



EVALUATION ON ADAPTABILITY OF INTRODUCED MORINGA (*Moringa oleifera*) ACCESSIONS IN QUANG TRI PROVINCE

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Abstract: The main objective of this study was to evaluate the ability of growth and biomass yield of introduced *Moringa* accessions in Quang Tri province. A total of eight accessions were used: four accessions from World Vegetable Center, namely VI048687, VI047492, VI048590, VI048718; two accessions, i.e, PKM-1 and Philippines local accession supplied by The University of the Philippines, one Thailand local accession and one Vietnam local accession (control) provided by Fruit and Vegetable Research Institute (Vietnam). The results showed that the control and PKM-1 had good growth and development: survival rate over 78 %, first harvesting time from 90 to 93 days and biomass yield above 356.43 g/plant (PKM-1). These accessions were suitable for local conditions. The survival rate of VI047492 and VI048687 was low, only 34.5 and 40.0 %, respectively. However, their first harvesting was on the 95th day, and biomass yield was 261.0–283.5 g/plant. These two accessions could be used for breeding and cultivation under local conditions.

Keywords: moringa, *Moringa oleifera*, Vietnam local accession, PKM-1, VI047492, VI048687, Quang Tri province

1 Introduction

Moringa (*Moringa oleifera*) is a very nutritious plant that contains a total of 90 nutrients, so it supports for people health. On the other hand, this plant is also easy to grow and brings many economic benefits. *Moringa* is considered to be the most useful plant in the world because all parts of it can be eaten and used for various purposes. *Moringa* is also a medicinal plant to reduce and heal many diseases such as anti-inflammatory, parasitic, diabetes, and cancer. Its leaves and flowers are vegetables with high levels of vitamins and nutrients; stems, branches, barks, and roots produce medicines, cosmetics, beverages, and functional foods (Palada, 1996; Makkar and Becker, 1996; Bennett et al. 2003; Fahey et al. 2005).

The World Health Organization and the Food and Agriculture Organization have recommended the application of this plant as the preeminent solution for mothers lacking milk,

malnourished children, and food solutions. Therefore, Moringa is planted and researched in many countries around the world, especially the poor ones.

Vietnam is a developing country, and its economy mainly depends on agriculture; the rate of poor people is high, especially in the central and mountainous areas. Besides, the malnourished children and the mothers lacking milk account for a large proportion. Quang Tri is a poor province and the war consequence has left serious problems concerning malnutrition. At Ba Nang commune, there are more than 50 % of children suffering from malnutrition. Therefore, this study presents research results to identify the Moringa accessions that can adapt to climate and soil conditions in Quang Tri province.

2 Materials and method

2.1 Materials

The study used a total of 8 Moringa accessions, namely one Vietnam local accession (control) provided by the Fruit and Vegetable Research Institute (Vietnam), four accessions provided by the World Vegetable Center (VI048687, VI047492, VI048590, VI048718), one Thailand local accession and two collected from The University of the Philippines (PKM-1, Local Philippines) (Table 1). Planting and nursing techniques were based on - The World Vegetable Center (AVRDC) guidelines.

Table 1. List of Moringa accessions used

No.	Name of accession	Pedigree/ cultivar name	Place of collection	Place of origin
1	Local Vietnam (Control)	Chum ngay	Fruit and Vegetable Research Institute	Ninh Thuan, Vietnam
2	VI048687	MARUM	World Vegetable Center	Thailand
3	VI047492	LA-MU	World Vegetable Center	Taiwan
4	VI048590	VIRGIN ISLANDS' DRUMSTICK	World Vegetable Center	USA
5	VI048718	MARUM	World Vegetable Center	Thailand
6	Local Thailand	MARUM	Yasothon province	Thailand
7	PKM-1	Malunggay	The University of the Philippines	Philippines
8	Local Philippines	Malunggay	The University of the Philippines	Philippines

2.2 Methods

Experimental design

The field experiment was conducted from January 2016 to October 2016 in an open field at Vinh Linh District, Quang Tri Province. The experiment was laid out in a random complete block design with three replicates. Each accession was observed with five plants per replicate. The plant density applied in this study was 1.5×1 m.

Agronomy characteristic collection

The data parameters depended on the AVRDC guidelines. They were survival rate and time of growth of each accession. The botanical characteristics included the leaf colour, shape of the last foliole and the middle foliole, pairs of foliose, and leaf attachment type. The ability of growth was evaluated based on the number of leaves, plant height, plant diameter and stem diameter. The biomass yield and biomass yield components consisted of the fresh branch leaf weight, fresh leaf weight, and dried leaf weight. The biomass yield, number of branches and branch length were collected every 30 days after first cutting.

Data analysis

Data were calculated using Excel 2007 and analysed with the statistical software Statistix 10.0.

2.3 Weather conditions during the experiment

Table 2 shows the effect of weather conditions on the Moringa growth during the experiment. In January and February, seedlings were affected by low average temperature with 20.8 °C and 18.4 °C, respectively; the average humidity was 91 % in January and 86 % in February.

From March to October, the average temperature ranged from 21.8 °C to 30.8 °C that was favourable for the growth and development of Moringa. March had the lowest average temperature (21.8 °C) and June the highest (30.8 °C). The high average humidity and high total of rainfall also affected Moringa growth.

Table 2. Meteorological conditions recorded from January 2016 to October 2016

Month	Average temperature (°C)	Average humidity (%)	Total of rainfall (mm)	Total sunny hours (h)
January	20.8	91	90.2	38
February	18.4	86	37.7	71
March	21.8	89	12.5	102
April	27.2	85	89.1	193
May	29.2	80	102	252
June	30.8	75	98.7	255

Month	Average temperature (°C)	Average humidity (%)	Total of rainfall (mm)	Total sunny hours (h)
July	30.0	76	75.4	261
August	30.0	74	98.4	204
September	28.5	81	443.3	157
October	26.8	90	558.1	121

Source: Center for Hydrometeorology Forecast of Dong Ha, Quang Tri Province

3 Results and discussion

3.1 Survival rate

The survival rate showed the adaptable ability of the introduced accessions under the cultivation condition. The accessions that have a high survival rate exhibit broad adaptability. The data were collected between the 21st day after transplanting (DAT) and the first cutting (plant height at 75 cm). The survival rate of Moringa accessions is presented in Table 3.

At 21 DAT, the survival rate among accessions was different because it depended greatly on the vitality of seeds and the adaptability of seedlings. PKM-1 had the survival rate at 100 %, the lowest was VI047492 with 79.3 %, and the survival rate of the remaining accessions ranged from 80 % to 89.2 %. At 120 DAT, the control check, Local Thailand and PKM-1 had the survival rate above 78 % and higher than that of the others. These accessions had high adaptability under the climate condition in Quang Tri Province.

Table 3. Survival rate of Moringa accessions

Accession	Days after transplanting								Unit: %
	21	30	60	90	120	150	180	210	
Control	89.2 ^b	88.2 ^{ab}	80.1 ^b	78.8 ^b	78.8 ^b	78.8 ^b	78.8 ^b	78.8 ^b	
VI048687	86.7 ^{bcd}	86.7 ^b	80.0 ^b	60.0 ^c	60.0 ^c	60.0 ^c	40.0 ^c	40.0 ^c	
VI047492	79.3 ^e	79.3 ^c	50.4 ^d	50.4 ^d	50.4 ^d	34.5 ^e	34.5 ^d	34.5 ^d	
VI048590	80.0 ^e	73.4 ^d	61.8 ^c	41.7 ^e	41.7 ^e	41.7 ^d	41.7 ^c	41.7 ^c	
VI048718	82.1 ^{de}	72.5 ^d	52.5 ^d	25.0 ^f	25.0 ^f	25.0 ^f	25.0 ^e	25.0 ^e	
Local Thailand	88.2 ^{bc}	88.2 ^{ab}	82.6 ^b	79.3 ^a	79.3 ^b	79.3 ^b	79.3 ^b	79.3 ^b	
PKM-1	100.0 ^a	92.4 ^a	87.5 ^a	85.0 ^a	85.0 ^a	85.0 ^a	85.0 ^a	85.0 ^a	
Local Philippines	83.3 ^{cde}	73.3 ^d	63.5 ^c	52.3 ^d	40.0 ^e	40.0 ^d	40.0 ^c	40.0 ^c	
LSD _{0.05}	2.52	2.65	2.29	2.08	2.18	2.04	2.14	2.14	
CV %	5.34	5.61	4.86	4.41	4.62	4.33	4.54	4.54	

Different letters a, b, c, d, e, f in each column indicate different means at $\alpha = 0.05$

3.2 Time of growth

The time of growth is an important factor to determine the crop season and planting time. The crops that have different ecological conditions will have a different growth time and harvesting time.

Table 4 shows the time of growth and development of Moringa accessions. The time from transplanting to the first harvesting had a significant difference among accessions. Accession PKM-1 had the shortest time at 90 days, followed by Local Thailand and VI048590 with 92 days, the control check with 93 days, and VI048718 and Local Philippines had the longest time at 98 days. There were no differences in the growth time at each of the rest 4 harvestings.

Table 4. Growth time of Moringa accessions

Unit: Day

Accession	Time from transplanting to				
	1 st harvesting	2 nd harvesting	3 rd harvesting	4 th harvesting	5 th harvesting
Control	93	120	150	180	210
VI048687	95	120	150	180	210
VI047492	95	120	150	180	210
VI048590	92	120	150	180	210
VI048718	98	120	150	180	210
Local Thailand	92	120	150	180	210
PKM-1	90	120	150	180	210
Local Philippines	98	120	150	180	210

3.3 Leaf morphological characteristics

Each accession had different leaf morphological characteristics, and they are signals to identify and distinguish the accessions. The leaf colour and foliole shape also show the economic value of an accession. The cultivar with beautiful folioles and green colour is preferred.

The leaf morphological parameters of Moringa accessions are presented in Table 5. The leaf colour of the control check, VI048687, VI047492, VI048590, and VI048718 was dark green; whereas Local Thailand, PKM-1 and Local Philippines had a green colour.

The shape of leaves is one of the morphological characteristics for each accession. While the top foliole of the control check, VI048718, Local Thailand was oval, VI048687 and PKM-1 had a long ellipse shape; VI047492 and VI048590 were long ovals; a round foliole was observed in Local Philippines.

The middle-foliolate shape of the accessions was also different. While the control check and VI048590 had a round middle foliole, VI048687, VI048718, and Local Thailand had an oval shape; PKM-1 and Local Philippines were long ovals; the middle foliole of VI047492 was in a long ellipse shape.

All accessions in this study had 3 pairs of folioles. This characteristic is controlled by genetics.

The leaf attachment type of petiole was different among accessions. The control check and Local Philippines had an upright attachment. Accessions VI048687, VI047492, VI048590, VI048718, and PKM-1 had a medium standing attachment. Local Thailand had a standing attachment.

Table 5. Leaf morphological characteristics of Moringa accessions

Accession	Leaf colour	Shape of top foliole	Shape of middle foliole	Pairs of foliole	Leaf attachment type
Control	Dark green	Oval	Round	3	Upright
VI048687	Dark green	Long ellipse	Oval	3	Medium standing
VI047492	Dark green	Long oval	Long ellipse	3	Medium standing
VI048590	Dark green	Long oval	Round	3	Medium standing
VI048718	Dark green	Oval	Oval	3	Medium standing
Local Thailand	Green	Oval	Oval	3	Standing
PKM-1	Green	Long ellipse	Long oval	3	Medium standing
Local Philippines	Green	Round	Long oval	3	Upright

Table 6. Number of leaves of Moringa accessions

Accession	Days after transplanting		
	30	60	90
Control	6.00 ^a	8.80 ^a	8.07 ^a
VI048687	5.70 ^a	8.20 ^a	9.47 ^a
VI047492	5.53 ^a	9.17 ^a	8.87 ^a
VI048590	5.77 ^a	9.17 ^a	9.83 ^a
VI048718	5.33 ^a	8.00 ^a	9.33 ^a
Local Thailand	5.00 ^a	8.47 ^a	8.13 ^a
PKM-1	6.53 ^a	9.27 ^a	8.93 ^a
Local Philippines	6.17 ^a	7.87 ^a	9.03 ^a
LSD _{0.05}	0.79	0.98	1.11
CV (%)	1.68	2.08	2.36

Unit: Leaves

^a Letter in each column indicate the means at $\alpha = 0.05$

3.4 Growth ability

Number of leaves

The number of leaves of Moringa accessions is presented in Table 6. At 30 DAT, the leaf number of Moringa accessions ranged from 5 to 6 leaves. At 60 DAT, Local Philippines had the lowest leaf number (7.87 leaves/plant), and PKM-1 had the highest leaf number (9.27 leaves/plant). This difference was insignificant. At 90 DAT, the leaf number ranged from 8.07 (control) to 9.83 (VI048590). However, the leaf number was reduced with the control check, VI047492, Local Thailand, and PKM-1 from 60 to 90 DAT. This could be due to the fact that the leaves dropped. Thus, the leaf life of the control check, VI047492, Local Thailand, and PKM-1 was shorter than that of VI048687, VI048590, VI048718, and Local Philippines. Thus, accessions VI048687, VI048590, VI048718, and Local Philippines had a long leaf life, and the leaf number increased every 30 DAT.

Plant height

The progress of the plant height of Moringa accessions is shown in Table 7. At 30 DAT, the plant height among the accessions had a significant difference. Accession PKM-1 had the highest plant height at 36.87 cm. The shortest plant height was observed in VI048718 with 16.27 cm.

From 30 to 60 DAT, the plant height increased significantly in VI047492 to 42.03 cm, whereas Local Thailand and the control check had the lowest increase with 15.90 cm and 13.67 cm, respectively.

From 60 to 90 DAT, accession PKM-1 still had the biggest height with 136.33 cm, and the lowest height was observed in Local Philippines with 74.83 cm.

Table 7. Plant height of Moringa accessions

Accession	Days after transplanting		
	30	60	90
Control	32.40 ^{ab}	13.67 ^e	99.08 ^c
VI048687	25.17 ^c	28.90 ^d	104.77 ^{bc}
VI047492	30.80 ^b	42.03 ^a	102.53 ^c
VI048590	29.60 ^{bc}	32.37 ^{cd}	104.23 ^{bc}
VI048718	16.27 ^d	38.93 ^{ab}	115.67 ^b
Local Thailand	25.80 ^c	15.90 ^e	99.23 ^c
PKM-1	36.87 ^a	36.80 ^b	136.33 ^a
Local Philippines	19.93 ^d	35.07 ^{bc}	74.83 ^d
LSD _{0.05}	2.24	2.00	6.17
CV (%)	4.75	4.26	13.08

Unit: cm

Different letters a, b, c, d, e in each column indicate different means at $\alpha = 0.05$

Plant diameter

The plant diameter is one of the indicators to predict the biomass yield of Moringa. This is an important factor to identify the plant density. Table 8 shows the plant diameter of the Moringa accessions. The data indicated a significant difference among accessions. At 30 DAT, the plant diameter ranged from 16.83 cm (Local Thailand) to 26.43 cm (VI047492).

From 60 to 90 DAT, the plant diameter increased greatly and had a significant difference among accessions. At 90 DAT, while accessions VI048590 and VI048687 had the largest plant diameter with 100.00 cm and 103.33 cm, respectively, Local Thailand had the smallest one with 62.00 cm.

Table 8. Plant diameter of Moringa accessions

Unit: cm

Accession	Days after transplanting		
	30	60	90
Control	22.83 ^{ab}	41.00 ^{cd}	74.67 ^{bc}
VI048687	23.17 ^{ab}	59.00 ^{ab}	103.33 ^a
VI047492	26.43 ^a	66.33 ^a	98.67 ^a
VI048590	20.77 ^{ab}	61.33 ^a	100.00 ^a
VI048718	18.90 ^b	42.00 ^{cd}	79.67 ^b
Local Thailand	16.83 ^b	40.67 ^{cd}	62.00 ^d
PKM-1	26.00 ^a	49.67 ^{bc}	99.67 ^a
Local Philippines	20.10 ^{ab}	37.00 ^d	68.00 ^{cd}
LSD _{0.05}	3.25	4.56	4.78
CV (%)	6.89	9.66	10.14

Different letters a, b, c, d in each column indicate different means at $\alpha = 0.05$

Stem diameter

The stem diameter is an important indicator for the growth ability of the accessions. The stem diameter was recorded and presented in Table 9.

At 30 DAT, the stem diameter of the accessions ranged from 0.41 cm to 0.62 cm. Accession VI048718 had the smallest stem diameter at 0.41 cm and the largest was PKM-1 at 0.62 cm.

At 150 DAT to 210 DAT, the stem diameter increased significantly, ranging from 2.52 cm (control) to 3.29 cm (PKM-1), and from 2.82 cm (VI048718) to 3.86 cm (PKM-1), respectively.

Table 9. Stem diameter of Moringa accessions

Accession	Days after transplanting						
	30	60	90	120	150	180	210
Control	0.57 ^a	1.05 ^{ab}	1.92 ^a	2.36 ^a	2.52 ^a	2.82 ^a	3.27 ^a
VI048687	0.53 ^{ab}	1.12 ^{ab}	1.95 ^a	2.68 ^a	3.08 ^a	3.28 ^a	3.61 ^a
VI047492	0.55 ^a	1.09 ^{ab}	2.14 ^a	2.70 ^a	2.85 ^a	3.07 ^a	3.30 ^a
VI048590	0.60 ^a	1.09 ^{ab}	2.40 ^a	2.71 ^a	2.85 ^a	2.96 ^a	3.22 ^a
VI048718	0.41 ^b	0.94 ^b	2.07 ^a	2.41 ^a	2.57 ^a	2.72 ^a	2.82 ^a
Local Thailand	0.57 ^a	1.15 ^{ab}	1.81 ^a	2.58 ^a	2.79 ^a	3.00 ^a	3.41 ^a
PKM-1	0.62 ^a	1.35 ^a	2.59 ^a	3.13 ^a	3.29 ^a	3.53 ^a	3.86 ^a
Local Philippines	0.51 ^{ab}	0.95 ^b	1.74 ^a	2.22 ^a	2.38 ^a	2.45 ^a	2.94 ^a
LSD _{0.05}	0.06	0.19	0.42	0.58	0.61	0.64	0.70
CV (%)	0.13	0.39	0.89	1.23	1.30	1.37	1.49

^{a, b} Different letters in each column indicate different means at $\alpha = 0.05$

3.5 Biomass yield and biomass yield components

The individual biomass yield was calculated after the second cutting (from 120 to 150 DAT), which showed the potential for the biomass yield of the accessions. The biomass yield and biomass yield components had a significant difference among accessions (Table 10).

The fresh branch leaf weight ranged from 144.42 grams (Local Philippines) to 356.43 grams (PKM-1). The highest fresh leaf weight was also obtained in PKM-1 (220.60 grams).

The dried leaf weight was significantly different among accessions. Accession PKM-1 had the highest dried leaf weight with 36.67 grams and the lowest was Local Philippines with 24.00 grams.

Table 10. Biomass yield and biomass yield components of Moringa accessions

Accession	Individual biomass yield		
	Fresh branch leaf weight	Fresh leaf weight	Dried leaf weight
Control	147.93 ^{fg}	92.20 ^e	35.67 ^a
VI048687	283.50 ^b	174.08 ^b	34.00 ^a
VI047492	261.00 ^c	160.60 ^c	28.67 ^{ab}
VI048590	235.32 ^d	147.00 ^d	21.33 ^{bc}
VI048718	155.26 ^e	96.7 ^e	24.33 ^{bc}
Local Thailand	152.14 ^{ef}	92.20 ^e	20.00 ^c

Accession	Individual biomass yield		
	Fresh branch leaf weight	Fresh leaf weight	Dried leaf weight
PKM-1	356.43 ^a	220.60 ^a	36.67 ^a
Local Philippines	144.42 ^s	89.20 ^e	24.00 ^{bc}
LSD _{0.05}	3.14	4.42	4.08
CV (%)	6.40	9.00	8.65

Different letters a, b, c, d, e, f, g in each column indicate different means at $\alpha = 0.05$

3.6 Number of Branches

The number of branches shows the shooting ability of each Moringa accession. Table 11 records the number of branches of the accessions. At the first harvesting time (HT), accession PKM-1 had the highest number of branches (4.20) and the lowest was the Local Philippines with 2.17 branches.

At the second and third HT, this parameter changed in each accession. At the fourth HT, accession PKM-1 still had the highest number of branches with 7.07, followed by VI047492 and VI048687 with 5.63 and 5.34 branches, respectively; Local Philippines had the lowest number of branches (3.53).

Table 11. Number of branches of Moringa accessions

Unit: Branches

Accession	After first cutting to			
	First harvesting	Second harvesting	Third harvesting	Fourth harvesting
Control	3.53 ^{ab}	3.30 ^a	3.87 ^{ab}	4.93 ^{bc}
VI048687	3.30 ^{abc}	4.20 ^a	4.53 ^{ab}	5.43 ^{abc}
VI047492	3.57 ^{ab}	4.43 ^a	4.33 ^{ab}	5.63 ^{ab}
VI048590	2.67 ^{bc}	3.17 ^a	3.50 ^{ab}	5.33 ^{abc}
VI048718	2.33 ^c	3.33 ^a	3.00 ^b	4.33 ^{bc}
Local Thailand	3.53 ^{ab}	3.53 ^a	3.87 ^{ab}	4.53 ^{bc}
PKM-1	4.20 ^a	4.33 ^a	5.93 ^a	7.07 ^a
Local Philippines	2.17 ^c	3.00 ^a	3.43 ^{ab}	3.53 ^c
LSD _{0.05}	0.54	0.71	1.27	0.96
CV (%)	1.14	1.50	2.70	2.03

^{a, b, c} Different letters in each column indicate different means at $\alpha = 0.05$

3.7 Branch length

Table 12 shows the branch length of the Moringa accessions. The branch length was significantly different among accessions every 30 days after the first cutting. At the first HT, the branch length of PKM-1 was the longest (67.98 cm), and Local Philippines had the shortest branch length (35.83 cm).

At the next harvestings, this indicator changed with each accession. Accession PKM-1 still had the longest branch length in all harvestings with 74.68 cm (the second HT), 71.92 (the third HT) and 84.67 cm (the fourth HT). This was one of the reasons making this accession have a high biomass yield.

Table 12. Branch length of Moringa accessions

Unit: cm

Accession	After first cutting to			
	First harvesting	Second harvesting	Third harvesting	Fourth harvesting
Control	36.13 ^d	44.07 ^d	49.93 ^{bc}	65.33 ^c
VI048687	46.42 ^c	51.33 ^c	54.92 ^b	75.92 ^b
VI047492	46.36 ^c	55.47 ^{bc}	67.80 ^a	74.08 ^b
VI048590	58.17 ^b	57.83 ^b	65.17 ^a	66.83 ^c
VI048718	62.33 ^{ab}	56.00 ^{bc}	46.00 ^c	54.67 ^d
Local Thailand	45.07 ^{cd}	41.60 ^{de}	48.67 ^{bc}	47.73 ^e
PKM-1	67.98 ^a	74.68 ^a	71.92 ^a	84.67 ^a
Local Philippines	35.83 ^d	35.27 ^e	53.14 ^b	48.44 ^{de}
LSD _{0.05}	4.43	2.99	3.31	3.20
CV (%)	9.40	6.34	7.02	6.79

Different letters a, b, c, d, e in each column indicate different means at $\alpha = 0.05$

4 Conclusions

The research showed the adaptability of Moringa accessions under Quang Tri Province climate. The survival rate of the control check, Local Thailand and PKM-1 were at 78.8 %, 79.3 %, and 85.0 %, respectively, higher than that of the others. Accession PKM-1 had the shortest time of the first harvesting after transplanting with 90 days, while Local Philippines and VI048718 were the longest with 98 days. Each accession had typical leaf morphological characteristics. The local conditions influenced the growth ability of Moringa accessions. Local Philippines had the lowest data of plant height, plant diameter among other accessions. The control check and PKM-1 had the highest dried leaf weight with 35.67 grams/plant and 36.67 grams/plant. Accession PKM-1 got the highest number of branches and the longest branch length.

5 Suggestion

The control check and PKM-1 were suitable for planting under the conditions in Quang Tri Province.

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