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Research Article

Effect of spacing and cutting management on survival, growth and biomass production of *Moringa oleifera* intercropped with maize on-farm at Gairo inland plateau, Morogoro in Tanzania

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ABSTRACT

A study was carried out at Gairo, Tanzania to determine appropriate planting spacing and cutting management for optimising maize yield without jeorpadising the potential of *Moringa oleifera* to produce sufficient biomass. Two trials (on-farm spacing-intercropping and on-farm pollarding height-intercropping) were laid out using Randomized Complete Block Design (RCBD). Assessments were done at tree ages of 6, 12, and18 for the spacing trial and at tree ages of 6, 12, 18, 24 and 36 months for the pollarding trial. Grain weights were measured on a yearly basis (seasons). Plot means for all response variables were subjected to standard Analysis Of Variance (ANOVA) and significant means were separated by Duncan's Multiple Range Test (DMRT). Results for the spacing trial showed that, overall all growth parameters increased significantly with spacing, and tree growth was generally higher in monoculture compared to intercropped plots. During the last assessment, foliar and stem biomass ranged from 571.57 kg/ha for maize+150cm pollarding height to 682.15 kg/ha for maize+50 cm pollarding height and from 181.72 kg/ha for 150 cm pollarding height to 254.29 kg/ha for maize+100 cm pollarding height respectively. *Moringa* intercropping is recommended to be done only during the first cropping season, due to severe competition thereafter.

INTRODUCTION

In Tanzania, as elsewhere in Sub-Saharan Africa (SSA), continuous cropping without adequate fertilization has led to soil fertility depletion and subsequent low crop yields (Ikerra *et al.,* 2006). Several agroforestry tree/shrub species like *Sesbania sesban*, *Gliricidia sepium*, *Cajanus cajan* and *Tephrosia vogelii* have been tested and used for soil fertility improvement in various semiarid areas in Tanzania including Gairo (Chamshama *et al.,* 2000).

Moringa oleifera is among the known promising exotic multipurpose tree species recommended for fuel wood, fodder, food, medicinal value and soil fertility improvement. The species has been reported to improve crop yield by improving soil fertility and providing semi-shade, useful in intercropping systems where intense direct sunlight can damage crops (Folkard and Sutherland, 1996). *Moringa oleifera* is a medium-sized (i.e. 5-15 m height) fast growing and highly coppicing multipurpose tree species native to northern India (Panga, 2002). *Moringa oleifera* grows very fast reaching a height of 4 m within one year after sowing (Folkard and Sutherland, 1996). Altitudinally, it is found between 0 – 500 m a.s.l. although it can perform up to 2000 m (Mbuya *et al.,* 1994). This species withstands long periods of drought and grows well in semi arid and arid conditions (Folkard and Sutherland, 1996; Coote *et al.*, 1997) like Gairo, in Tanzania.

Moringa oleifera has never been grown on farm in Gairo and other parts of Tanzania. Because of its potential, this study was carried out to determine appropriate planting spacing and cutting management for optimising maize growth and yield without jeorpadising the potential of *Moringa oleifera* to produce sufficient biomass to influence soil fertility and yield of crops in land–scarce semi arid areas like Gairo in Tanzania.

MATERIALS AND METHODS

Study site

The study was carried out at Gairo which is located in Kilosa District, Morogoro Region, Tanzania (36º 45' E; 6º 0º S; 1300 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 have been 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.

Experimental design

Two trials were carried out, one on spacing and the other on pollarding height. The experimental designs and treatments are presented in the following sections.

(a) On-farm spacing-intercropping trial

The design of the experiment was Randomized Complete Block Design (RCBD). In this case each participating farmer was treated as a replicate. Each farmer established seven plots of different sizes, where six were planted with 25 trees while one was a sole maize plot. The plots were subjected to the following treatments: (i) Trees planted at 2 x 2 m (size: 8 x 6m), (ii) Trees planted at 2.5 x 2.5 m (size: 10 x 7.5 m) and (iii) Trees planted at 3 x 3 m (size: 12 x 9 m), (iv) Trees planted at 2 x 2 m plus maize, (v) Trees planted at 2.5 x 2.5 m plus maize, (vi) Trees planted at 3 x 3 m plus maize and (vii) sole maize crop (size: 8 x 6 m).

(b) On-farm pollarding height-intercropping trial

The design of the trial was a RCBD where each block (replicate) was made up of seven treatments. In this case each participating farmer was treated as a replicate. Thus, each farmer established seven plots each measuring 10 x 7.5 m and a spacing of 2.5 x 2.5 m. The treatments were: (i) pollarding height of 50 cm, (ii) pollarding height of 100 cm, (iii) pollarding height of 150 cm, (iv) pollarding height of 50 cm plus maize, (v) pollarding height of 100 cm plus maize, (vi) pollarding height of 150 cm plus maize, and (vii) sole maize. The Moringa plots were pollarded at the age of one year and before establishment of the maize crop in the following years.

Field procedures

Trial sites were prepared by digging manually all stumps followed by ploughing and pitting and planted with trees and maize. Plots were replanted with maize during the following two years. Three months old seedlings raised in polythene tubes (10 cm height and 4 cm lay flat diameter) using nursery techniques appropriate for *Moringa* were planted in pits measuring 30 cm diameter and depth. All experiments were clean weeded three

times during the rainy season and once during the dry season.

Data collection

Assessments of trees were carried out at ages of 6, 12, 18, 24 and 36 months after planting. During the first assessment which was done before commencement of pollarding, survival, root collar diameter (RCD), total height (HT) and crown width (CW) were assessed while in subsequent assessments; diameter at breast height (DBH) and biomass production were also measured. Grain weight assessment was measured on a yearly basis here after referred to as seasons. Height was measured to the nearest 0.01 m using calibrated height measuring pole while RCD and DBH were measured to the nearest 0.01 cm using a veneer calliper. Measuring tape was used to measure crown width.

Data analysis

For all response variables (tree survival, DBH, HT, CW, maize yields and tree biomass), plot means were calculated and subjected to standard Analysis Of Variance (ANOVA) of RCBD and significant means were separated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1983) at 5% probability level. Prior to ANOVA, tree survival percentage data was transformed to arc sine values to induce normality and equal variance (Sokal and Rohlf, 1969).

The General Linear Model was denoted as:
Y= replication + treatment + error..... (1)
Where Y = the measurement.

RESULTS AND DISCUSSION

(a) On-farm spacing-intercropping trial

***Moringa* growth performance**

The results for tree survival, RCD, DBH, HT and CW for different spacing treatments planted alone or intercropped with maize are presented in Tables 1, 2 and 3 respectively. The differences in all parameters assessed were significant ($P<0.05$) during all assessment occasions. At final assessment, untransformed survival ranged from 89.52% to 98.89%, RCD ranged from 5.01 cm to 7.80 cm, DBH ranged from 2.82 cm to 4.70 cm, HT ranged from 3.13 m to 4.12 m and CW ranged from 1.08 m to 1.80 m.

Table 1: Survival and transformed survival of 6, 12, and 18 months old *Moringa oleifera* planted on-farm (spacing trial) at Gairo, Morogoro, Tanzania

	Age (months)					
	6		12		18	
Treatments	**UTSV**	**TSV**	**UTSV**	**TSV**	**UTSV**	**TSV**
2x2+maize	*89.52b	78.95b	89.52b	78.95b	89.52b	78.95b
	(3.84)	(3.92)	(3.84)	(3.92)	(3.84)	(3.92)
2.5x2.5+maize	97.22a	85.98a	97.22a	85.98ab	97.22ab	85.98ab
	(1.51)	(2.18)	(1.51)	(2.18)	(1.51)	(2.18)
3x3+maize	98.15a	87.32a	98.15a	87.32a	97.78ab	86.78ab
	(1.27)	(1.84)	(1.27)	(1.84)	(1.51)	(2.19)
2x2 trees alone	98.15a	87.32a	98.15a	87.32a	97.78ab	86.78ab
	(1.27)	(1.84)	(1.27)	(1.84)	(1.51)	(2.19)
2.5x2.5 trees alone	99.07a	88.66a	99.07a	88.66a	98.89a	88.39ab
	(0.93)	(1.34)	(0.93)	(1.34)	(1.11)	(1.61)
3x3 trees alone	99.07a	88.66a	98.33a	87.59a	98.33a	87.59a
	(0.93)	(1.34)	(1.15)	(1.66)	(1.15)	(1.66)
P>F RATIO	0.0048	0.0197	0.0254	0.046	0.08	0.09
RMSE	7.8647	9.2063	6.16	8.12	5.60	7.36
CV	8.12	10.69	6.31	9.35	5.69	8.41

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

Table 2: Root collar diameter and diameter at breast height of 6, 12, and 18 months old *Moringa oleifera* planted on-farm (spacing trial) at Gairo, Morogoro, Tanzania

	Age (months)				
	6	12		18	
Treatments	**RCD**	**RCD**	**DBH**	**RCD**	**DBH**
2x2+maize	*1.49c	2.83d	1.71c	5.01d	2.82d
	(0.11)	(0.22)	(0.10)	(0.26)	(0.15)
2x2 trees alone	3.05a	4.27b	2.53b	6.13c	3.57bc
	(0.20)	(0.25)	(0.20)	(0.31)	(0.33)
2.5x2.5+maize	1.95b	3.38c	1.99c	5.92c	3.26cd
	(0.13)	(0.23)	(0.15)	(0.26)	(0.20)
2.5x2.5 trees alone	3.20a	4.57b	2.70ab	6.90b	4.07b
	(0.20)	(0.26)	(0.18)	(0.36)	(0.35)
3x3+maize	2.05b	3.74c	1.98c	7.04b	3.69bc
	(0.14)	(0.30)	(0.16)	(0.36)	(0.29)
3x3 trees alone	3.35a	5.10a	2.97a	7.80a	4.70a
	(0.24)	(0.29)	(0.23)	(0.42)	(0.35)
P>F RATIO	<. 0001	<.0001	<.0001	<.0001	<.0001
RMSE	0.5519	0.81	0.60	0.94	0.77
CV	21.94	20.27	25.86	14.48	20.92

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

Table 3: Height and crown width of 6, 12, and 18 months old *Moringa oleifera* planted on-farm (spacing trial) at Gairo, Morogoro, Tanzania

	Age (months)					
	6		12		18	
Treatments	**HT**	**CW**	**HT**	**CW**	**HT**	**CW**
2x2+maize	*1.16c	0.65c	1.61d	1.10d	3.13c	1.08c
	(0.08)	(0.04)	(0.10)	(0.06)	(0.15)	(0.07)
2x2 trees alone	1.70a	1.06a	2.30b	1.37bc	3.46bc	1.32bc
	(0.09)	(0.04)	(0.12)	(0.07)	(0.19)	(0.07)
2.5x2.5+maize	1.33b	0.80b	1.84cd	1.30c	3.44bc	1.43b
	(0.09)	(0.04)	(0.12)	(0.08)	(0.13)	(0.08)
2.5x2.5 trees alone	1.67a	1.07a	2.42ab	1.47b	3.77b	1.51ab
	(0.09)	(0.05)	(0.11)	(0.07)	(0.18)	(0.09)
3x3+maize	1.35b	0.81b	1.91c	1.31c	3.66b	1.76a
	(0.08)	(0.04)	(0.11)	(0.08)	(0.19)	(0.21)
3x3 trees alone	1.76a	1.12a	2.56a	1.65a	4.12a	1.80a
	(0.10)	(0.06)	(0.13)	(0.08)	(0.20)	(0.12)
P>F RATIO	<. 0001	<. 0001	<.0001	<.0001	<.0001	<.0001
RMSE	0.2562	0.1408	0.37	0.22	0.46	0.41
CV	17.14	15.34	17.78	15.76	12.81	27.35

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

Overall, all parameters increased with increasing spacing. These trends have been observed in other spacing studies (Iddi *et al*., 1996). However growth was generally retarded by intercropping. The retardation of growth due to intercropping could be attributed to maximum plant inter-specific competition for growth resources as observed in other intercropping studies (Janick, 1972; Chamshama *et al*., 1998; Nair, 1984, 1993).

Maize production

The results for grain weight in plots where *Moringa* was intercropped with maize are presented in Table 4. Treatments differed significantly (P<0.05) in season 1 while in season 2, treatments did not differ significantly (P>0.05) in grain weight production. Grain weight ranged from 1020.54 kg/ha for 2x2+maize to 1431.73 kg/ha for 2.5x2.5+maize during the first season of assessment. The yield dropped sharply during the

second year of assessment mainly due to low rainfall in that year. Grain weight ranged from 36.89 kg/ha for 3x3+maize to 94.57 kg/ha for 2x2+maize. Due to crown closure, further maize planting in the third season was not carried out. There was no clear trend of change in grain weight with increasing spacing. Grain weight was expected to increase with increase in spacing due to lower competition from the fewer trees arising from wider spacing. Maize yield was likely affected more by other factors beside spacing, including observed differences in the management of plots by farmers which has to some extent compounded the results.

Table 4: Maize grain yield (Kg/ha) planted on–farm (spacing trial) with *Moringa oleifera* at Gairo, Morogoro Tanzania

	SEASON 1	SEASON 2
Treatments	**Grain**	**Grain**
Maize alone	*1057.79b	78.32a
	(94.96)	(61.23)
Maize+2x2	1020.54b	94.57a
	(100.39)	(65.09)
Maize+2.5x2.5	1431.73a	60.23a
	(137.36)	(41.98)
Maize + 3x3	1242.92ab	36.89a
	(94.92)	(26.61)
P>F Ratio	0.004	0.26
RMSE	358.68	95.03
CV	30.19	140.78

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

(b) On-farm pollarding-intercropping trial

***Moringa* Growth performance**

The results (before the pollarding treatment was imposed) for survival, transformed survival, HT, RCD and CW of *Moringa oleifera* planted on-farm and intercropped with maize are presented in Table 5. As pollarding had not yet been done, these results essentially compare Moringa monoculture and Moringa and maize intercropping treatments. *Moringa oleifera* survival and growth differed significantly ($P<0.05$) in all parameters assessed. Untransformed survival ranged between 92.16% for maize + 50 cm pollarding height and 99.02 % for 100 cm alone. The HT development ranged between 1.27 m for maize + 50 cm pollarding height and 1.73 m for 50 cm pollarding height for trees alone. RCD ranged between 1.85 cm for maize + 50 cm pollarding height and 3.25 cm for 50 cm pollarding height alone. CW ranged between 0.76 m for maize + 50 cm pollarding height and 1.15 m for 100 cm pollarding height alone during the 6 months of assessment. Generally, intercropped plots showed poor performance by having lower values in survival, HT, RCD, and CW compared to the monoculture plots. As observed in the spacing trial, intercropped plots seem to be affected by competition for moisture and light (Nair, 1984, 1993) between *Moringa* and maize and among *Moringa* trees themselves resulting in poor growth.

Table 5: Survival (UTSV), transformed survival (TSV), height, root collar diameter and crown width of *Moringa oleifera* planted on-farm before commencement of pollarding at Gairo, Morogoro, Tanzania

Treatments	Age (months) 6				
	UTSV	TSV	HT (m)	RCD (cm)	CW (m)
150 cm + Maize	*94.12ab	82.25ab	1.39b	2.03b	0.82c
	(2.45)	(3.06)	(0.09)	(0.14)	(0.05)
100 cm + Maize	98.04ab	87.16ab	1.37b	1.99b	0.78c
	(1.34)	(1.94)	(0.09)	(0.13)	(0.04)
50 cm + Maize	92.16b	81.02b	1.27b	1.85b	0.76c
	(3.53)	(3.66)	(0.08)	(0.13)	(0.05)
50 cm pollarding alone	98.04ab	87.16ab	1.73a	3.25a	1.08ab
	(1.34)	(1.94)	(0.10)	(0.24)	(0.05)
100 cm pollarding alone	99.02a	88.58a	1.68a	3.21a	1.15a
	(0.98)	(1.42)	(0.09)	(0.23)	(0.06)
150 cm pollarding alone	96.08ab	85.09ab	1.63a	3.10a	1.03b
	(2.27)	(2.71)	(0.09)	(0.21)	(0.04)
P>F Ratio	0.1237	0.1616	<. 0001	<. 0001	<. 0001
RMSE	8.19	9.72	0.28	0.57	0.15
CV	8.51	11.40	18.29	22.26	16.06

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

Maize production

Maize grain weight in the pollarded plots is shown in Table 6. Treatments did not differ significantly (P<0.05) in grain weight production throughout the first two seasons of assessment. Grain weight in the first season ranged from 1225.28 kg/ha for maize alone to 1411.30 kg/ha for maize+50 cm pollarding height. The maize yield was much poor during the second year of assessment unlike the first season. This was probably due to bad weather experienced in that season. Grain weight ranged from 528.52 kg/ha for maize+150cm pollarding height to 836.52 kg/ha for maize alone during the last season of assessment.

Table 6: Maize grain yield (Kg/ha) planted on–farm (pollarding trial) with *Moringa oleifera* at Gairo, Morogoro, Tanzania

	Season 1	Season 2	Season 3
Treatment	Grain	Grain	Grain
Maize+50cm Pollarding height	*1411.30a	34.24a	801.77ab
	(159.99)	(34.24)	(249.73)
Maize+100cm Pollarding height	1354.84a	15.11a	769.80ab
	(162.74)	(15.11)	(201.50)
Maize+150cm Pollarding height	1388.48a	34.05a	528.52b
	(117.60)	(34.05)	(170.66)
Maize Alone	1225.28a	63.56a	836.52a
	(126.45)	(63.56)	(214.04)
P>F RATIO	0.54	0.40	0.12
RMSE	414.51	89.46	388.80
CV	30.82	243.51	52.96

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

Overall, maize yield in this study was far below the levels observed in improved fallow trials in the area (Chingonikaya, 1999; Mgangamundo, 2000), an indication that other than competition for moisture and nutrients, pollarding did not provide adequate biomass to improve soil fertility for maize production and/or there was unsynchronized nutrient release from green manure due to fast decomposition common in *Moringa*. Over 2 tons per hectare of foliar biomass is needed to increase maize yield to between 2 and 4 tons per hectare depending on the tree/shrub species (Chingonikaya, 1999; Mgangamundo, 2000).

Moringa foliar and stem biomass

In terms of foliar and stem biomass production, treatments did not differ significantly ($P<0.05$) in all assessment periods except for foliar and stem biomass in first assessment and stem biomass during the second and third assessment periods (Table 7).

Table 7: Foliar and stem biomass production (Kg/ha) of *Moringa oleifera* planted on–farm (pollarding trial) at Gairo, Morogoro, Tanzania

	Age (months)					
	12		24		36	
Treatment	**Foliage**	**Stems**	**Foliage**	**Stems**	**Foliage**	**Stems**
Maize+50cm	*36.09a	31.41a	398.06a	1801.42a	682.15a	244.17a
Pollarding height	(0.97)	(0.96)	(150.00)	(264.93)	(64.79)	(29.26)
Maize+100cm	34.46a	29.77ab	291.17a	1589.62ab	669.06a	254.29a
Pollarding height	(2.05)	(1.84)	(52.68)	(222.17)	(69.48)	(39.84)
Maize+150cm	30.18b	26.94b	339.57a	1108.21b	571.57a	195.73ab
Pollarding height	(3.04)	(2.75)	(73.71)	(134.16)	(89.04)	(27.33)
50cm Pollarding	36.09a	31.41a	405.77a	2068.33a	576.71a	229.44ab
height	(0.97)	(0.96)	(110.52)	(364.25)	(50.70)	(35.91)
100cm Pollarding	36.09a	31.41a	394.74a	1941.80a	680.45a	228.56ab
height	(0.97)	(0.96)	(111.58)	(313.18)	(92.91)	(29.47)
150cm Pollarding	36.09a	31.41a	310.27a	1492.70ab	677.73a	181.72b
height	(0.97)	(0.96)	(91.45)	(220.25)	(102.58)	(24.92)
P>F RATIO	0.03	0.06	0.50	0.0064	0.39	0.07
RMSE	6.68	5.43	224.80	788.90	215.23	79.21
CV	19.16	17.85	63.04	47.32	33.48	35.63

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

During the last assessment, foliar and stem biomass ranged from 571.57 kg/ha for maize+150cm pollarding height to 682.15 kg/ha for maize+50 cm pollarding height and from 181.72 kg/ha for 150 cm pollarding height to 254.29 kg/ha for maize+100 cm pollarding height respectively. These values are much higher than the ones reported by Manh *et al.,* (2005). All treatments showed higher foliar and stem biomass production during the second period of assessment than the first and the last assessment periods. Studies done in Tinh Bien district, a Giang province indicated the reverse that biomass showed larger values in the first assessment and decreased thereafter (Manh *et al.,* 2005). Site and management variations could explain these differences.

CONCLUSION

Its is concluded that for the spacing used in this study, intercropping *Moringa oleifera* with maize is only possible during the first cropping season thereafter competition effects retards maize production. For the pollarding trial, overall, the various pollarding heights did not influence maize yield. The pollarded biomass was generally inadequate to influence soil fertility and/or there was unsynchronized nutrient release from green manure due to fast decomposition.

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