International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 6, No. 3, p. 97-105, 2015

RESEARCH PAPER OPEN ACCESS

Morphological variation, cultivation techniques and management practices of *Moringa oleifera* in Southern Benin (West Africa)

Eric E. Agoyi[1,2], Elie A. Padonou[1*], Amoussa W[3]., Achille E. Assogbadjo[1], Romain Glèlè Kakaï[4], Brice Sinsin[1]

[1]*Laboratory of Applied Ecology, University of Abomey-Calavi, Cotonou, Benin.*

[2]*Department of crop science, Makerere University of Uganda, Kampala, Uganda*

[3]*Department of Nutrition and Food Sciences, University of Abomey-Calavi, Cotonou, Benin.*

[4]*Laboratory of Biomathematics and Forest estimations, University of Abomey-Calavi, Cotonou, Benin*

Article published on March 21, 2015

Key words: *Moringa oleifera*, Phenotypic variation, Management practices, Phytodistricts.

Abstract

This study examined the phenotypic variation and the modalities for integrating *Moringa oleifera* in agroforestry systems in southern Benin in order to contribute to sustainable management of the species. Morphological characterization of *M. oleifera* based on measurements taken on the trees, leaves, leaflets and fruits, and ethno-botanical survey on cultivation techniques and management of plantation of the species were performed. The morphological analysis showed significant variation between populations of *M. oleifera* in the phytodistricts considered in relation to tree height, leaf length, petiole diameter, length and width of leaflets ($P < 0.001$); length, median diameter and fresh weight of pods ($P < 0.01$). In the phytodistricts considered in the southern Benin, the culture of *M. oleifera* was mainly by cuttings (92.85 to 97.8%) and row planting (91.83 to 98.03%). The adoption rate of *M. oleifera* varied between 89.79 and 97.05%. There was significant dependence between the management practices and the willing for adoption ($\Delta G2 = 5.59$, $P = 0.018$), between management practices and the origin of planting materials ($\Delta G2 = 5.50$, $P = 0.019$).

* **Corresponding Author:** Elie A. Padonou ✉ padonouelie@yahoo.fr

Introduction

Moringa oleifera is a multipurpose plant species that originated from India and widespread in Africa. It is used by rural populations in human and animal feeding, traditional medication, house and field fencing. *M. oleifera* has gained interest in this last century because of its nutritional and medicinal values. Fahey (2005), Thurber and Fahey (2009) reported that *M. oleifera* contains all the essential nutritional elements essential for livestock and human beings (highly digestible proteins, Calcium, Iron and Vitamin A and C). It also contains vitamin B-Complex, chromium, copper, magnesium, manganese, phosphorus and zinc (Fuglie, 2001a,b). Since 1998, the World Health Organization has promoted *M. oleifera* as an alternative of imported food supplies to treat malnutrition (Sreelatha and Padma, 2009). Authors reported that to solve malnutrition issues, doctors, nurses, and midwives were trained in preparing and using *M. oleifera* leaves powder (Johnson, 2005; Manzoor *et al.*, 2007; Sreelatha and Padma, 2009; UNWFP, 2004). Number of studies have shown that *M. oleifera* induces antiulcer effect, effect on immune response, spasmolytic activities, hypercholesterolemia effects, antibacterial activity (Talreja, 2010). Sympatholytic activity and antiviral activity against herpes simplex virus type-1 (Haristoy *et al.*, 2005). According to (Sreelatha and Padma, 2009), the extracts of *M. oleifera* leaves have probable antioxidant activity against free radicals, prevent oxidative damage to major biomolecules and afford significant protection against oxidative damage. It has been reported that *M. oleifera* leaves are suitable for livestock feed and fodder (Mathur, 2006; Reyes- Sánchez *et al.*, 2006). Recently, *M. oleifera* has been reported having a role in growth enhancement (Anjorin *et al.*, 2010; Phiri and Mbewe, 2010; Ali *et al.*, 2011; Yasmeen *et al.*, 2013) of crops such as wheat (Yasmeen *et al.*, 2012 and 2013). Authors have been interested in management practices of plantations of *M. oleifera*. Plants spacing and harvesting frequencies were the most targeted. Amaglo *et al.* (2006) recommended a spacing of 5 cm x 15 cm for leaves production coupled by an interval between two harvestings of 35 d where the leaves are found to be richest in nutrients. Gadzirayi *et al.* (2013) found a spacing of 15 cm x 15 cm or 20 cm x 20 cm more efficient. According to them cutting should occur at intervals of 60 to 75 days. In Benin, *M. oleifera* is well known and appreciated by the local populations for its nutritional and medicinal values, even some initiatives of commercializing its products arose (Agoyi *et al.*, 2014). Despite the NGOs and other associations promoting *M. oleifera* in Benin, little has been done in terms of research on this species (Aissi *et al.*, 2014; Agoyi *et al.*, 2014). In view of the importance *M. oleifera* gains in Benin and worldwide, there is need for seeking its best management. For this purpose, the present study aims at assessing i) the morphological variation between populations of *M. oleifera,* and (ii) the cultivation techniques and management practices of *M. oleifera* plantations.

Materials and methods

Study area

The study took place in four phytodistricts (Plateau, Coast, Oueme and Pobe) located in humid climate zone in Benin (Fig. 1).

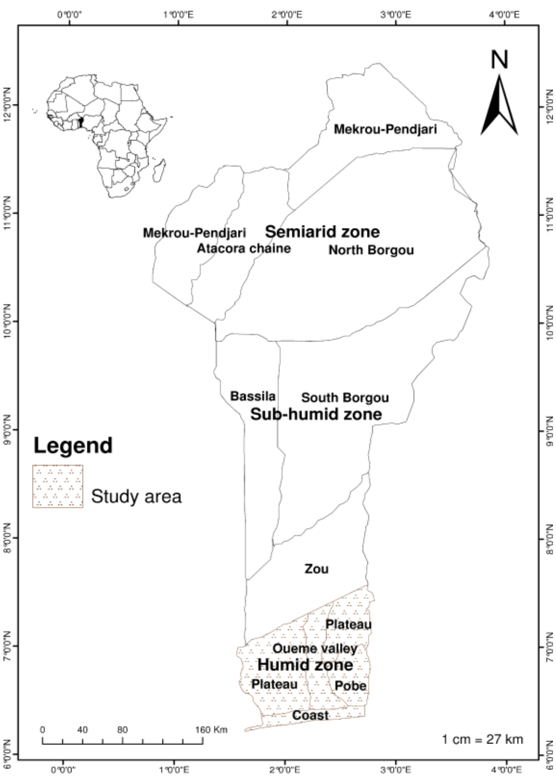

Fig. 1. Location of the phytodistricts considered in the climate zones of Benin.

The rainfall in this zone is bimodal with an annual average of 1200 mm. The annual average temperature ranges between 25 and 29°C and the relative humidity between 69 and 97 %. The soils are deep ferralsols or rich in clay, in humus and minerals. The main ethnic groups in the zone are Fon, Adja, Yoruba and other assimilated groups (Floquet and Van den Akker, 2000).

Morphological variation of M. oleifera between phytodistricts

The morphological characterization of *M. oleifera* concerned the trees, leaves, leaflets and fruits. In each phytoditrict, 25 trees were sampled at random. Plant height (H) and diameter at breast height (DBH) were measured using respectively a clinometer SUUNTO and a girthing tape.

A total of 15 fresh leaves and 15 fruits were collected at random per tree because a minimum of 10 samples of a given plant part is enough to describe the existing variations in the population regarding the plant part for a given agro-ecological zone (Palmerg, 1985). The leaf length (LFe), the diameter of petiole (Dp), the leaflet length (LFo) and width (lfo) were measured in centimeter (cm) using electronic calipers. On the fruits collected, pod length (LFr), diameter (Dm) and fresh pod weight (PFr) were measured with a spring balance (American Weigh Scale Sr-1kg Gray Digital Hanging Scale, Gray, 1000g X 1 G).

Analysis of variance (ANOVA) and Student Newman Keuls test were used to compare the variation observed on the tree (height and DBH), the leaves (leaf length, diameter of petiole, leaflet length and width) and the fruits (pod length, median diameter and fresh pod weight) between phytodistricts using SAS 9.2 statistical software (SAS Inc., 2008). No data transformation was applied because normality and homoscedasticity were checked without transformation using the Ryan-Joiner test of Normality, and the Levene test for homogeneity of variances (Glèlè Kakaï *et al*., 2006).

Cultivation techniques and management practices of M. oleifera

Data on the cultivation techniques and management practices of *M. oleifera* were collected through individual semi-structured interviews. Focus group discussions were completed to check the reliability of the data collected during the individual interview. The discussion groups were often formed by 5 to 7 people. The information collected were about: (i) the cultivation techniques and management practices, (ii) the willingness to plant the species at large scale as well the origin of the cuttings, seeds and nurseries used for plantation. The sample size was determined using the normal approximation of binomial distribution (Dagnelie, 1998):

$n= U^2_{1-\alpha/2} \times P(1-P)/d^2$ where n is the sample size, P is the proportion of informants using and planting the species. $U_{1-\alpha/2}$ is the value of the normal random variable. For a probability value of $1-\alpha/2$, $U^2_{1-\alpha/2} \approx 1.96$ with $\alpha = 0.05$. d is the margin error of the estimation; 5 % was considered.

To compute the size of the sample, a brief survey on 30 persons per locality was carried out. The interviewed persons were asked if they have planted *M. oleifera*. The proportion P of positive answers was considered. On this basis 384 people with 150 women were interviewed.

Data on the cultivation techniques and management practices were encoded after counting the questionnaire sheets. Frequencies were attributed to the variables measured (origin of seed, cultivation techniques, space management and willingness to adopt). Log-linear analysis was used to test the relationships between the variables and the phytodistricts.

Results

Morphological variation in M. oleifera between phytodistricts

The analysis of variance showed significant difference ($p < 0.001$) between phytodistricts regarding tree (height and DBH) and leaves (leaf length, diameter of petiole, leaflet length and width). The difference between phytodistricts regarding fruit (pod length, median diameter and fresh pod weight) was significant at 0.01. The tallest trees (7.18 m) were found in Oueme ($p < 0.05$) while the shortest (3.51 m) were found in Plateau (Table 1).

Table 1. Morphological variation in *M. oleifera* trees in height and DBH between phytodistricts.

Phytodistricts	Height (cm)	DBH (cm)
Coast	4.25 ± 0.29^{c}	10.26 ± 0.70^{a}
Plateau	3.51 ± 0.14^{c}	6.38 ± 0.21^{b}
Pobe	5.95 ± 0.37^{b}	7.58 ± 0.90^{b}
Oueme	7.18 ± 0.20^{a}	4.51 ± 0.30^{c}

Values are means ± standard error. The mean values followed by the same letter in the same column are not statistically different at 5% (Student Newman Keuls test).

The variation between the Plateau and the Coast regarding the trees height was not significant. The DBH of the trees from the Coast were the highest (10.26 cm), while the smallest (4.51 cm) were from Oueme. The variation in DBH of the trees between Plateau and Pobe was not significant (table 1). Overall, the Oueme had the tallest and slimmest trees whereas the Coast had the shortest and fattest trees.

The Oueme had the highest values for the variables measured on leaves compared to the other phytodistricts (Table 2).

Table 2. Morphological variation in *M. oleifera* leaves and leaflets between phytodistricts.

Phytodistricts	Variation in leaves		Variation in leaflets	
	Leaf length (cm)	Diameter of petiole (cm)	Leaflet length (cm)	Leaflet width (cm)
Coast	40.93 ± 1.12^{b}	0.55 ± 0.01^{c}	2.33 ± 0.05^{c}	1.23 ± 0.03^{b}
Plateau	36.72 ± 0.77^{c}	0.49 ± 0.01^{d}	2.43 ± 0.03^{cb}	1.29 ± 0.02^{b}
Pobe	39.65 ± 1.15^{b}	0.61 ± 0.01^{b}	2.53 ± 0.04^{b}	1.38 ± 0.03^{a}
Oueme	48.56 ± 1.11^{a}	0.66 ± 0.01^{a}	2.71 ± 0.05^{a}	1.41 ± 0.03^{a}

Values are means ± standard error. The mean values followed by the same letter in the same column are not statistically different at 5% (Student Newman Keuls test).

The difference in leaf length between the phytodistricts of Coast and Pobe was not significant. The phytodistrict of Plateau had the shortest leaves with small diameter of petiole (Table 2). The shortest leaflets in length were found in the Coast (Table 2). The leaflet width was statistically similar in the Coast and Plateau in one hand and in Pobe and Oueme in other hand (Table 2).

The variation in fruit (pod length, median diameter and fresh pod weight) between phytodistricts was presented in Table 3. The longest pods (34.20 cm) were from the phytodistrict of Plateau, while the shortest (27.45 cm) from Oueme. The difference in pod length between the Coast and Pobe was no significant (Table 3).

Table 3. Morphological variation in *M. oleifera* fruit (pod length, median diameter and fresh pod weight)

Phytodistricts	Pod length	Median diameter	Average weight
Coast	30.56 ± 1.61^{ab}	2.06 ± 0.06a	66.80 ± 7.34^{a}
Plateau	34.20 ± 0.83^{a}	1.89 ± 0.03^{ab}	83.96 ± 3.80^{a}
Pobe	30.76 ± 1.73^{ab}	1.87 ± 0.07^{ab}	67.07 ± 7.89^{a}
Oueme	27.45 ± 1.66^{b}	1.73 ± 0.07^{b}	73.65 ± 7.60^{a}

The values are means ± standard error. The mean values followed by the same letter in the same column are not statistically different at 5% (Student Newman Keuls test).

Concerning the median diameter of pods, the phytodsitricts of Plateau and Pobe were statistically similar (Table 3). The biggest pods were from the Coast while the smallest were from the Oueme. The average weight of pods was statistically similar in all the phytodistricts (Table 3).

Cultivation techniques and management practices of M. oleifera

Generally, the planting materials of *M. oleifera* were collected directly in the locality, either given by a neighbor or bought from others (Table 4). The cultivation with the cuttings was the most spread. In the Coast and Plateau, the direct seedling had a non-negligible share (14.28 and 14.70%) likewise the use of nurseries in the Plateau (8.79%). The space management was mainly done by row planting (91 to 98%), in the purpose of fencing fields and houses. However, *M. oleifera* was also planted in house gardens (Table 4). The open field cultivation was at its beginning and met only in localities where initiatives seeking the valorization and commercialization of *M. oleifera* were going on or in project. The spacing was 0.3 m - 2 m in the Plateau and 0.5 m in the Oueme. Most of the people were willing to adopt the cultivation of *M. oleifera* at large scale in a condition of an available market (Table 4).

Table 4. Cultivation techniques and management practices of *M. oleifera*

Phytodistricts	**Origins of planting materials (%)**		**Cultivation techniques (%)**			**Management practices (%)**			**Willingness to adopt**
	Locally	Imported	Direct seedling	Propagation by cutting	Propagation by nurseries	Row planting	House garden	Open field planting	
Coast (n=102)	96.07	3.92	14.70	96.07	6.86	98.03	11.76	1.96	97.05
Plateau (n=91)	94.50	5.49	14.28	97.80	8.79	95.60	7.69	9.89	95.60
Pobe(n=93)	100	0	7.52	93.54	7.52	95.69	12.90	7.52	95.69
Oueme (n=98)	97.95	2.04	2.04	92.85	4.08	91.83	7.14	2.04	89.79

n is the number of respondents

The log-linear analysis showed high significant difference between management practices and the origin of planting materials (ΔG^2= 5.50; p = 0.02), likewise between management practices and the willing for adoption (ΔG^2= 5.59; p = 0.02). However, there was no difference between phytodistricts and respectively cultivation techniques (ΔG^2= 2.66; p = 0.95), management practices (ΔG^2 = 1.34; p = 0.99), origins of planting materials (ΔG^2=0.40; P = 0.82), willingness to adopt the species (ΔG^2= 2.11; p = 0.55). The difference between the cultivation techniques and the origins of planting materials in one hand (ΔG^2= 1.26; p = 0.53) and the management practices (row planting, house garden and open field planting) in another hand (ΔG^2= 9.01; p = 0.06) was not significant.

Discussion

Morphological variation of M. oleifera *between phytodistricts*

M. oleifera trees in our study area were 3.51 m to 7.18 m in height and 4.51 cm to 10.26 cm in diameter in the phytodistricts considered. The trees are then short and small in these phytodistricts compared to the size reported by Parrotta (1993), up to 10 to 12 m in height with stem diameter up to 75 cm. The shortest and biggest trees were observed in the Coast. This can be explained by the precociously mass harvesting of the leaves in this phytodistrict (Agoyi *et al.*, 2014), leading to the stunting of the trees.

The average leaf length of *M. oleifera* in the phytodistricts considered was 40.47 cm. This value falls into the range of 6.5 to 60 cm observed by Bosch (2004) and the one (20 to 70 cm) observed by Foidl *et al.* (2001) and Roloff *et al.* (2009). This suggests that the leaves in Southern Benin are relatively long. The average leaflet length is above 2 cm in all the phytodistricts compared to those (1.2 to 2 cm) reported by Roloff *et al.* (2009), and the one (1.3 to 2 cm) reported by Ashfaq *et al.* (2012). The same observation was found with the leaflet width which is above 1 cm in all the phytodistricts compared to those (0.6 to 1 cm and 0.3 to 0.6 cm) mentioned respectively by Roloff *et al.* (2009) and Ashfaq *et al.* (2012). This suggests that like the leaves, the leaflets are large in our study area.

The average pod length observed 32.22 cm fall into the range 20 to 50 cm evoked by Roloff *et al.* (2009) as well as 20 to 60 cm found by Foidl *et al.* (2001). This result contrast with 30 cm to 120 cm reported by Ashfaq *et al.* (2012) and 15 to 23 cm found by Suthanthirapandian *et al.* (1989). The longest pods were observed in the Plateau. This performance may be explained by the fact that in the plantations found in this phytodistrict, the plants were well spaced (2 m x 2 m) and the leaves were not frequently harvested.

Cultivation techniques and management practices of M. oleifera

Concerning the management practices and cultivation techniques in Southern Benin, *M. oleifera* is mostly cultivated using cuttings. According to the populations, this is because cuttings allow rapid growth. This statement is confirmed by several authors (Nautiyal and Venhataraman, 1987; Ramachandran *et al.*, 1980; Nouman *et al.*, 2012). However, the seed germination which might take up to 30 days after sowing (Sharma and Raina, 1982; Jahn *et al.*, 1986) coupled with the loss of seed viability when stored longer than two months and low germination percentage (60, 48 and 7.5 %) evoked by Verma (1973); Sharma and Raina (1982); Morton (1991) must be regarded as major causes of preferring propagation by cuttings. This cultivation technique makes the populations to become clones leading to inbreeding depression and low diversity. The fact that the management practices are similar between phytodistricts might worsen the above mentioned. Moreover the precocious and frequent harvesting prevents flowering and podding to occur and therefore hinders cross-pollinations which increase genetic diversity. The high willingness to adopt shows how rural populations are interested in this species and can lead to a well pleading for its introduction in agroforestry systems and development of the chain value of *M. oleifera* in Benin.

Conclusion

In Southern Benin *M. oleifera* is propagated, mostly by cuttings. Propagation by seed is still at low rate. Garden and house fencing still the most management practiced. The open field planting is likely to gain more importance, since more than 90% of the local population is willing to adopt it in agroforestry. The differences between encountered populations were significant or sometimes inexistent. The significant difference observed may be due to the soil fertility and the amount of rainfall rather than genetic diversity, since the best performances were observed in the Oueme which has the highest rainfall coupled with fertile soils. Thus, there is need of carrying out genetic diversity studies to confirm whether these differences are due to genetic variations in order to make them useful tools for further breeding programs.

Aknowledgement

Our acknowledgment goes to the local authorities and populations for facilitation and help in data collection also to Prof. Dr. Brice TENTE and Ruth Mukhongo for their revisions. We thank SALAKO Valère and BALOGOUN Ibouraîma for technical support.

References

Agoyi EE, Assogbadjo AE, Gouwakinnou G, Okou FAY, Sinsin B. 2014. Ethnobotanical Assessment of *Moringa oleifera* in the Southern Benin (West Africa). Ethnobotany Research and Applications **12**, 551-560.

Aissi AK, Pazou EY, Ahoyo TA, Fah L, Fanou B, Koumolou L, Koudokpon H, Agbangla C, Gnandi K, Loko F, Edorh AP. 2014. Evaluation of Toxicological Risk Related to Presence of Lead and Cadmium in *Moringa oleifera* Lam. Leaves Powders Marketed in Cotonou (Benin). Food and Nutrition Sciences **5**, 770-778.

Ali Z, Basra SMA, Munir H, Mahmood A, Yousaf S. 2011. Mitigation of drought stress in maize by natural and synthetic growth promoters. Journal of Agriculture, Forestry and the Social Sciences **7**, 56-62.

Amaglo NK, Timpo GM, Ellis WO, Bennett RN. 2006. Effect of spacing and harvesting frequency on the growth and leaf yield of Moringa (*Moringa oleifera* Lam), a leafy vegetable crop. Workshop report (November, 16th -18th) on Moringa and other highly nutritious plant resources: Strategies, standards and markets for better impact on nutrition in Africa, Accra.

Anjorin TS, Ikokoh P, Okolo S. 2010. Mineral composition of *Moringa oleifera* leaves, pods and seeds from two regions in Abuja, Nigeria. International Journal of Agricultural and Biological Engineering **12**, 431-434.

Ashfaq M, Basra SMA, Ashfaq U. 2012. Moringa: A Miracle Plant of Agro-forestry. Journal of Agriculture, Forestry and the Social Sciences **8**, 115-122.

Bosch CH. 2004. *Moringa oleifera* Lam. In: Grubben GJH, Denton OA, eds. PROTA4U (Plant Resources of Tropical Africa), Wageningen. http://www.prota4u.org/search.asp, Accessed 8 September 2014.

Dagnelie P. 1998. Statistique théorique et appliquée. Tome 2: Inférence statistique à une et à deux dimensions, De Boeck et Larcier, Paris et Bruxelles, p. 659.

Fahey JW. 2005. *Moringa oleifera*: A Review of the Medical Evidence for Its Nutritional, Therapeutic, and Prophylactic Properties. Trees for Life Journal (www.TFLJournal.org), Accessed 8 September 2014.

Floquet A, Van Den Akker E. 2000. "Ethnic groups and settlement patterns in Benin". In: Graef F, Lawrence P, Von Oppen M, eds. Adapted Farming in West Africa: Issues, Potentials and Perspectives. Stuttgart, Germany, p. 255-258.

Foidl N, Makkar HPS, Becker K. 2001. The potential of *Moringa oleifera* for agricultural and industrial uses. In: Fuglie LJ, eds. The Miracle Tree, the Multiple Attributes of Moringa. CTA/CWS, Dakar, p. 45-76.

Fuglie LJ. 2001. The Multiple uses of Moringa. In: Fuglie LJ, eds. The Miracle Tree, the Multiple Attributes of Moringa. CTA/CWS, Dakar, p. 7-10.

Fuglie LJ. 2001. The Natural nutrition for the Tropics. In: Fuglie LJ, eds. The Miracle Tree, the Multiple Attributes of Moringa. CTA/CWS, Dakar, p. 103-115.

Gadzirayi CT, Kubiku FNM, Mupangwa JF, Mujuru L, Chikuvire TJ. 2013. The effect of plant spacing and cutting interval on growth of *Moringa Oleifera*. Journal of Agricultural Science and Applications **2**, 131-136.

Glèlè Kakaï R, Sodjinou E, Fonton HN. 2006. Conditions d'Application des Méthodes Statistiques Paramétriques. Bibliothèque Nationale, Cotonou, p. 86.

Haristoy X, Fahey JW, Scholtus I, Lozniewski A. 2005. Evaluation of antimicrobial effect of several isothiocyanates on Helicobacter pylori. Planta Medica **71**, 326-330.

Jahn SA, Musnad HA, Burgstaller H. 1986. The tree that purifies water: cultivating multipurpose Moringaceae in the Sudan. Unasylva **38**, 23-28.

Johnson BC. 2005. Clinical Perspectives on the Health Effects of *Moringa Oleifera*: A Promising Adjunct for Balanced Nutrition and Better Health. KOS Health Publications, California, p. 1-5.

Manzoor M, Anwar F, Iqbal T, Bhnager MI. 2007. Physicochemical characterization of Moringa concanensis seeds and seed oil. Journal of the American Oil Chemists' Society **84**, 413-419.

Mathur B. 2006. Moringa for Cattle Fodder and Plant Growth. www.treesforlife.org, Accessed 8 September 2014.

Morton JF. 1991. The horseradish tree, Moringa pterygosperma (Moringaceae) – a boon to arid lands? Economic Botany **45**, 318-333.

Nautiyal BP, Venhataraman KG. 1987. Moringa (Drumstick) – an ideal tree for social forestry. My forest **23**, 53-58.

Nouman W, Siddiqui MT, Basra SMA, Afzal I, Rehman HU. 2012. Enhancement of emergence potential and stand establishment of *Moringa oleifera* Lam. by seed priming. Turkish Journal of Agriculture and Forestry **36**, 227-235.

Palmberg G. 1985. L'échantillonnage dans la récolte des semences forestières. In : FAO and Danida eds. Amélioration Génétique des arbres forestiers. Rapport FAO n° 20, forêts, Rome, p. 44-48.

Parrotta JA. 1993. *Moringa oleifera* Lam. Reseda, horseradish tree. Moringaceae. Horseradish tree family, USDA Forest Service, International Institute of Tropical Forestry, SO-ITF-SM, New Orleans.

Phiri C, Mbewe DN. 2010. Influence of *Moringa oleifera* leaf extracts on germination and seedling survival of three common legumes. International Journal of Agricultural and Biological Engineering **12**, 315-317.

Ramachandran C, Peter KV, Gopalakrishnan PK. 1980. Drumstick (*Moringa oleifera*): a multipurpose Indian vegetable. Economic Botany **34**, 276-283.

Reyes-Sánchez N, Spörndly E, Ledin I. 2006. Effect of feeding different levels of foliage of *Moringa oleifera* to creole dairy cows on intake, digestibility, milk production and composition. Livestock Sciences **101**, 24-31.

Roloff A, Weisgerber H, Lang U, Stimm B. 2009. *Moringa oleifera* Lam., 1785. In: Stimm B, eds. Enzyklopädie der Holzgewächse, Handbuch und Atlas der Dendrologie. USDA Forest Service, Research & Development 1601 North Kent Street, Arlington, p. 1-8.

SAS Institute Inc. 2008. SAS OnlineDoc® 9.2. SAS Institute Inc, Cary, NC.

Sharma GK, Raina V. 1982. Propagation techniques of *Moringa oleifera* Lam. In: Khosla PK, eds. Improvement of Forest Biomass, Symposium proceeding, Indian Society of Tree Scientists, Solan, HP, p. 175-181.

Sreelatha S, Padma PR. 2009. Antioxidant Activity and Total Phenolic Content of *Moringa oleifera* Leaves in Two Stages of Maturity. Plant Foods Human Nutrition **64**, 303-311.

Suthanthirapandian IR, Sambandamurthy S, Irulappan I. 1989. Variations in seedling populations of annual moringa (*Moringa pterygosperma* Gaertn.). South Indian Horticulture **37**, 301-302.

Talreja T. 2010. Screening of crude extract of flavonoids of *Moringa oleifera* against bacteria and fungal pathogen. Journal of Phytology **2**, 31-35.

Thurber MD, Fahey JW. 2009. Adoption of *Moringa oleifera* to combat under-nutrition viewed through the lens of the "Diffusion of Innovations" theory. Ecology of Food and Nutrition **48**, 212-225.

UNWFP. 2004. Interactive Hunger Map. UN World Food Programme, Rome.

Verma SC. 1973. Studies on the factors affecting seed germination of Moringa. Plant Science **5**, 64-70.

Yasmeen A, Basra SMA, Farooq M, Rehman H, Hussain N, Athar HR. 2013. Exogenous application of moringa leaf extract modulates the antioxidant enzyme system to improve wheat performance under saline conditions. Plant Growth Regul **69**, 225-233.

Yasmeen AY, Basra SMA, Wahid A. 2012. Performance of late sown wheat in response to foliar application of *Moringa oleifera* Lam. leaf extract. Chilean Journal of Agricultural Research **72**, 92-97.