academicJournals

Vol. 8(1), pp. 54-64, January 2014
DOI: 10.5897/AJPS12.158
ISSN 1996-0824 ©2014 Academic Journals
http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

Survival, growth and biomass production of *Moringa oleifera* provenances at Gairo inland plateau and Ruvu Coastal Region in Tanzania

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Accepted 9 December, 2013

Survival, growth and biomass production was studied among 14 *Moringa oleifera* provenances at Gairo inland plateau-Morogoro, and Ruvu Coastal Region in Tanzania employing randomized complete block design with three replications. Growth assessment was done at six months intervals while biomass assessment was only done at 30 months. During final assessment, untransformed survival at Gairo site ranged from 65.33% for Chikwawa/Domasi (Malawi) to 98.67% for Ihumwa (Tanzania) while at Ruvu site, it ranged from 92% for PKM 2 (India) to 100% for Chikwawa/Domasi (Malawi), Mahalapye (Botswana) and Mbololo 472-029/03 (Kenya) provenances. Height ranged from 2.66 m for Makhanga (Malawi) to 5.04 m for Maun (Botswana) at Gairo site and from 4.82 m for Makhanga (Malawi) to 8.16 m for Maun (Botswana) at Ruvu site. Breast height diameter ranged from 2.80 cm for Makhanga (Malawi) to 6.07 cm for Mahalapye (Botswana) at Gairo site and from 5.18 cm for PKM 3 (India) to 8.58 cm for Maun (Botswana) at Ruvu site. Provenances Mahalapye and Maun (Botswana), Ihumwa (Tanzania), Mbololo 472-029/03 (Kenya) and PKM 1 (India) at Gairo site and Maun and Mahalapye (Botswana), Mbololo 472-029/03 (Kenya) and Ihumwa (Tanzania) at Ruvu site are recommended for planting at these and similar sites.

Key words: *Moringa,* survival, growth, biomass production, Tanzania.

INTRODUCTION

Moringa is the only genus in the family Moringaceae. This genus comprises 13 species, all of which are trees that grow in tropical and sub-tropical climates. *Moringa* is drought resistant and can be grown in a wide variety of poor soils, even barren ground, with soil pH between 4.5 and 9.0. The most popular species is *Moringa oleifera*, a multi-purpose tree originally from India and now found in most tropical countries (Africa, Asia and America). Some records indicate that the species is native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan (Fahey, 2005). Fahey (2005) further indicated that the tree species is locally known by many names like horseradish tree, drumstick tree, benzolive tree, kelor, marango, mlonge, moonga, mulangay, nébéday, saijhan, sajna or ben oil tree. The species is easy to reproduce and its growth is very fast that have raised growing international interest due to its social, economic and environmental importance which can benefit humans and animals nutritionally, economically and as an energy source.

Moringa is an important food source in many countries. In India, *Moringa* pods are widely consumed and

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Table 1. Sources of *M. oleifera* provenances planted at Gairo and Ruvu sites, Tanzania.

Provenance	Collection site/country/state
Chikwawa/Domasi	Chikwawa/Domasi, Malawi
Makhanga	Makhanga, Malawi
Ngabu	Ngabu, Malawi
Mangochi	Mangochi, Malawi
Mtakataka/Dedza	Mtakataka/Dedza, Malawi
Mahalapye	Mahalapye, Botswana
Maun	Maun, Botswana
PKM 1	India
PKM 2	India
PKM 3	India
Jafna/Jaffana	India
Honduras	Honduras
Mbololo 472-029/03	Mbololo, Kenya
Ihumwa	Ihumwa, Tanzania

Plantations exist to produce pods for export, fresh and tinned, to overseas consumers. In West Africa, *Moringa oleifera* leaves are commonly used to make sauces. *Moringa stenopetala* leaves are the staple food of the Konso people in Ethiopia. Studies have shown *M. oleifera* leaves to be an excellent source of vitamins, minerals and protein: perhaps more than any other tropical vegetable. Many programmes use *Moringa* leaves to fight against malnutrition and its associated diseases including blindness. Fragrant/tender flowers of *Moringa* are also used as a source of vegetables and bee forage (Mbuya et al., 1994), twigs with leaves as fodder, green leaves as mulch and solid wood as energy source (FAO, 1988; Morton, 1991; D'Souza and Kulkarmi, 1993).

Moringa seeds contain a cationic polyelectrolyte that has proved efficient in water treatment, as a substitute to aluminium sulphate and other flocculents (Evans, 1991; Mayer and Stelz, 1993; Olayemi and Alabi, 1994; Folkard and Sutherland, 1996). Oil extracted from the seeds is an excellent edible vegetable oil and is also useful in the cosmetics industry. The press cake left after oil extraction from the seeds can be used as a soil conditioner or as fertilizer and forage, it has the potential use as protein supplement for livestock (ruminants) (Sá nchez et al., 2006) and poultry (Evans, 1991; Olayemi and Alabi, 1994; Folkard and Sutherland, 1996).

Although *M. Oleifera* is wide spread in many African countries its original sources is unknown (Jahn, 1988a, b, c; Folkard and Sutherland, 1996; Panga, 2002). The material therefore, is most likely of narrow genetic base. Also, the knowledge about genetic improvement and proper management of this valuable multipurpose tree species is limited. Given dangers of planting materials based on a narrow genetic base, there is a need to evaluate different provenances of this species with a view of identifying the provenances that maximize productivity in various parts of Tanzania. In addition to increasing wood biomass productivity, pod, seed and leaf quality, broadening the genetic base will serve as an insurance against pests, diseases and climatic fluctuations. This study therefore evaluated *M. oleifera* provenances in terms of survival, height, diameter growth and biomass production.

MATERIALS AND METHODS

The study sites

The study was carried out at two contrasting sites: Gairo and Ruvu sites with established replicate trials in each. Gairo site is located in Gairo District, Morogoro Region (36° 45' E; 6° 0° S; 1 300 m a. s. l.) along the Morogoro-Dodoma highway about 130 km from Morogoro town and 140 km from Dodoma. Rainfall is poorly distributed, and varies from year to year. The average annual rainfall is around 499 mm, most of which falls between November and May (Herbert et al., 2002). The geology of the site is Usagaran system. The soil is generally classified as Haplic Lixisols (Msanya and Msaky, 1994). The soil properties of the study site are as described by Mugasha et al. (2000). The soil has low inherent fertility. The soil texture is sandy clay loam with pH in the upper 50 cm soil depth varying from 6.1-6.3, total nitrogen 0.11-0.16% and Bray I available phosphorus 0.18-3.38 ug/g. The natural vegetation found around the site consists mainly of shrubs and few scattered miombo tree species.

Ruvu site is located at Kibaha District, Coast Region (6° 33' - 6° 43'; 38° 48' S - 39v 03' E) some 60 km from Dar-es-Salaam city along Dar-es-Salaam - Morogoro highway. It is within low elevations some 80 m a. s. l. The area has mean rainfall of 900 mm per annum falling in average of 81 days (Maghembe, 1979) with irregular pattern. Heavy rains fall between March and May and light rains between November - December. Temperatures are always high tending to be the highest in January and on average the temperature ranges between 23 and 27°C having occasional minima as low as 18°C and maxima of 33°C. Soils vary substantially over short distances. They are free draining, primarily sandy, sandy loam and gravel. Soil pH varies with soil depth. The top 50 cm has pH predominantly ranging from 5 - 6.5, increasing with increase in soil depth reaching extremes of pH 9.4 at 72 cm below surface (Holmes, 1988). The common natural vegetation found at Ruvu can be described as semi deciduous open to partly closed woodland to fairly open evergreen thicket and riverine forest. Main genera include, *Pteleopsis, Strichnos, Combretum, Albizia, Brachystegia, Jubernadia, Vitex, Afzelia* and *Dalbergia*.

Source of provenances

Fourteen (14) *M. oleifera* provenances were studied in each site (Table 1). Potted seedlings of the provenances were raised at Gairo and Ruvu nurseries using standard cultural techniques (Forest Division, 1982).

Experimental design

Trials were planted in a randomised complete block design (RCBD) with three replications. Each plot represented a provenance planted at 5 x 5 rows in a contiguous arrangement at an espacement of 2 x 2 m. Plots measured 8 x 8 m and contained 25 trees. Distances between blocks were 4 m. Each block had one buffer row planted at the same spacing.

Field procedures

Sites were prepared by clearing all vegetation using hand hoes followed by ploughing and pitting (pit size: 30 x 30 cm). Planting was done in January and March 2006 at Gairo and Ruvu sites respectively. Weeding was done three times during the rainy season and once during the dry season.

Data collection

Assessments were carried out at ages of 6, 12, 18, 24 and 30 months after planting. During the first assessment, survival, root collar diameter 30 cm above ground (RCD) and height (HT) were assessed while in subsequent assessments diameter at breast height (Dbh) was also measured. Biomass production was measured at final assessment. Height was measured using calibrated height measuring pole while RCD and Dbh were measured to the nearest 0.01 cm using a veneer calliper.

Data analysis

All statistical analyses were carried out using General Linear Model (GLM) of Statistical Analysis Systems (SAS) (SAS Inst. Inc., 1991). For all statistical analysis, a fixed effect model was fitted (equation 1) and a type III SS analysis was carried out. All data were subjected to analysis of variance (ANOVA) using plot means. Data for percentage survival was arcsine transformed prior to analysis to remove bias (Sokal and Rohlf, 1969). For significantly different provenance means, the Duncan's multiple range test (DMRT) was used for separating means (Gomez and Gomez, 1983) at 5% probability level.

The general linear model was denoted as:

$$Y = \text{replication} + \text{provenance} + \text{error} \quad (1)$$

Where, Y = the measurement

To identify the best and the worst overall performing provenance at final assessment, ordinal ranking was performed. This was done as follows; for each significant variable evaluated, provenances were assigned ranks from the best (assigned 1 point) to the worst (assigned 14 points) performing provenance. Thereafter, ranks were added, averaged, and the overall score was taken as a basis of the overall provenance ranking.

RESULTS

Survival

The results for tree survival for different *M. oleifera* provenances planted at Gairo and Ruvu sites are presented in Tables 2 and 3, respectively. The differences in survival were significant ($P<0.05$) throughout the assessment period at Gairo site while at Ruvu site provenances did not differ significantly ($P>0.05$).

During the last assessment occasion (30 months after planting), untransformed survival at Gairo site ranged from 61.33% for Chikwawa/Domasi (Malawi) to 98.67% for Ihumwa (Tanzania) while at Ruvu site untransformed survival ranged from 92% for PKM 2 (India) to 100% for Chikwawa/Domasi (Malawi), Mahalapye (Botswana) and Mbololo 472-029/03 (Kenya).

Root collar diameter

The results of tree RCD for different *M. oleifera* provenances planted at Gairo and Ruvu sites are presented in Table 4. Provenances differed significantly ($P<0.05$) in RCD at both sites in all months of assessment. RCD ranged between 5.36 cm for Mangochi (Malawi) and 8.91 cm for Mahalapye (Botswana) at Gairo site and 7.43 cm for PKM 3 (India) and 10.67cm for Maun (Botswana) at Ruvu site during the final assessment occasion.

Diameter at breast height

The results of tree Dbh for both sites are presented in Table 5. Provenances differed significantly ($P<0.05$) in Dbh at both sites in all months of assessment. Dbh ranged between 2.86 cm for Makhanga (Malawi) and 6.07 cm for Mahalapye (Botswana) at Gairo site and 5.28 cm for PKM 3 (India) and 8.58 cm for Maun (Botswana) at Ruvu site during the final assessment occasion.

Height growth

Trends for height growth of *M. oleifera* provenances for Gairo and Ruvu sites are as shown in Table 6. Significant variation ($P<0.05$) in height development was observed at all assessment occasions. The mean height ranged between 2.66 m for Makhanga (Malawi) and 5.04 m for Maun (Botswana) at Gairo site and 4.82 m for Makhanga (Malawi) and 8.16 m for Maun (Botswana) at Ruvu site during the final assessment occasion (30 months after planting).

It is interesting to note that at many assessment occasions in both sites, Maun (Botswana) showed superiority in height growth even though no one single provenance maintained one rank throughout the period. Makhanga (Malawi) provenance showed poor height growth at all assessment occasions in both sites.

Biomass production

The results for stem and foliar biomass for *M. oleifera* provenances at Gairo and Ruvu sites are presented in Table 7. Provenances differed significantly ($P<0.05$) in biomass production at Gairo site during the last assessment occasion while at Ruvu site provenances did not differ significantly ($P>0.05$) in biomass production. Stem and foliar biomass at Gairo site ranged from 5 901.08 kg ha^{-1} for Mangochi (Malawi) to 24 733.60 kg ha^{-1} for PKM 2 (India) and 491.02 kg ha^{-1} for Ngabu (Malawi) to 4 407.18 kg ha^{-1} for Maun (Botswana), respectively. At

Table 2. Survival and transformed survival of 6, 12, 18, 24 and 30 months old *M. oleifera* provenances planted at Gairo, Morogoro, Tanzania.

Species/provenances	Age (months)									
	6		12		18		24		30	
	UTSv	TSv	UTSv	TSv	UTSv	TSv	UTSv	TSv	UTSv	TSv
Chikwawa/Domasi - Malawi	*61.33 (10.41)	51.92^{d} (6.35)	61.33 (10.41)	51.92^{d} (6.35)	61.33 (10.41)	51.92^{d} (6.35)	61.33 (10.41)	51.92^{d} (6.35)	61.33 (10.41)	51.92^{e} (6.35)
Makhanga - Malawi	85.33 (2.67)	67.63^{c} (2.10)	85.33 (2.67)	67.63^{cd} (2.10)	84.00 (2.31)	66.53^{cd} (1.82)	82.67 (1.33)	65.43^{cd} (0.99)	78.67 (2.67)	62.59^{de} (1.92)
Ngabu - Malawi	89.33 (4.81)	71.82^{bc} (4.42)	88.00 (4.00)	70.19^{bc} (3.38)	88.00 (4.00)	70.19^{bcd} (3.38)	88.00 (4.00)	70.19^{cd} (3.38)	85.33 (4.81)	67.99^{bcde} (3.82)
Mangochi - Malawi	86.67 (11.39)	73.86^{abc} (10.89)	85.33 (10.91)	72.23^{bc} (10.66)	84.00 (12.22)	71.45^{bcd} (11.37)	80.00 (12.22)	65.55^{cd} (8.91)	80.00 (12.22)	65.55^{cde} (8.91)
Mtakataka/Dedza - Malawi	97.33 (1.33)	82.31^{abc} (3.85)	97.33 (1.33)	82.31^{abc} (3.85)	97.33 (1.33)	82.31^{abc} (3.85)	97.33 (1.33)	82.31^{abc} (3.85)	96.00 (0.00)	78.46^{abcd} (0.00)
Mahalapye - Botswana	96.00 (0.00)	78.46^{abc} (0.00)	96.00 (0.00)	78.46^{abc} (0.00)	96.00 (0.00)	78.46^{abc} (0.00)	96.00 (0.00)	78.46^{abc} (0.00)	96.00 (0.00)	78.46^{abcd} (0.00)
Maun - Botswana	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{ab} (3.85)	97.33 (2.67)	84.52^{ab} (5.48)
PKM 1 - India	90.67 (5.81)	75.67^{abc} (7.74)	90.67 (5.81)	75.67^{abc} (7.74)	90.67 (5.81)	75.67^{abc} (7.74)	90.67 (5.81)	75.67^{abc} (7.74)	90.67 (5.81)	75.67^{abcd} (7.74)
PKM 2 - India	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{ab} (3.85)	97.33 (2.67)	84.52^{ab} (5.48)
PKM 3 - India	93.33 (4.81)	78.29^{abc} (6.81)	93.33 (4.81)	78.29^{abc} (6.81)	93.33 (4.81)	78.29^{abc} (6.81)	93.33 (4.81)	78.29^{abc} (6.81)	93.33 (4.81)	78.29^{abcd} (6.81)
Jafna/Jaffana - India	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{ab} (3.85)	97.33 (2.67)	84.52^{ab} (5.48)
Honduras - Honduras	92.00 (2.31)	73.92^{abc} (2.53)	90.67 (1.33)	72.29^{bc} (1.28)	90.67 (1.33)	72.29^{abc} (1.28)	89.33 (1.33)	71.01^{bcd} (1.28)	88.00 (0.00)	69.73^{abcde} (0.00)
Mbololo 472-029/03 - Kenya	96.00 (4.00)	83.24^{abc} (6.76)	96.00 (4.00)	83.24^{ab} (6.76)	96.00 (4.00)	83.24^{ab} (6.76)	94.67 (3.53)	79.40^{abc} (5.87)	94.67 (3.53)	79.40^{abcd} (5.87)
Ihumwa - Tanzania	100.00 (0.00)	90.00^{a} (0.00)	100.00 (0.00)	90.00^{a} (0.00)	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{ab} (3.85)	98.67 (1.33)	86.15^{a} (3.85)
P>F Ratio	0.0011	0.0038	0.0004	0.0013	0.0013	0.0032	0.0016	0.0008	0.0006	0.0032
RMSE	8.4784	9.2076	7.26	8.59	7.70	8.90	7.48	7.95	7.96	9.08
CV	9.24	11.87	7.90	11.02	8.33	11.31	8.19	10.41	8.84	12.07

*Means of individual species/provenance with standard error in parenthesis. Means of the same letter within the same column are not significantly different. UTSv, untransformed survival; TSv, transformed survival.

Table 3. Survival and transformed survival of 6, 12, 18, 24 and 30 months old *M. oleifera* provenances planted at Ruvu, Coast Region, Tanzania.

Species/provenances	Age (months)									
	6		12		18		24		30	
	UTSv	TSv	UTSv	TSv	UTSv	TSv	UTSv	TSv	UTSv	TSv
Chikwawa/Domasi - Malawi	* 100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)
Makhanga - Malawi	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	97.33 (2.67)	84.52[a] (5.48)	96.00 (2.31)	80.00[a] (4.87)
Ngabu - Malawi	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)
Mangochi - Malawi	96.00 (2.31)	80.68[a] (4.87)	96.00 (2.31)	80.68[a] (4.87)	96.00 (2.31)	80.68[a] (4.87)	96.00 (2.31)	80.68[a] (4.87)	96.00 (2.31)	80.68[a] (4.87)
Mtakataka/Dedza - Malawi	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	98.67 (1.33)	86.15[a] (3.85)
Mahalapye - Botswana	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)
Maun - Botswana	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	96.00 (2.31)	80.68[a] (4.87)	93.33 (3.53)	77.77[a] (6.22)
PKM 1 - India	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	97.33 (2.67)	84.52[a] (5.48)	96.00 (2.31)	80.68[a] (4.87)
PKM 2 - India	96.00 (2.31)	80.68[a] (4.87)	96.00 (2.31)	80.68[a] (4.87)	96.00 (2.31)	80.68[a] (4.87)	94.67 (3.53)	79.40[a] (5.87)	92.00 (2.31)	79.40[a] (5.87)
PKM 3 - India	97.33 (1.33)	82.31[a] (3.85)	97.33 (1.33)	82.31[a] (3.85)	97.33 (1.33)	82.31[a] (3.85)	97.33 (1.33)	82.31[a] (3.85)	97.33 (1.33)	82.31[a] (3.85)
Jafna/Jaffana - India	100.00 (0.00)	90.00[a] (0.00)	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	96.00 (0.00)	78.46[a] (0.00)	96.00 (0.00)	78.46[a] (0.00)
Honduras - Honduras	96.00 (2.31)	80.68[a] (4.87)	96.00 (2.31)	80.68[a] (4.87)	96.00 (2.31)	80.68[a] (4.87)	96.00 (2.31)	80.68[a] (4.87)	94.67 (3.53)	79.40[a] (5.87)
Mbololo 472-029/03 - Kenya	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)	100.00 (0.00)	90.00[a] (0.00)
Ihumwa - Tanzania	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)	98.67 (1.33)	86.15[a] (3.85)
P>F Ratio	0.1593	0.188	0.69	0.75	0.32	0.38	0.28	0.20	0.0251	0.1963
RMSE	2.23	5.48	3.01	5.92	1.91	5.09	2.72	6.01	2.79	6.38
CV	2.26	6.34	3.05	6.83	1.93	5.82	2.78	7.10	2.87	7.64

*Means of individual species/provenance with standard error in parenthesis. Means of the same letter within the same column are not significantly different. UTSv, untransformed survival; TSv, transformed survival.

Ruvu site stem and foliar biomass ranged from 15 796.17 kg ha^{-1} for Makhanga (Malawi) to 41 403.26 kg ha^{-1} for Mahalapye (Botswana) and 697.10 kg ha^{-1} for Makhanga (Malawi) to 1 917.21 kg ha^{-1} for Maun (Botswana) respectively.

Ordinal ranking

When the ranking of provenances in six tree variables (survival, mean height, RCD, Dbh, stem biomass and foliage biomass production) was computed, provenances were ranked as shown in Tables 8 and 9 for Gairo and Ruvu sites, respectively.

The most outstanding provenances were Mahalapye (Botswana), Maun (Botswana), Ihumwa (Tanzania), Mbololo 472-029/03 (Kenya) and PKM 2 (India) for Gairo site and Maun (Botswana), Mahalapye (Botswana), Mbololo 472-029/03 (Kenya) and Ihumwa (Tanzania) for Ruvu site.

DISCUSSION

Survival

General assessment at all occasions, showed good performance among provenances. All provenances in both sites except two at Gairo site had survival assessments above 80%. The significant differences in survival at Gairo site could be attributable to provenances difference in tolerance to arid/semi arid conditions of the study site (Edward et al., 2006). In this case provenances from Ihumwa (Tanzania), Mtakataka/Dedza (Malawi), Maun (Botswana), PKM 2 (India) and Jafna/Jaffana (India) appear to tolerate dry conditions than Chikwawa/-Domasi (Malawi). The excellent performance of these provenances is an indication of better adaptation to the site condition while the insignificant differences among provenances at Ruvu site implies that all provenances have adapted well in the sub-humid conditions of this

Table 4. Root collar diameter of 6, 12, 18, 24 and 30 months old *Moringa oleifera* provenances planted at Gairo site, Morogoro and Ruvu site, Coast Region, Tanzania.

Species/provenances	Gairo site					Ruvu site				
	Age (months)									
	6	12	18	24	30	6	12	18	24	30
Chikwawa/Domasi - Malawi	3.12^{c}	4.25^{cde}	5.67^{de}	6.12^{de}	6.63^{defg}	2.69^{def}	6.45^{cde}	8.40^{cde}	8.54^{cde}	8.81^{bcd}
	(0.07)	(0.12)	(0.20)	(0.13)	(0.53)	(0.21)	(0.33)	(0.34)	(0.12)	(0.48)
Makhanga - Malawi	2.14^{c}	3.16f	4.88^{ef}	5.28^{e}	5.73^{fg}	2.30f	5.88^{e}	7.77^{de}f	8.17^{de}	8.38^{cd}
	(0.16)	(0.18)	(0.47)	(0.45)	(0.56)	(0.24)	(0.52)	(0.89)	(0.74)	(1.15)
Ngabu - Malawi	2.41^{de}	3.51^{ef}	4.75^{ef}	5.46^{e}	6.19^{efg}	2.79^{cdef}	6.73^{bcde}	8.59^{bcd}	8.84^{bcd}	8.98^{bcd}
	(0.21)	(0.34)	(0.20)	(0.29)	(0.22)	(0.16)	(0.08)	(0.12)	(0.04)	(0.11)
Mangochi - Malawi	1.89^{e}	3.09^{f}	4.59f	5.15^{e}	5.36g	2.44f	6.58^{cde}	8.65^{bcd}	8.84^{bcd}	8.93^{bcd}
	(0.04)	(0.05)	(0.08)	(0.10)	(0.11)	(0.52)	(0.38)	(0.50)	(0.63)	(0.65)
Mtakataka/Dedza - Malawi	2.82^{cd}	4.10^{de}	6.35^{cd}	6.82^{bcd}	7.48^{bcde}	2.51^{e}f	7.07^{bcd}	9.36^{abc}	9.57^{abc}	10.12^{ab}
	(0.20)	(0.03)	(0.27)	(0.11)	(0.34)	(0.22)	(0.40)	(0.46)	(0.47)	(0.44)
Mahalapye - Botswana	4.01^{a}	6.11^{a}	7.94^{a}	8.31^{a}	8.91^{a}	3.40^{abcd}	7.29^{abc}	9.19^{bc}	9.34^{abc}	9.38^{abc}
	(0.08)	(0.12)	(0.21)	(0.15)	(0.28)	(0.28)	(0.49)	(0.52)	(0.43)	(0.17)
Maun - Botswana	3.71^{ab}	5.44^{ab}	7.56^{ab}	8.07^{a}	8.46^{ab}	3.82^{ab}	8.11^{a}	10.24^{a}	10.54^{a}	10.67^{a}
	(0.28)	(0.31)	(0.43)	(0.50)	(0.33)	(0.23)	(0.32)	(0.27)	(0.41)	(0.24)
PKM 1 - India	4.11^{a}	5.33^{ab}	7.16^{abc}	7.72^{ab}	7.79^{abcd}	3.93^{a}	7.04^{bcd}	8.58^{bcd}	8.70^{bcd}	8.70^{bcd}
	(0.37)	(0.52)	(0.63)	(0.50)	(0.84)	(0.19)	(0.32)	(0.39)	(0.36)	(0.45)
PKM 2 - India	3.80^{ab}	5.24^{b}	6.94^{abc}	7.46^{abc}	7.90^{abcd}	3.18^{bcde}	6.06^{de}	7.74^{def}	7.77^{de}	8.13^{cd}
	(0.18)	(0.11)	(0.33)	(0.30)	(0.18)	(0.04)	(0.26)	(0.30)	(0.28)	(0.35)
PKM 3 - India	3.98^{a}	5.26^{b}	6.86^{abc}	7.37^{abc}	7.54^{bcde}	3.24^{abcd}	6.10^{de}	7.15^{e}	7.35^{d}	7.43^{e}f
	(0.14)	(0.25)	(0.17)	(0.12)	(0.14)	(0.31)	(0.32)	(0.23)	(0.25)	(0.35)
Jafna/Jaffana - India	3.86^{ab}	4.68^{bcd}	6.54^{bcd}	6.75^{bcd}	6.88^{def}	3.47^{abc}	6.32^{cde}	7.82^{def}	7.96^{de}	8.03^{cd}
	(0.06)	(0.16)	(0.13)	(0.34)	(0.27)	(0.06)	(0.25)	(0.27)	(0.41)	(0.35)
Honduras - Honduras	2.85^{cd}	4.07^{de}	6.15^{cd}	6.59^{cd}	7.03^{cdef}	2.77^{cdef}	5.68^{e}	7.35^{f}	7.43^{de}	7.77^{cd}
	(0.21)	(0.38)	(0.55)	(0.45)	(0.63)	(0.57)	(0.37)	(0.19)	(0.20)	(0.13)
Mbololo 472-029/03 - Kenya	3.07^{c}	4.69^{bcd}	7.14^{abc}	7.59^{abc}	8.32^{abc}	3.78^{ab}	8.14^{a}	9.79^{ab}	9.80^{ab}	10.08^{ab}
	(0.16)	(0.35)	(0.37)	(0.44)	(0.29)	(0.11)	(0.04)	(0.12)	(0.09)	(0.39)
Ihumwa - Tanzania	3.31^{bc}	5.01^{bc}	6.86^{abc}	7.46^{abc}	8.00^{abcd}	3.40^{abcd}	7.67^{ab}	9.66^{abc}	9.67^{abc}	10.13^{ab}
	(0.14)	(0.11)	(0.25)	(0.22)	(0.22)	(0.07)	(0.25)	(0.24)	(0.16)	(0.26)
P>F Ratio	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0008
RMSE	0.3327	0.46	0.58	0.55	0.72	0.38	0.55	0.62	0.72	0.84
CV	10.33	10.09	9.15	8.02	9.83	12.18	8.05	7.13	8.35	9.36

*Means of individual species/provenance with standard error in parenthesis. -Means of the same letter within the same column are not significantly different.

site.

Root collar diameter

Significant variation (P<0.05) in RCD development was observed at all sites during the whole assessment period. At Gairo site, the study indicates the superior RCD development of Mahalapye (Botswana) and Maun (Botswana), Mbololo 472-029/03 (Kenya) and Ihumwa (Tanzania) and poor RCD development of Mangochi (Malawi) and Makhanga (Malawi). Similar results have been observed in Zimbabwe (Gadzirayi et al., 2013; Goss, 2012). At Ruvu site, the study indicates the superior RCD development of Maun (Botswana), Ihumwa (Tanzania), Mtakataka/Dedza (Malawi) and Mbololo 472-029/03 (Kenya) and poor RCD development of PKM 3 (India) and Honduras (Honduras). The differences in RCD development within a site could be attributed to variations in adaptability among provenances, but generally the provenances at Ruvu site showed good performance in RCD development, which is expected due to the sub-humid conditions of the site.

Diameter at breast height

Significant variation (P<0.05) in Dbh was observed on all

Table 5. Diameter at breast height of 12, 18, 24 and 30 months old *M. oleifera* provenances planted at Gairo site, Morogoro and Ruvu site, Coast Region, Tanzania.

Species/provenances	Gairo site				Ruvu site			
	Age (months)							
	12	18	24	30	12	18	24	30
Chikwawa/Domasi - Malawi	2.27^{de}	3.38^{ef}	3.52^{def}	3.87^{efg}	3.93^{ef}	5.66^{cde}	5.84^{def}	6.30^{cde}
	(0.09)	(0.23)	(0.16)	(0.34)	(0.33)	(0.35)	(0.25)	(0.38)
Makhanga - Malawi	1.89^{f}	2.80^{f}	2.84^{f}	2.86^{h}	3.69^{f}	4.85^{e}	5.48^{ef}	6.05^{cde}
	(0.09)	(0.39)	(0.28)	(0.23)	(0.34)	(0.43)	(0.71)	(0.91)
Ngabu - Malawi	1.95^{ef}	2.70^{f}	2.86^{f}	3.11^{gh}	4.74^{cde}	5.74^{cde}	6.23^{cdef}	6.35^{cde}
	(0.06)	(0.16)	(0.11)	(0.11)	(0.06)	(0.17)	(0.25)	(0.28)
Mangochi - Malawi	1.83^{f}	3.02^{f}	3.11^{ef}	3.22^{gh}	5.06^{bcd}	6.31^{bc}	6.69^{bcd}	6.98^{bcd}
	(0.04)	(0.07)	(0.07)	(0.16)	(0.41)	(0.64)	(0.47)	(0.65)
Mtakataka/Dedza - Malawi	1.96^{ef}	3.37^{ef}	3.61^{de}	3.74^{fgh}	4.87^{bcde}	6.38^{bc}	7.19^{abc}	7.81^{ab}
	(0.21)	(0.07)	(0.09)	(0.04)	(0.43)	(0.32)	(0.30)	(0.27)
Mahalapye - Botswana	3.90^{a}	5.61^{a}	5.67^{a}	6.07^{a}	5.71^{abc}	7.23^{ab}	7.26^{abc}	7.32^{abc}
	(0.22)	(0.25)	(0.22)	(0.10)	(0.36)	(0.28)	(0.40)	(0.31)
Maun - Botswana	3.49^{ab}	5.09^{ab}	5.32^{ab}	5.72^{ab}	6.21^{a}	7.73^{a}	8.25^{a}	8.58^{a}
	(0.18)	(0.31)	(0.37)	(0.28)	(0.51)	(0.27)	(0.27)	(0.29)
PKM 1 - India	3.30^{b}	4.49^{bcd}	4.79^{bc}	5.01^{bcd}	5.48^{abc}	6.21^{bcd}	6.49^{bcde}	6.77^{bcd}
	(0.26)	(0.41)	(0.36)	(0.64)	(0.20)	(0.36)	(0.27)	(0.45)
PKM 2 - India	3.29^{b}	4.52^{bcd}	4.64^{bc}	4.93^{bcd}	4.37^{def}	5.03^{de}	5.65^{def}	6.07^{cde}
	(0.06)	(0.12)	(0.15)	(0.03)	(0.23)	(0.06)	(0.27)	(0.18)
PKM 3 - India	3.30^{b}	4.53^{bcd}	4.67^{bc}	4.84^{bcde}	4.11^{def}	5.18^{cde}	5.21^{f}	5.28^{e}
	(0.19)	(0.25)	(0.24)	(0.26)	(0.33)	(0.34)	(0.29)	(0.74)
Jafna/Jaffana - India	2.66^{cd}	3.99^{cde}	4.01^{cd}	4.17^{defg}	4.76^{cde}	5.61^{cde}	6.07^{def}	6.27^{cde}
	(0.22)	(0.06)	(0.31)	(0.16)	(0.05)	(0.24)	(0.18)	(0.25)
Honduras - Honduras	2.53^{cde}	3.82^{de}	4.08^{cd}	4.21^{cdef}	4.18^{def}	5.21^{cde}	5.61^{def}	5.67^{de}
	(0.15)	(0.28)	(0.25)	(0.41)	(0.49)	(0.31)	(0.24)	(0.25)
Mbololo 472-029/03 - Kenya	3.03^{bc}	4.59^{bc}	4.74^{bc}	5.14^{abc}	6.27^{a}	7.28^{ab}	7.81^{a}	7.82^{ab}
	(0.36)	(0.36)	(0.46)	(0.44)	(0.13)	(0.11)	(0.06)	(0.22)
Ihumwa - Tanzania	3.00^{bc}	4.59^{bcd}	4.71^{bc}	5.24^{abc}	5.81^{ab}	6.97^{ab}	7.48^{ab}	7.87^{ab}
	(0.14)	(0.33)	(0.27)	(0.34)	(0.27)	(0.40)	(0.31)	(0.25)
P>F Ratio	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001
RMSE	0.33	0.42	0.39	0.55	0.52	0.64	0.60	0.73
CV	11.86	10.27	9.31	12.51	10.43	10.43	9.16	10.69

*Means of individual species/provenance with standard error in parenthesis. -Means of the same letter within the same column are not significantly different.

sites during the whole assessment period. At Gairo site, the study indicates the superior Dbh development of Mahalapye (Botswana) and Maun (Botswana) and poor Dbh development of Makhanga (Malawi) and Ngabu (Malawi). These results are in agreement with those reported in Zambabwe where Mutoko provenance from Zimbabwe performed very well as compared to Malawi provenance (Gadzirayi et al., 2013). For Ruvu site, the study indicates the superior Dbh development of Maun (Botswana) and Ihumwa (Tanzania) and poor Dbh development of PKM 3 (India) and Honduras - Honduras. The differences in Dbh development could be attributed to variations in adaptability among provenances, but generally the provenances at Ruvu site showed good performance in Dbh development. Good climatic condition, that is, availability of rainfall and genetic superiority could have contributed to the good performance of these provenances at Ruvu site and those from Botswana at Gairo site.

Height growth

This study has shown superior height growth for Maun (Botswana) and Mahalapye (Botswana) provenances at Gairo site and poor height growth of Makhanga (Malawi), Ngabu (Malawi) and Mtakataka/Dedza (Malawi) provenances. At Ruvu site, only Maun (Botswana) provenance

Table 6. Height growth of 6, 12, 18, 24 and 30 months old *M. oleifera* provenances planted at Gairo site, Morogoro and Ruvu site, Coast Region, Tanzania.

Species/provenances	Gairo site					Ruvu site				
	Age (months)									
	6	12	18	24	30	6	12	18	24	30
Chikwawa/Domasi - Malawi	1.28^{d} (0.03)	1.74^{c} (0.05)	2.89^{e} (0.09)	3.05^{d} (0.04)	3.12^{e} (0.23)	2.11^{d} (0.17)	4.10^{de} (0.27)	4.74^{de} (0.26)	4.93^{e} (0.37)	5.02^{ef} (0.33)
Makhanga - Malawi	1.11^{de} (0.10)	1.48^{c} (0.10)	2.57^{e} (0.18)	2.65^{d} (0.20)	2.66^{e} (0.22)	2.08^{d} (0.10)	3.92^{e} (0.26)	4.43^{e} (0.39)	4.48^{f} (0.37)	4.82^{f} (0.40)
Ngabu - Malawi	1.22^{d} (0.09)	1.64^{c} (0.10)	2.76^{e} (0.08)	2.82^{d} (0.19)	3.02^{e} (0.13)	2.63^{c} (0.03)	4.59^{cde} (0.12)	5.03^{cde} (0.25)	5.09^{cdef} (0.17)	5.25^{cdef} (0.29)
Mangochi - Malawi	0.89^{e} (0.01)	1.53^{c} (0.03)	2.56^{e} (0.05)	2.96^{d} (0.19)	3.15^{e} (0.15)	2.00^{d} (0.22)	4.82^{bcd} (0.31)	5.77^{bc} (0.29)	5.85^{bc} (0.27)	6.16^{bcd} (0.35)
Mtakataka/Dedza - Malawi	1.23^{d} (0.07)	1.76^{c} (0.04)	2.88^{e} (0.16)	2.99^{d} (0.09)	3.09 (0.11)	2.07^{d} (0.13)	4.38^{cde} (0.37)	5.23^{cde} (0.37)	5.32^{bcde} (0.34)	5.81^{bcdef} (0.28)
Mahalapye - Botswana	2.28^{ab} (0.10)	3.30^{a} (0.06)	4.58^{ab} (0.07)	4.72^{ab} (0.08)	4.83^{ab} (0.06)	3.26^{ab} (0.12)	5.35^{b} (0.22)	5.98^{b} (0.10)	6.20^{b} (0.19)	6.22^{bc} (0.62)
Maun - Botswana	2.15^{b} (0.12)	3.22^{a} (0.13)	4.84^{a} (0.09)	4.93^{a} (0.14)	5.04^{a} (0.17)	3.38^{ab} (0.20)	6.38^{a} (0.39)	7.46^{a} (0.52)	7.73^{a} (0.50)	8.16^{a} (0.57)
PKM 1 - India	2.53^{a} (0.06)	3.07^{a} (0.14)	4.14 ^{c} (0.27)	4.24^{bc} (0.20)	4.28^{cd} (0.26)	3.73^{a} (0.18)	5.08^{bc} (0.12)	5.63^{bcd} (0.09)	5.72^{bcd} (0.02)	6.06^{bcde} (0.22)
PKM 2 - India	2.40^{ab} (0.04)	3.04^{a} (0.05)	4.11^{c} (0.12)	4.22^{bc} (0.07)	4.28^{cd} (0.10)	3.14^{b} (0.04)	4.43^{cde} (0.19)	4.93^{de} (0.25)	5.03^{cdef} (0.24)	5.26^{cdef} (0.26)
PKM 3 - India	2.49^{a} (0.14)	2.98^{a} (0.03)	3.97^{c} (0.13)	3.99^{c} (0.13)	4.06^{cd} (0.07)	3.36^{ab} (0.19)	4.46^{cde} (0.12)	5.01^{cde} (0.03)	5.08^{cdef} (0.02)	5.12^{cde} (0.04)
Jafna/Jaffana - India	2.48^{a} (0.10)	2.98^{a} (0.06)	3.78^{c} (0.17)	3.79^{c} (0.23)	3.87^{d} (0.14)	3.68^{a} (0.01)	4.48^{cde} (0.09)	4.88^{de} (0.13)	5.12^{cdef} (0.21)	5.16^{def} (0.29)
Honduras - Honduras	1.64^{c} (0.12)	2.44^{b} (0.24)	3.44^{d} (0.16)	3.76^{c} (0.23)	3.81^{d} (0.20)	2.64^{c} (0.44)	4.37^{cde} (0.25)	4.99^{de} (0.16)	5.08^{cdef} (0.12)	5.33^{bcdef} (0.18)
Mbololo 472-029/03 - Kenya	1.87^{c} (0.22)	2.60^{b} (0.24)	4.07^{c} (0.07)	4.22^{bc} (0.14)	4.47^{bc} (0.18)	3.50^{ab} (0.21)	5.42^{b} (0.16)	6.04^{b} (0.13)	6.11^{b} (0.12)	6.30^{b} (0.17)
Ihumwa - Tanzania	1.79^{c} (0.05)	2.55^{b} (0.07)	4.10^{c} (0.19)	4.20^{bc} (0.19)	4.22^{cd} (0.17)	3.08^{bc} (0.11)	5.09^{bc} (0.12)	5.72^{bcd} (0.25)	5.81^{bcd} (0.27)	6.16^{bcd} (0.29)
P>F Ratio	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
RMSE	0.1656	0.20	0.22	0.30	0.28	0.28	0.38	0.46	0.45	0.53
CV	9.14	8.11	6.13	8.10	7.21	9.56	7.85	8.41	8.24	9.24

*Means of individual species/provenance with standard error in parenthesis. -Means of the same letter within the same column are not significantly different.

showed superior height growth while Makhanga (Malawi) and Chikwawa/Domasi (Malawi) pro-venances showed poor growth in height. The differences in height growth within a site could be attributed to variations in adaptability among provenances while the between site differences in growth relate with rainfall differences between the two sites with Ruvu having higher rainfall as compared to Gairo. Generally, the provenances showed good performance in height development at Ruvu site. The growth performance of outstanding provenances in the present study compare favourably with results reported in Song Hau State farm, Cantho City, Vietnam (Manh et al., 2005) and in Zimbabwe (Gadzirayi et al., 2013; Goss, 2012). The Vietnam site has higher annual rainfall of 1800 - 2000 mm as compared to that of the study sites.

Biomass

Most provenances grown at the Ruvu site showed high production of foliar and stem biomass than those grown at Gairo site. This could be due to sufficient availability of growth resources (rainfall) at Ruvu site unlike the Gairo site. The lowest yield in stem biomass at Gairo site were recorded from Ngabu (Malawi) and Mangochi (Malawi) while at Ruvu site were recorded for Mangochi (Malawi) and Makhanga (Malawi) provenances. The lowest yield in

Table 7. Biomass production of 30 months old *M. oleifera* provenances planted at Gairo site, Morogoro and Ruvu site, Coast Region, Tanzania.

Species/Provenances	Age (months)			
	Gairo site		Ruvu site	
	Stems(Kg/ha)	Foliage(Kg/ha)	Stems(Kg/ha)	Foliage (Kg/ha)
Chikwawa/Domasi - Malawi	8235.60^{cde} (2173.46)	1324.10^{cde} (378.86)	21036.74^{ab} (4163.94)	738.19^{ab} (107.89)
Makhanga - Malawi	8481.34^{cde} (803.95)	982.04^{de} (461.58)	15796.17^{b} (5022.39)	697.10^{b} (187.76)
Ngabu - Malawi	6200.41^{de} (1781.16)	491.02^{e} (98.81)	20858.93^{ab} (6500.60)	1423.19^{ab} (542.02)
Mangochi - Malawi	5901.08^{e} (1027.08)	1035.61^{de} (104.09)	15816.98^{b} (2015.65)	972.51^{ab} (31.67)
Mtakataka/Dedza - Malawi	11386.00^{bcde} (1053.55)	1723.31^{bcde} (598.34)	17292.03^{b} (4111.31)	1383.46^{ab} (243.10)
Mahalapye - Botswana	21212.24^{ab} (4618.29)	3108.98^{ab} (590.92)	41403.26^{a} (12290.79)	1717.77^{ab} (587.61)
Maun - Botswana	20285.88^{ab} (2910.27)	4407.18^{a} (1227.52)	34888.16^{ab} (4362.86)	1917.21^{a} (205.66)
PKM 1 - India	21012.81^{ab} (7635.45)	2213.56^{bcd} (129.57)	31943.36^{ab} (11629.09)	1865.19^{ab} (550.69)
PKM 2 - India	24733.60^{a} (1063.24)	2562.68^{bcd} (628.82)	19061.91^{b} (4741.96)	1506.82^{ab} (361.19)
PKM 3 - India	16183.97^{abcde} (3687.52)	2159.61^{bcd} (152.48)	22859.98^{ab} (3360.61)	1484.22^{ab} (164.91)
Jafna/Jaffana - India	19981.74^{ab} (2759.02)	2740.89^{bc} (552.82)	24946.83^{ab} (1697.49)	1437.73^{ab} (130.37)
Honduras - Honduras	12280.77^{bcde} (1835.96)	1574.84^{bcde} (685.94)	19679.77^{b} (2399.60)	1450.30^{ab} (250.07)
Mbololo 472-029/03 - Kenya	17542.76^{abcd} (4795.64)	2280.33^{bcd} (599.18)	28120.39^{ab} (8479.69)	1398.37^{ab} (553.10)
Ihumwa - Tanzania	18859.69^{abc} (3138.39)	2987.07^{ab} (971.92)	17610.75^{b} (3767.78)	1104.62^{ab} (225.14)
P>F RATIO	0.0049	0.007	0.1820	0.3987
RMSE	6016.97	853.42	10969.71	612.24
CV	39.68	40.38	46.35	44.88

*Means of individual species/provenance with standard error in parenthesis. Means of the same letter within the same column are not significantly different

foliar biomass at Gairo site were recorded for Ngabu (Malawi) and Makhanga (Malawi) provenances while at Ruvu site were recorded at Makhanga (Malawi) and Chikwawa/Domasi (Malawi) provenances. This poor performance could probably be due to poor genetic adaptations influenced by climatic conditions in these areas.

Conclusions and recommendations

The present study has shown that provenances differ significantly in survival and biomass production (Gairo site), and diameter and height growth in both sites. The best performing provenances at Gairo site were Mahalapye (Botswana), Maun (Botswana), Ihumwa (Tanzania), Mbololo 472-029/03 (Kenya) and PKM 1 (India) while at Ruvu site were Maun (Botswana), Mahalapye (Botswana), Mbololo 472-029/03 (Kenya) and Ihumwa (Tanzania). These provenances have shown promising growth throughout the study period indicating their suitability to the locality and other areas with similar soil/climatic conditions. On the other hand Chikwawa/-Domasi (Malawi), Makhanga (Malawi), Ngabu (Malawi) and Mangochi (Malawi) at Gairo and Mangochi (Malawi), Honduras (Honduras), Chikwawa/Domasi (Malawi) and Makhanga (Malawi) at Ruvu site failed to put on promising growth on these sites. The best performing provenances are recommended for planting at these and similar sites.

ACKNOWLEDGEMENTS

We are very grateful to AFORNET for funding this research project. We are also strongly indebted to the support provided by technicians from both sides for their tireless efforts in making the work a success. Also last but not least the efforts of the late Naomi Masanika who assisted in various stages of the study cannot go

Table 8. Ordinal ranking of 30 months old *M. oleifera* provenances planted at Gairo site, Morogoro, Tanzania.

Species/Provenances	Surv1	ht	rcd	dbh	fbio	sbio	Mean	Overall rank
Chikwawa/Domasi - Malawi	11	10	11	10	11	12	11	7
Makhanga - Malawi	10	13	13	14	13	11	12	8
Ngabu - Malawi	8	12	12	13	14	13	12	8
Mangochi - Malawi	9	9	14	12	12	14	12	8
Mtakataka/Dedza - Malawi	4	11	8	11	9	10	9	6
Mahalapye - Botswana	4	2	1	1	2	2	2	1
Maun - Botswana	2	1	2	2	1	4	2	1
PKM 1 - India	6	4	6	5	7	3	5	3
PKM 2 - India	2	4	5	6	5	1	4	2
PKM 3 - India	5	6	7	7	8	8	7	5
Jafna/Jaffana - India	2	7	10	9	4	5	6	4
Honduras - Honduras	7	8	9	8	10	9	9	6
Mbololo 472-029/03 - Kenya	3	3	3	4	6	7	4	2
Ihumwa - Tanzania	1	5	4	3	3	6	4	2

[1]Surv., Survival; ht, height; rcd, root collar diameter; dbh, diameter at breast height; fbio, foliar biomass; sbio, stem biomass.

Table 9. Ordinal ranking of 30 months old *M. oleifera* provenances planted at Ruvu site, Coast Region, Tanzania.

Species/Provenances	Surv[1]	ht	rcd	dbh	fbio	sbio	Mean	Overall rank
Chikwawa/Domasi - Malawi	1	12	8	9	13	7	8	7
Makhanga - Malawi	5	13	10	12	14	14	11	9
Ngabu - Malawi	2	9	6	8	8	8	7	6
Mangochi - Malawi	4	4	7	6	12	13	8	7
Mtakataka/Dedza - Malawi	2	6	3	4	10	12	6	5
Mahalapye - Botswana	1	3	5	5	3	1	3	2
Maun - Botswana	8	1	1	1	1	2	2	1
PKM 1 - India	4	5	9	7	2	3	5	4
PKM 2 - India	6	8	11	11	4	10	8	7
PKM 3 - India	3	11	14	14	5	6	9	8
Jafna/Jaffana - India	7	10	12	10	7	5	9	8
Honduras - Honduras	6	7	13	13	6	9	9	8
Mbololo 472-029/03 - Kenya	1	2	4	3	9	4	4	3
Ihumwa - Tanzania	2	4	2	2	11	11	5	4

[1]Surv.-Survival; ht-height; rcd-root collar diameter; dbh-diameter at breast height; fbio-foliar biomass; sbio-stem biomass.

unacknowledged.

REFERENCES

D'souza J, Kulkarmi AR (1993). Comparative studies on nutritive values of seedlings and mature plants of *Moringa oleifera* Lam. J. Econ. Tax. 17(2):479-485.

Edward E, Chamshama SAO, Mugasha AG (2006). Growth performance of lesser-known *Leucaena* species/provenances at Gairo inlang plateau, Morogoro, Tanzania. South. Afr. For. J. 208:53-62.

Evans J (1991). Safe drinking water for developing world. Our Planet (UNEP) 3(1):12-13.

Fahey JW **(**2005). *Moringa oleifera:* A review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1: Trees life J. 1:5. Available at: http://www.tfljournal.org/article.php/ [Accessed 20 May 2009].

FAO (1988). Non timber uses of selected arid zone trees and shrubs in Africa. Edited by F. E. Booth and G. E. Wickens, FAO Conservation Guide19, FAO, Rome, pp. 92-101.

Folkard GK, Sutherland JP (1996). *Moringa oleifera*: a tree and a litany of potential. Agrofor. Today. pp. 5-8.

Forest Division (1982). Management practices in Conifer Plantations in Tanzania: Notes on Forestry Operations. Ministry of Natural Resources and Tourism. p. 68.

Gadzirayi CT, Kubiku FNM, Mupangwa JF, Mujuru L, Chikuvire TJ

(2013). The Effect of plant spacing and cutting interval on growth of *Moringa oleifera.* JASA 2(2):131- 136.
Gomez KA, Gomez AA (1983). Statistical Procedure for Agricultural Research. John Willey and sons, New York. p. 680.
Goss M (2012). A study of the initial establishment of multi - purpose moringa (*Moringa oleifera* Lam) at various plant densities, their effect on biomass accumulation and leaf yield when grown as vegetable. Afr. J. Plant Sci. 6(3):25-129.
Herbert M, Mugasha AG, Jahn SAA, Chamshama SAO (2002). Evaluation of 19 provenances of *Calliandra calothyrsus* at Gairo and SUA Farm, Morogoro, Tanzania. South. Afr. For. J. 194:15-25.
Holmes J (1988). Ruvu Fuelwood Project. Ruvu South Forest Reserve Natural Woodlands management proposal. Unpublished. Dar-es-Salaam. pp. 232.
Jahn SAA (1988a). Flocculation experiments with waste waters in Guatemala and field notes from Costa Rica. Unpublished report for GTZ.
Jahn SAA (1988b). Using *Moringa* seeds as a coagulant in developing countries. J. Am. Water Works Assoc. 80:43-50.
Jahn SAA (1988c). Chemotaxonomy of flocculating plant materials and their application for rural water purification in developing countries. Acta Univ. Ups. Symb. Bot. Ups. 28(3):171-185. Uppsala. ISBN 91-554-2348-5.
Maghembe JA (1979). Effect of Weeding and some soil characteristics on the survival and growth of *Pinus caribaea* in plantation at Ruvu. Division of Forestry, University of Dar-es-Salaam. Record No. 8, pp. 12.
Manh LH, Dung NNX, Ngoi TP (2005). Introduction and evaluation of *Moringa oleifera* for biomass production and as feed for goats in the Mekong delta. LRRD 17(9): Available at http://www.cipav.org.co/lrrd/lrrd17/9/edit1709.htm. [Accessed 9 January 2007].
Mayer FA, Stelz E (1993). *Moringa stenopetala* provides food and low-cost water purification. Agrofor. Syst. 5:16-18.
Mbuya LP, Msanga HP, Ruffo CK, Birnie A,Tengnas B (1994). Useful Trees and Shrubs for Tanzania, Identification and Management for Agriculture and Pastoral Communities. Technical Handbook No. 6. SIDA's Regional soil Conservation Unit. Nairobi: p. 542.
Morton JF (1991). The horseradish tree, *Moringa pterygosperma-a* boon to arid lands? Econ. Bot. 45(3):318-333.
Msanya BM, Msaky JJT (1994). Land use and land evaluation systems research project. Progress Report (August 1993-March 1994). Department of Soil Science, SUA, National Soil Service, Ministry of Agriculture, Tanzania and Center for African Area Studies, Kiplo University, Japan.
Mugasha AG, Chamshama SAO, Nshubemuki L (2000). Effect of spacing on growth and yield of *Sesbania sesban* at Gairo in Morogoro region, Tanzania. TJFNC 73:53 -63.
Olayemi AB, Alabi RO (1994). Studies on traditional water purification using *Moringa oleifera* seeds. Afr. Study Monogr. 15(3):135-141.
Panga JT (2002). Effect of processing on nutritional quality of *Moringa oleifera* leaves and pods. MSc. Dissertation, SUA, Tanzania. pp. 81.
Sa´ Nchez NR, Ledin S, Ledin I (2006). Biomass production and chemical composition of *Moringa oleifera* under different management regimes in Nicaragua. Agrofor. Syst. 66(3):231-242.
SAS Institute Inc. (1991). SAS/STAT Guide for personal computers. Version 8th Edition. SAS. Inc. Cary, North Carolina, USA. pp. 672.
Sokal RR, Rohlf FJ (1969). Biometry. W.H.Freeman and Co. NY. USA.