest yield (Table 12). The World Vegetable Center recommends a pruning height of 75 cm, however, in central Vietnam, heavy rainfall and strong wind during typhoon season can damage taller plants due to lodging that eventually results in decreased yield. In this study we found that plants pruned at 55 cm above ground were much stronger and resistant to lodging, thus, resulting in increased biomass yield.

Table 12. Influence of pruning heights on biomass yield of moringa.

Height of pruning treatment (cm)	Biomass yield (kg $plot^{-1}$)
45	5.9 b
55	10.3 a
65	10.1 a
75	8.5 ab
85	9.1 ab

Values in a column with different upper case letters are significantly different ($P<0.05$).

CONCLUSIONS

- This study indicates that moringa accession VI08718 is the most adapted for the growing conditions in central Vietnam.
- Moringa can grow in any soil type but it gained the highest yield in alluvial soil. However, improvement of sandy soil as well as improvement of fallow sandy soil can be used for successful growing of moringa.
- A plant density of 160,000 plants ha^{-1} is the most suitable for planting moringa in home gardens and plants should be pruned at 55 cm from the soil surface to promote strong growth and increase resistance to lodging during heavy rainfall and strong

wind.

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