Adaptability and horticultural characterization of *Moringa* accessions under Central Philippines conditions

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ABSTRACT
This study was conducted to determine the adaptability and describe the horticultural characteristics of *Moringa oleifera* Lam. accessions under central Philippines conditions. Eighteen *Moringa* accessions obtained from AVRDC – The World Vegetable Center were evaluated in observational trials at Central Philippine University, Iloilo City, Philippines in 2009. The accessions originated from India (3), Laos (1), Philippines (1), Taiwan (1), Tanzania (1), Thailand (10), and USA (1). Three-month-old seedlings were transplanted in non-replicated plots at a spacing of 2 m between rows and 1.5 m between plants. Data were recorded on growth and stand survival, plant height, stem diameter, number of branches, fresh leaf yield, pod and seed production, and incidence of insect pests and diseases. Percentage seed germination ranged from 40 to 100%, with eight accessions having 100% and eight accessions 80% germination. Two accessions from Thailand had poor germination (40%). All seeds that germinated developed into healthy seedlings with 80 to 100% survival. At 28 weeks after second pruning, accessions Mo-2 (USA) and Mo-40 (India) produced the tallest plants (5.6 and 5.1 m, respectively), whereas Mo-34 (India) produced the shortest plants (2.9 m). Mean stem diameter ranged from 3.5 cm (Mo-34) to 8.5 cm (Mo4-Thailand). Mo-38 (Thailand) produced the highest number of branches (5.3), whereas Mo-33 (Philippines) showed the lowest number of branches (2.0) per plant. Two accessions from Thailand resulted in the highest leaf fresh weight, which exceeded 2 kg/plant from two prunings. Eight accessions produced leaf fresh biomass that exceeded 1 kg/plant. Mo-3 (Taiwan) developed the highest number of pods, whereas Mo-34 produced the highest number of seeds. Red mites (*Tetranychus urticae*), Coccinellid beetles (Coccinellidae), leaf-footed bug (*Leptoglossus phyllopus*) and whiteflies (*Bemisia* sp.) were present, but caused only minor damage to plants. Stem rot was the only disease observed in a few plants.

Keywords
Indigenous vegetables, drumstick tree, horticultural traits, germination, stand establishment.

INTRODUCTION
The multiple uses and high micronutrient density of *Moringa oleifera* Lam., commonly known as *malunggay* in the Philippines and by several names elsewhere, have led to growing interest in this crop and resulted in its extensive cultivation worldwide. A small, fast-growing evergreen that reaches up to 12 m high, *Moringa* is characterized by its spreading, open crown of drooping, fragile branches, feathery foliage of tripinnate leaves, and thick, corky, whitish bark.

It has edible leaves, flowers, fruits, roots, and seed oil, and has been traditionally used for herbal medicine. It is also a source of dye, used as livestock forage, and for water purification (Palada 1996; Palada and Chang 2003). In some countries, it is grown mainly as an ornamental and in hedgerows and hedges (Little and Wadsworth 1964; Palada 1996).

Moringa has been observed to tolerate temperature fluctuations from -1 to 48°C. It is drought tolerant (Troup 1921) and is known to thrive in places that have annual rainfall of as much as 1800 mm (Ramachandran et al. 1980). It grows well from sea level to 1,200-m elevation (Jahn et al. 1986) in most light to medium-textured soils, but best growth occurs in sandy loams (Ramachandran et al. 1980) with a pH between 5.5 and 7.5 (Francis and Liogier 1991).

Germination is epigeal and occurs between 7 to 30 days after sowing. Although seedling growth is rapid, germination percentage is usually low. Propagation is also possible with cuttings, but studies show that trees propagated from seeds produce longer roots (Sharma and Raina 1982).

Moringa pods and leaves are the most nutritious parts of the plant (from www.nap.edu). The edible, tender pods have a taste similar to asparagus. The tender leaves taste like watercress and, along with its flowers, are consumed cooked or raw (Bodner and Gereau 1988). They are rich in protein, minerals, beta-carotene, thiamin, riboflavin, and other vitamins particularly vitamins A and C (Dahot 1988). Gram for gram, *Moringa* leaves contain 7 times the Vitamin C in oranges, 4 times the calcium in milk, 4 times the Vitamin A in carrots, 2 times the protein in milk/yogurt, and 3 times the potassium in bananas (Fuglie 2001 from http://deepfitness.com/3244/*Moringa*-Leaf-Powder—The-Worlds-Greatest-UnknownSupplement.aspx; Fuglie 1999). The immature seeds, which taste like peanuts after frying, are also consumed cooked or raw (Dastur 1964). They contain 19 to 47% oil (Ibrahim et al. 1974) and are rich in palmitic, stearic, behemic, and oleic acids and can be used for human consumption, illumination, and in cosmetics and soaps. The oil, also known as ben oil, is valued for its power of absorbing and retaining odors, and is used by watchmakers as a lubricant (Verma et al. 1976). The crushed seeds can be used to remove turbidity and reduce bacterial contamination from drinking water (Sutherland 1989; Yongbai 2005) while leaf extracts can increase root nodulation, nodule weight, and *Rhizobium* nitrogenase activity in mungbean (Bandana 1987). The roots are used as a condiment or garnish after peeling, drying, and mixing with vinegar (Martin and Ruberte 1979).

The medicinal uses of *Moringa* are well-documented. The juice extracted from leaves has strong antibacterial and antimalarial properties (Chopra et al. 1956) and are taken for diabetes and high blood pressure control (Vietmyer 2006).

Leaf extracts were found to exhibit antimicrobial activity including inhibition of growth of *Staphylococcus aureus* strain isolated from food and animal intestines. It can also be a potential substitute for antibiotics in broiler production (Yang et al. 2006). The flowers and roots contain pterygospermin, an antibiotic that is highly effective in the treatment of cholera (Lizzy et al. 1968); it inhibits growth of gram positive and gram negative bacteria. The root bark contains the alkaloids moringine and spirochine that act on the nervous system (from www.nap.edu). Ben oil is used in the treatment of gout and rheumatism (Singh et al. 1983). The numerous medicinal properties and uses of *Moringa* are likewise enumerated by Holst (2000) and Fahey (2005). Research conducted at AVRDC – The World Vegetable Center revealed that the four *Moringa* species (*M. oleifera*, *M. peregrina*, *M. stenopetala* and *M. drouhardii*) studied contain high amounts of antioxidants and nutrients, high antioxidant activity, and low oxalate content. *M. peregrina* has the highest antioxidant content while *M. oleifera* has the highest nutrient values (Yang et al. 2006).

There are numerous *Moringa* accessions in the germplasm bank of AVRDC – The World Vegetable Center in Shanhua, Taiwan. However, their adaptability to other conditions, specifically under the tropical climate in Central Philippines where the plant is mainly grown in the backyard as leafy vegetable, has never been tested. This study will help in determining which among the various accessions has the best yield and is able to adapt well under local soil, weather, pest and disease conditions, and can be rapidly regenerated using stem cuttings. This study was conducted to determine the adaptability and horticultural characteristics of different

Moringa accessions under local conditions. The different phases of the study under corresponding specific objectives are as follows:

Observation nursery

This study was conducted to describe: 1) the percentage germination and survival of the different *Moringa* accessions under Central Philippine University (CPU) conditions; 2) horticultural characteristics of the various *Moringa* accessions; 3) susceptibility to insect pests and/or diseases; 4) regeneration capacity of the various *Moringa* accessions by stem cutting; and 5) coppicing capacity of *Moringa* accessions.

Adaptability trial

This study is being conducted to determine: 1) which *Moringa* accessions will grow well under CPU Zarraga Farm conditions; 2) horticultural characteristics of various *Moringa* accessions; 3) susceptibility to insect pests and/or diseases of the different *Moringa* accessions; and 4) coppicing capacity of the different Moringa accessions.

Propagation study

This study is being conducted to determine: 1) percentage germination and survival of different *Moringa* accessions; 2) early growth horticultural characteristics of *Moringa* accessions; and 4) regeneration capacity of the various *Moringa* accessions by stem cutting propagation.

MATERIALS AND METHODS

Only five seeds each were supplied from the first batch of *Moringa* accessions from AVRDC-Taiwan. Because this amount is not enough for a replicated field trial, these seeds were grown inside a greenhouse then transplanted later in the field for observation purposes.

Observation nursery

Moringa seeds were sown in small plastic bags containing a mixture of 1:1:1 garden soil, commercial organic fertilizer, and sand. The seedlings were transferred to larger pots containing 2 kg of the same potting mixture at 2 to 3 weeks after sowing. The potted plants were grown under greenhouse conditions for 3 months to study the horticultural characteristics at the seedling and early developmental stages.

The observational nursery was established in October 2009. When the seedlings from the first batch of seeds were four months old, these were transferred to bigger pots while waiting for the availability of an area inside the campus. Two and a half months later, the potted plants were pruned 75 cm above the soil surface to facilitate transplanting to the field. Holes were made on prepared raised seedbeds. A kilogram of organic fertilizer was placed into each hole, and then covered with soil to avoid direct contact with the plant roots. The individually labeled plants were planted in the holes then sufficiently covered with soil. The pruned stems were cut 30 cm long, placed in a shady place for 3 days for conditioning, then planted in small pots for possible vegetative regeneration.

Adaptability trial

Greenhouse study. Potted seedlings of the different *Moringa* accessions were used in the greenhouse study. Each accession had 5to 10 potted plants. Accessions with low germination percentage were regenerated in a non-replicated greenhouse propagation trial.

Field study. The experimental area was thoroughly prepared prior to transplanting. The potted seedlings of the different accessions from the greenhouse study were planted in single rows on 60-cm wide well-prepared raised beds. Plants were spaced 2 m between rows and 1.5 m within rows, which is equivalent to 3,333 plants/ha. Each row was planted with 5 seedlings.

Fertilization. For faster plant establishment two kilograms of organic fertilizer were applied at the bottom of the holes in the seedbed just before transplanting the *Moringa* seedlings. No additional fertilizer was applied when plants were fully established.

Watering. Seedlings were watered immediately after transplanting to promote early root development. During dry months watering was done regularly.

Crop protection. Thorough tillage of the experimental area suppressed early weed growth. The weed-free field was maintained by applying organic mulch around the base of the young trees and by hand-pulling or hoeing the area between beds and rows. Although *Moringa* is resistant to most pests and diseases, some outbreaks may occur under certain conditions. Pests such as red mites, aphids, leafminers, whiteflies, and caterpillars were controlled using botanical concoctions. Proper drainage was maintained to avoid waterlogging; this cannot be tolerated by *Moringa* and can encourage/enhance *Diplodia* root rot infection.

Pruning and harvesting. Six months after field transplanting, the plants were pruned 30 cm from the ground level. The stem cuttings/shoots were used for the vegetative propagation study under greenhouse conditions. Green leaves in the pruned branches were harvested by snapping the leaf petioles from the branches.

Experimental treatments and design

Eighteen *M. oleifera* accessions from AVRDC germplasm collection were used as treatments. A local *Moringa* variety was included as control. The *Moringa* accessions are presented in Table 1.

In the observational nursery (field) trial the accessions were planted in non-replicated single rows. No experimental design was used for this trial. In the greenhouse study, the accessions were arranged in a completely randomized design. The field study, on the other hand, utilized a randomized complete block design with two replications.

Data collection

The following data were collected from the greenhouse and field studies.

Greenhouse study

1. Percent germination and plant survival within 2 to 4 weeks.

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

$$\% \text{ Survival} = \frac{\text{No. of alive seedlings 1 mo after emergence}}{\text{No. of seedlings that emerged}} \times 100$$

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. Plant height was measured at biweekly intervals starting one week after emergence from the soil level in the pot to the last node.

3. Number of leaf petioles. This was counted at biweekly intervals starting 2 weeks after emergence until just before field planting.

Field study

1. Plant height. This was measured starting 2 weeks after transplanting at weekly intervals during the first three months, thereafter at monthly intervals until the first pruning.
2. The number of developed leaf petioles was counted starting 2 weeks after transplanting at 3-week to monthly intervals until the first pruning.
3. The number of side shoots or branches that developed after pruning was determined.
4. Growth habit, either erect or prostate, was determined.
5. Stem diameter was measured at monthly intervals.
6. Leaf color, either green, light green or dark green, was determined.

7. The number of days to flower formation and pod development was assessed. This was recorded when a plant had developed at least one branch of fully developed/well-formed close flowers while that for the pod was counted when at least one plant had developed one pod at least 5 cm long.
8. Leaf yield. Green leaves was snapped off from the stems after pruning and then weighed.
9. Incidence of pests and diseases. Pests that infested and diseases that infected the plants were recorded.

Propagation study
The same growth parameters were measured from propagated stem cuttings obtained from mother plants. However, percent germination and percent survival were
calculated using the formula:

$$\% \text{ Germination} = \text{No. of stem cuttings with at least one healthy shoot} \div \text{no. of cuttings planted} \times 100$$

$$\% \text{ Survival} = \frac{\text{No. of alive stem cuttings}}{\text{No. of cuttings which germinated}} \times 100$$

Data analysis
All quantitative data were statistically analyzed using ANOVA for CRD and RCBD at the 5% level of significance. Significant differences between and among means were determined using DMRT at the 5% level of significance. Susceptibility to pests and/or diseases was categorized as susceptible, moderately susceptible, or not susceptible.

RESULTS AND DISCUSSION
Field and propagation studies are still in progress; only results of greenhouse and observational studies are reported here.

Greenhouse study and observational trial
The number of days from sowing (seeding) to seedling emergence varied with accessions and ranged from 6.3 to 10.6 days (Table 2). Accession Mo-34 (La Mu E) from India was the earliest to emerge and Mo-40 (PKM-1) from India was the latest.

The percentage seed germination ranged from 40 to 100%, with eight accessions having 100% and eight accessions with 80% germination (Table 3). Two accessions from Thailand had poor germination (40%). All seeds that germinated developed into healthy seedlings with 80 to 100% survival (Table 3).

At 28 weeks after second pruning (Table 4), accessions Mo-2 (USA) and Mo-40 (India) produced the tallest plants (5.6 and 5.1 m, respectively), whereas Mo-34 (India) produced the shortest plants (2.9 m).

Mean stem diameter (Table 5) ranged from 3.5 cm (Mo-34) to 8.5 cm (Mo-4, Thailand). Mo-38 (Thailand) produced the highest number of branches (5.3), whereas Mo-33 (Philippines) showed the lowest number of branches (2.0) per plant.

Two accessions from Thailand resulted in the highest leaf fresh weight, which exceeded 2 kg/plant from two prunings (Table 5). Eight accessions produced leaf fresh biomass that exceeded 1 kg/plant. Based on this yield and the plant population, these accessions have yield potential of 3 to 6 t/ha of fresh leaf biomass. Results of previous evaluation trials at AVRDC indicated that at high plant population density (44,444 plants/ha) accessions Mo-29 (India), Mo-34 (India) and Mo-35 (Tanzania) produced 60-70 t/ha of young shoot biomass from two harvests (Palada et al. 2007). Mo-3 (Taiwan) developed the highest number of pods, whereas Mo-34 produced the highest number of seeds.

Plant survival under waterlogged conditions
Moringa plants are very sensitive to water logging and typically will not survive under prolonged flooding or water logged conditions. In the Philippines frequent rainfall brought about by typhoons during monsoon season results in fields being flooded for several days. In

the field trial, most of the *Moringa* accessions survived the intermittent flooded condition of the field. It was observed that plants tolerated the waterlogged soil conditions for several days and when water receded and soil moisture decreased, plants developed new shoots.

Data of Table 6 show that 84% of the accessions had 100% plant survival. Only three accessions (Mo-4, Mo-12 and Mo-40) had less than 100% survival. Between accessions the rate of recovery and regrowth (development of new shoots) varied (data not shown). Although most of the accessions survived the flooded conditions, after frequent rainfall this factor delays normal growth and development of plants. *Moringa* accessions with high tolerance to flooding are therefore ideal and suitable for areas with high annual rainfall. The results reported here are different from studies conducted at AVRDC, Taiwan where in general, plant survival of most accessions was below 100% (Palada et al. 2012).

Incidence of pests and diseases

Throughout the field trial few insect pests were identified. Red mites (*Tetranychus urticae*), Coccinellid beetles (Coccinellidae), leaf-footed bug (*Leptoglossus phyllopus*) and whiteflies (*Bemisia* sp.) were present, but caused only minor damage to plants. Stem rot was the only disease observed in a few plants.

CONCLUSION

This preliminary evaluation trial suggests that there are promising *Moringa* accessions adapted for Central Philippines conditions with potential for high leaf biomass production. Accessions from Thailand and India possess desirable horticultural traits such as leaf fresh weight, stem diameter and number of side branches. These accessions should be propagated and multiplied for commercial production. This will be the next step in the R&D program at Central Philippine University.

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TABLES

Table 1. *Moringa* germplasm accessions selected for horticultural characterization study at CPU, Iloilo, Philippines. 2009.

Acc. No.	Genus	Species	Pedigree Cultivar	Country
Mo-2	*Moringa*	*oleifera*	Virgin Islands	USA
Mo-3	*Moringa*	*oleifera*	La-Mu	Taiwan
Mo-4	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-6	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-7	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-8	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-9	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-12	*Moringa*	*oleifera*	Ma Rum Khaw Nheaw	Thailand
Mo-14	*Moringa*	*oleifera*	Ma Rum Khaw Jaw	Thailand
Mo-15	*Moringa*	*oleifera*	Ma Rum Khaw Nheaw	Thailand
Mo-20	*Moringa*	*oleifera*	Ma Rum	Thailand
Mo-29	*Moringa*	*oleifera*	TNAU-1	India
Mo-33	*Moringa*	*oleifera*	Davao Malunggay	Philippines
Mo-34	*Moringa*	*oleifera*	La Mu E	India
Mo-35	*Moringa*	*oleifera*	RCA Moringa	Tanzania
Mo-37	*Moringa*	*oleifera*	Vientiane Pak-Ihum	Lao PDR
Mo-38	*Moringa*	*oleifera*	Ma Rum C	Thailand
Mo-40	*Moringa*	*oleifera*	PKM-1	India

Table 2. Number of days from sowing to seedling emergence in *Moringa* accessions. CPU, Iloilo, Philippines. 20 June 2009. Observational nursery, greenhouse.

Acc. No.	Pedigree Cultivar	Country	No. days emergence
Mo-2	Virgin Islands	USA	7.4
Mo-3	La-Mu	Taiwan	7.6
Mo-4	Ma Rum	Thailand	8.5
Mo-6	Ma Rum	Thailand	8.0
Mo-7	Ma Rum	Thailand	8.6
Mo-8	Ma Rum	Thailand	8.0
Mo-9	Ma Rum	Thailand	7.5
Mo-12	Ma Rum Khaw Nheaw	Thailand	8.0
Mo-14	Ma Rum Khaw Jaw	Thailand	8.0
Mo-15	Ma Rum Khaw Nheaw	Thailand	9.8
Mo-20	Ma Rum	Thailand	7.8
Mo-29	TNAU-1	India	7.3
Mo-33	Davao Malunggay	Philippines	8.3
Mo-34	La Mu E	India	6.3
Mo-35	RCA Moringa	Tanzania	6.4
Mo-37	Vientiane Pak-Ihum	Lao PDR	9.8
Mo-38	Ma Rum C	Thailand	10.3
Mo-40	PKM-1	India	10.6

Table 3. Germination and plant survival of *Moringa* accessions. CPU, Iloilo, Philippines

Acc. No.	Country	Germination (%)	Survival (%)
Mo-2	USA	100	100
Mo-3	Taiwan	100	100
Mo-4	Thailand	100	80
Mo-6	Thailand	40	100
Mo-7	Thailand	100	100
Mo-8	Thailand	80	100
Mo-9	Thailand	80	100
Mo-12	Thailand	40	100
Mo-14	Thailand	80	100
Mo-15	Thailand	100	100
Mo-20	Thailand	100	100
Mo-29	India	80	100
Mo-33	Philippines	80	80
Mo-34	India	80	100
Mo-35	Tanzania	100	100
Mo-37	Lao PDR	80	100
Mo-38	Thailand	80	80
Mo-40	India	100	100

Total: 18 accessions with 30 seeds per accession

Table 4. Mean plant height of *Moringa* accessions CPU, Iloilo.

Acc. No.	Country	19 WA1P* (m)	28 WA2P** (m)
Mo-2	USA	2.86	5.59
Mo-3	Taiwan	2.90	4.26
Mo-4	Thailand	2.14	4.80
Mo-6	Thailand	2.20	4.22
Mo-7	Thailand	2.18	3.59
Mo-8	Thailand	2.55	3.89
Mo-9	Thailand	2.02	3.39
Mo-12	Thailand	2.18	2.95
Mo-14	Thailand	2.10	3.53
Mo-15	Thailand	1.92	3.92
Mo-20	Thailand	2.73	4.09
Mo-29	India	3.03	3.75
Mo-33	Philippines	2.74	3.58
Mo-34	India	3.25	2.88
Mo-35	Tanzania	3.64	3.32
Mo-37	Lao PDR	2.65	4.00
Mo-38	Thailand	2.04	3.31
Mo-40	India	2.24	5.08

*19 weeks after 1st pruning; **28 weeks after 2nd pruning

Table 5. Mean stem diameter, number of branches and leaf fresh weight of *Moringa* accessions.

Acc. No.	Country	Stem Diameter (cm)	No. of Branches	Leaf fresh weight (kg)
Mo-2	USA	8.4	2.8	1.78
Mo-3	Taiwan	5.1	2.6	0.77
Mo-4	Thailand	8.5	3.0	2.34
Mo-6	Thailand	5.6	2.5	1.80
Mo-7	Thailand	5.5	3.8	0.72
Mo-8	Thailand	5.2	3.8	1.15
Mo-9	Thailand	5.8	4.0	0.76
Mo-12	Thailand	4.8	3.5	0.80
Mo-14	Thailand	4.6	2.5	2.11
Mo-15	Thailand	5.7	3.4	1.64
Mo-20	Thailand	6.1	2.8	1.54
Mo-29	India	5.2	2.5	0.65
Mo-33	Philippines	5.4	2.0	1.00
Mo-34	India	3.5	3.0	0.56
Mo-35	Tanzania	4.9	3.0	0.88
Mo-37	Lao PDR	5.7	3.2	1.53
Mo-38	Thailand	5.7	5.3	1.33
Mo-40	India	7.1	4.0	1.63

Table 6. Plant survival of *Moringa* accessions after several typhoons. CPU, Iloilo, 10 Nov 2011.

Acc. No.	Pedigree Cultivar	Country	No. of seedlings	Surv. (%)
Mo-2	Virgin Islands	USA	5	100
Mo-3	La-Mu	Taiwan	5	100
Mo-4	Ma Rum	Thailand	4	75
Mo-6	Ma Rum	Thailand	5	100
Mo-7	Ma Rum	Thailand	5	100
Mo-8	Ma Rum	Thailand	5	100
Mo-9	Ma Rum	Thailand	5	100
Mo-12	Ma Rum Khaw Nheaw	Thailand	3	75
Mo-14	Ma Rum Khaw Jaw	Thailand	5	100
Mo-15	Ma Rum Khaw Nheaw	Thailand	5	100
Mo-20	Ma Rum	Thailand	4	100
Mo-29	TNAU-1	India	5	100
Mo-33	Davao Malunggay	Philippines	4	100
Mo-34	La Mu E	India	5	100
Mo-35	RCA Moringa	Tanzania	5	100
Mo-37	Vientiane Pak-Ihum	Lao PDR	5	100
Mo-38	Ma Rum C	Thailand	4	100
Mo-40	PKM-1	India	5	60
	Local variety	Philippines	5	100