Research Article

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Journal of Plant Sciences and Agricultural Research

2022
Vol.6 No.1:64

Contribution of *Moringa* Trees to the Production of Alley Maize Crops in Arba Minch Zuria District, Southern Ethiopia

Desta Hamore[1*], Getahun Yakob[2], Tizazu Bushura[1], Degefu Asfaw[1], Asfaw Debella[3] and Agena Anjulo[4]

[1]Arbaminch Agricultural Research Center, Arbaminch, Ethiopia

[2]Southern Agricultural Research Institute, Awasa, Ethiopia

[3]Ethiopian Public Health Institute, Addis Ababa, Ethiopia

[4]Ethiopian Environment and Forest Research Institute, Addis Ababa, Ethiopia

***Corresponding author:** Desta Hamore, Arbaminch Agricultural Research Center, Arbaminch, Ethiopia, E-mail: destahm3799@gmail.com

Received date: January 31, 2022, Manuscript No. IPJPSAR-22-12191; **Editor assigned date:** February 02, 2022, PreQC No. IPJPSAR-22-12191(PQ); **Reviewed date:** February 16, 2022, QC No. IPJPSAR-22-12191; **Revised date:** February 23, 2022, Manuscript No. IPJPSAR-22-12191(R); **Published date:** March 02, 2022, DOI: 10.36648/plant-sciences.6.1.64

Citation: Hamore D, Yakob G, Bushura T, Asfaw D, Debella A, et al. (2022). Contribution of Moringa Trees to the Production of Alley Maize Crops in Arba Minch Zuria District, Southern Ethiopia. J Plant Sci Agri Res Vol.6 No.1:64

Abstract

Better understanding on the role of *Moringa* trees for production of alley maize has a paramount important for improving traditional agroforestry practices in southern Ethiopia. On-farm experiment was conducted in Arba Minch Zuria district to evalute the growth and leaf yield of two *Moringa* tree species (*Moringa stenopetala* and *Moringa olifera*), and their impact on the grain yield of alley maize. The experiment consisted of four treatments (*Moringa stenopetala*+maize, *Moringa olifera*+maize, 50% *Moringa stenopetala* and 50% *Moringa olifera*+maize and maize mono-cropping) in randomized complete block design with four replications. Growth parameters and agronomic data were collected from tree and maize respectively. Most studied tree growth parameters except height and fresh leaf biomass, the rest showed significant differences (P<0.05) among treatments. In the case of 100% intercropped *M. stenopetala*, maize grain yield reduction ranged from 16% in the first cropping season (2018) up to 23% in the second (2019). Reduction of maize grain yields by 100% intercropped *M. olifera* trees was more drastic than in the plots with *M. stenopetala*, ranging from 32% in the first cropping up to 48% in the second cropping season. However, yield reduction was compensated by outputs from tree products and *Moringa*-maize intercropping systems are financially attractive than maize mono-cropping. Therefore, in southern Ethiopia, integrating *Moringa stenopetala* with maize intercropping, in their farming systems is a feasible option to generate income and other benefits derived from planted *Moringa* trees.

Keywords: Agroforestry; Distance; Interaction; Intercropping; Leaf biomass; Shade

Introduction

Agroforestry has been defined in several ways **[1,2]**. ICRAF's current definition is a collective name for land-use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land-management unit. Growing trees with crops in agroforestry systems can increase total productivity, reduce land degradation and improve recycling of nutrients, while producing fuel wood, fodder, fruits and timber in addition to products from annual crops **[3]**. However, the potential benefits of higher productivity, improved sustainability and reduced risk of such simultaneous agroforestry systems in comparison with monocultures are the outcome of a complex set of spatial and temporal interactions between the different components of the system. An important aspect of these interactions is the increasing dominance of the perennial trees as they mature (Ong et al., 2004) and competes with crops for light, water and nutrients (Ong et al., 1996) **[4,5]**. Impacts of trees on crops in agroforestry affected by the density of trees, age of trees, height of mature trees, system design, tree and crop species and the direction of the tree row which could leads to crop yield higher or lower. Reducing competition may be achieved by selecting trees with less competitive or/and appropriate tree management **[6-8]**.

In southern Ethiopia, agroforestry practices are an integral part of farming system and practiced for economic, social and environmental benefits. *Moringa stenopetala* based homegarden and parkland agroforestry practices are among the major ones that have been practiced traditionally in the region for many years particularly in areas such as Konso, Gamo, Gofa, Derashe, South Omo, Wolaita and Dawaro **[9]**. Improving the productivity of the practices through managing tree-crop interaction could be an appropriate option to encourage adoption of agroforestry technique by framers to enhance increased crop output for rural development. Information regarding the role of *Moringa* for production of alley maize, growth and leaf biomass production at different management regimes and contribution for soil fertility enhancement is lacking. Thus, scientific studies need to be undertaken in order to improve the productivity of the plant through integrating with different agro-forestry practices and management activities. This study was initiated to evaluate the growth and leaf yield of two *Moringa* trees species (*Moringa stenopetala* and *Moringa olifera*), and their impact on the grain yield of intercropped alley maize in Arba Minch zuria district, Southern Ethiopia.

Materials and Methods

Site description

The study was conducted at Chano Mille substation from 1st October 2016 to 30th September 2019. The study site is found in Arba Minch Zuria District of Gamo zone, southern Ethiopia. The study area is geographically located at 6°5′ 30″ N, 37° 35′ 0″ E with an altitudinal range of 1200 m above sea level. Meteorological records reveal that rainfall pattern in Arba Minch Zuria is bimodal with mean annual rainfall ranges between 1100 mm - 1600 mm, whereas the minimum and maximum air temperature varying between 17 and 35°C. The soil of the study site is characterized by clay loam texture and landscape of gentle slope. Some other soil physcio-chemical characteristics of the study site and the ratings are presented in the Table 1. The rating was done with the help of publication by Hazelton et al. **[10,11] (Table 1) (Figure 1)**.

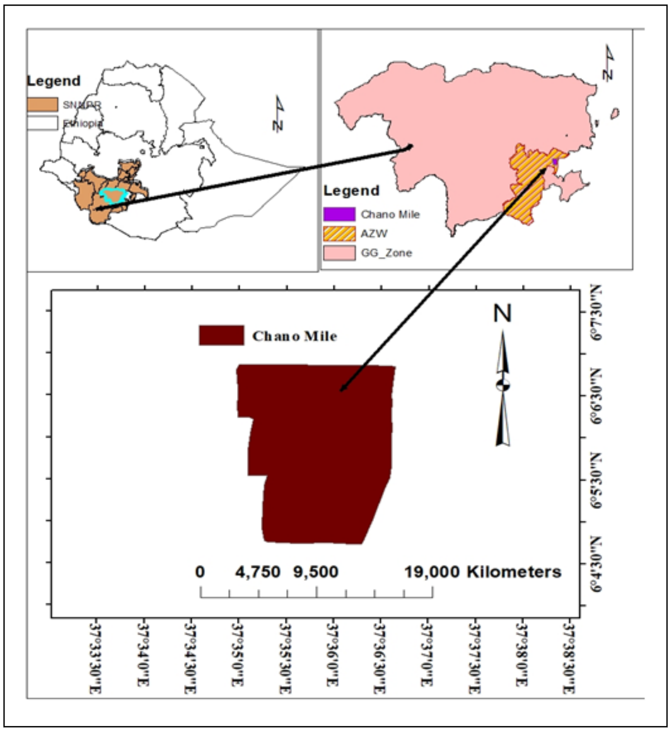

Figure 1: Location map.

Soil parameters	Mean values ± SD	Rating
pH	7.31 ± 0.13	Neutral
Available phosphorus (ppm)	21.9 ± 8.66	Medium
Organic carbon (%)	1.57 ± 0.05	Medium
Total nitrogen (%)	0.22 ± 0.02	Medium
Bulk density (gm/cm3)	1.32 ± 0.01	-
Particle density (gm/cm3)	2.15 ± 0.16	-

Table 1: Some soil characteristics of the study site; SD: Standard Deviation.

Experimental design

The study was conducted on permanent plots laid out in a randomized complete block design with four treatments and four replications. The treatments were; 1) *Moringa stenopetala* +maize, 2) 50% *Moringa stenopetala*+50% *Moringa olifera* +maize, 3) *Moringa* olifera+maize , and 4) Control (maize only).

Field Procedures and Management

In order to establish Moringa hedgerow along the contour at Chano Mile research site, two species of Moringa (Moringa stenopetala and Moringa olifera) seedlings was raised in the nursery. The trail site had previously been cropped with Cassava (Manihot esculenta). A total land area of 46 × 86 meters was used for the study. Soil samples were taken before the establishment of the experiment at depth of 0 cm-40 cm for analysis of some psycho-chemical properties (pH, phosphorous, organic carbon, nitrogen, bulk density and particle density) of the soil. Land preparation was conducted and seedlings were transplanted after 60 days of nursery life. Nineteen seedlings were planted in row arrangement with 0.5 m and 20 m spacing between each seedling and alleys, respectively. A total of 57 seedlings were planted in one treatment (19 seedlings for single row) and the total rows used in one plot were three. Plots and blocks were separated from each other by 2 and 3 meter walkways, respectively. Maize cropping was carried out after seven months of the tree planting, and continued for two cropping seasons. During the course of the study, all maize and tree farming operation were performed manually following local practices. Every cropping season, maize variety, BH 140, was sown into furrows at spacing of 25 cm along each row and 75 cm between rows. Each maize crop was fertilized with the recommended rate. Ring weeding around tree seedlings was conducted. Pollarding was done at height of 1.75 m above ground three months before every planting season once a year (Figure 2).

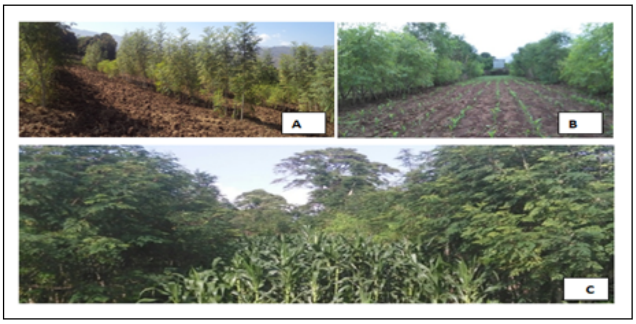

Figure 2: Shows *Moringa* alleys at age of seven months (A) and *Moringa* alley after pollarding (B) and integrated *Moringa* with maize crops (C).

Controlling insect pest

An insect pest known to be *Moringa* moth (Noorda blitealis Walker) has been observed during field study. The pest is known to cause extensive damage to the leaves of *Moringa* trees mostly during the rainy seasons (April–August) **[12]**. Botanical control measure was conducted to control the pest. Accordingly, four kilogram of grounded seeds powder of *Azadirachta indica* was mixed with 24 liters of clean water (16.7 mg per ml) thoroughly. The mixture was used to spray for a hectare of *Moringa* plantation using knapsack. Spraying was done early in the morning and evening to minimize the evaporation of the sprayed solution. Application on rainy days was avoided to lower washing down of the spray.

Data Collection

Data on growth performance of *Moringa* such as Root Collar Diameter (RCD), Plant Height (HT), Branch Number (BN), and Diameter at Breast Height (DBH) were collected from six selected trees at each plot. To evaluate the performance of maize, data on Grain Yield (GY), Hundred Seed Weight (100 SW), biomass weight, plant height, cob number and cob length were also collected from five plants at each row every year. The height of tree and maize was measured by using measuring tape. Caliper was used to measure tree Diameter at Breast Height (DBH) and Root Collar Diameter (RCD). Data on Survival Rate (SR) and Branch Number (BN) was taken by counting the number of trees per plot and the number branches per tree, respectively.

Data Analysis

Analysis of Variance (ANOVA) was used to analyze variation of parameters across the treatments. The differences between treatment means were determined using the student T-Test. Cost benefit analysis was employed to investigate the economic feasibility of treatments based on the inputs used for both land use and the output produced. The estimated market price of *Moringa* leaves as a vegetable, animal fodder and fuel wood obtained from agroforestry practice/mono cropping system and others were considered the analysis. The market value of these benefits was based on its current market price in its respective local units which was estimated during FGD. The yield obtained from each component of the systems and price of outputs sold in local market were used to calculate the revenue of each land use. Total revenue is calculated by multiplying total unit of output obtained from each component by its price in local market. After calculating the benefits of each item in the system the total revenue of the system was calculated by summing up revenues of respective land uses. And each cost incurred such as, labor cost, fertilizer cost, pesticide cost, and others were summed up to get total cost incurred in one single year. Then the Net Benefit (NB) calculated by deducting total cost from total revenue.

Results and Discussion

Tree growth performance

Growth performance in terms of Tree Height (TH), Root Collar Diameter (RCD), Branch Number (BN), Diameter at Breast Height (DBH) and Fresh Leaf Biomass (FLB) after seven months of planting at Chano Mile sites are presented in Table 2. Branch Number (BN), Diameter at Breast Height (DBH) and Tree Height (TH) were significantly different (p<0.05) among the tree species. In the case of branch number, *Moringa stenopetala* was significantly higher than *Moringa olifera*. Regarding DBH and tree height, *Moringa olifera* was significantly higher than *Moringa stenopetala* **(Table 2)**. In terms of leaf yield no significant difference was observed between *Moringa* species but relatively higher leaf (0.80 kg/tree) was recorded in *Moringa olifera* plant.

Moringa species	BN	DBH (cm)	TH (m)	RCD (cm)	FLW (Kg/tree)
M. stenopetala	10.8^{a}	2.28^{c}	2.52^{c}	6.6^{a}	0.65^{a}
M. olifera	4.25^{b}	5.1^{a}	4.6^{a}	7.6^{a}	0.80^{a}
50% *M. stenopetala* +50% *M. olifera*	7.75^{ab}	3.88^{b}	3.53^{b}	6.9^{a}	0.69^{a}
LSD	4.11	1.04	0.77	NS	NS
CV	31.3	16.1	12.5	12	40.9

Table 2: Growth performance of Moringa trees at age of seven months (before integrating with maize) at Chano Mille, Arba Minch Zuria district, Southern Ethiopia. BN: Branch Number; DBH: Diameter at Breast Height; RCD: Root Collar Diameter; TH: Tree Height; FLW: Fresh Leaf Biomass.

Note: Means showing different letters are significantly different in a column at a 5% probability level.

Tree effect on maize yield

The results of yield and yield components of maize under *Moringa stenopetala* and *Moringa olifera* alley at two cropping seasons (2018 and 2019) were presented in Tables 3 and 4. The analysis of variance on studied traits in maize revealed that both tree species showed suppression of maize yield and yield components.

Maize plants in control plots (away from trees) revealed significantly higher grain yield, biomass weight, cob number and cob length at both cropping seasons consistently. This could be due to sufficient sunshine intensity for photosynthesis which lead good grain filling and subsequently better yield. In the case of M. stenopetala, maize grain yield reduction ranged from 16% in the first cropping (2018) up to 23% in the second (2019) (Tables 3 and 4).

Treatments	**GY**	**100 SW**	**Biomass W (ton/ha)**	**Plant H (m)**	**Cob No**	**Cob length (cm)**
	(ton/ha)	**(g)**				
Control(maize only)	7.2a	34.8	7.8a	2.9	1.6a	29.0a
M. stenopetala +maize	6.0b	37.6	6.7ab	2.9	1.2b	25.7bc
M. olifera+maize	4.9c	35.8	4.8c	2.2	1.0b	23.1c
50% Ms+50% Mo+maize	5.6bc	37.5	5.8bc	2.8	1.1b	26.2b
LSD(0.05)	0.92	NS	1.47	NS	0.3	2.74
CV%	9.8	4.1	14.7	17.5	15.4	6.6

Table 3: Effect of *Moringa* trees on alley maize planted at first cropping season in 2018 at Chano Mille, Arba Minch Zuria District, southern Ethiopia.

Treatments	**GY**	**100 SW**	**Biomass W (ton/ha)**	**Plant H (m)**	**Cob No**	**Cob length (cm)**
	(t/ha)	**(g)**				
Control(maize only)	5.08a	34.5ab	7.4a	2.8	1.2a	21.9a
M. stenopetala + maize	3.90b	34.8a	6.2b	2.6	1.1b	19.9a
50% Ms+50% Mo+maize	2.63c	32.8bc	3.5c	2.4	1.0b	16.8b
M. olifera + maize	2.7c	31.0c	2.8c	2.4	1.0b	15.7b
LSD(0.05)	1.12	1.81	0.93	NS	0.12	2.16
CV%	19.6	3.4	11.7	8.3	6.6	7.3

Table 4: Effect of Moringa trees on alley maize planted at second cropping season in 2019 at Chano Mille, Arba Minch Zuria district, Southern Ethiopia. GY: Grain Yield; SW: Seed Weight; BW: Biomass Weight; PH: Plant Height; CN: Cob Number; Ms: Moringa stenopetala; Mo: Moringa olifera.

Note: Means showing different letters are significantly different in a column at a 5% probability level.

Reduction of maize grain yields by *Moringa olifera* trees was more drastic than in the plots with *Moringa stenopetala*, ranging from 32% in the first cropping up to 48% in the second cropping season. This could be due to higher above and below ground competition of *Moringa olifera* than *Moringa stenopetala*. For instance, sparse canopy of *Moringa stenopetala* could facilitate better penetration of sunlight for maize plants than *Moringa oliefera*. This could lead to get better grain and biomass yield of maize. Reduced growth due to Intercepted Photo Synthetically Active Radiation (IPAR) has been reported by Sinclair and Muchow ; Liu et al. **[13,14]**.

Economic Analysis

The economic analysis of the treatments was assessed in terms of Benefit Cost Ratio (BCR). Accordingly, the analysis of returns to maize mono-cropping revealed lower BCR (2.36) than agro-forestry treatments (Table 5). The highest BCR was recorded with treatment that integrates Moringa stenopetala with maize (5.64) followed by Moringa oliefera+maize (5.19). A project with benefit cost ratio greater, equal or less than unity, indicates profit, breakeven or loss, respectively.

Since all ratios are greater than unity for this production system, the greater ratio was recorded in Moringa stenopetala +maize production which is more profitable than others. Even though not well documented, agroforestry practices increased income opportunities, economic stability, reduced cost of production, increased ability to manage sustained yield and improved the livelihood of the farmers in the area. Yohannes report the average total income earned from agro-forestry practice exceeds mono-croping system in the same units of lands in Konso district, Southern Ethiopia.

Cost item	**Mean amount (ETB)**			
	Maize+(100%) *M. stenotetala*	**Maize+(100%)** *M. oliefera*	**Maize+50%** *M. stenotetala***+50%** *M. oliefera*	**Maize mono-cropping**
Total Revenue/ha (TR)	213,330.00	196,040.00	176,460.00	61,270,0
Variable costs				
Planting materials/ha	6932	6932	6932	0
Cost of inputs	4207.5	4207.5	4207.5	5100
Cost of labor	24362.3	24362.3	24362.3	18613.3
Cost of transportation	1200	1200	1200	1200
Total Variable Cost/ha (TVC)	36,701.80	36,701.80	36,701.80	24,913.30
Gross Marginal/ha (GM)=(TR-TVC)	176628.2	159338.2	139758.2	36356.7
Total Fixed Cost/ha (TFC)	1100	1100	1100	1100
Total Cost/ha(TC)=(TFC +TVC)	37801.8	37801.8	37801.8	26013.3
Net Income (NI)=(GM-TFC)	175528.2	158238.2	138658.2	35256.7
Benefit Cost Ratio (BCR)	5.64	5.19	4.67	2.36

Table 5: Benefit cost analysis of *moringa* trees based alley maize cropping in Chano Mille, Arba Minch Zuria district, Southern Ethiopia. Source: Field data, 2017-2019.

Conclusion and Recommendation

Both tree species (*Moringa stenoetala* and *Moringa olifera*) showed suppression of maize growth and grain yield but compensated by outputs from tree products such as leaf and wood biomass yield. *Moringa olifera* showed significantly higher growth performance and leaf biomass than *Moringa stenopetala* and hence more competitive with intercropped maize. he overall yield of maize and *Moringa* fresh leaf obtained from *Moringa stenopetala* treatment revealed better product than the rest three treatments. The on-farm trials conducted in this study showed that *Moringa*-maize intercropping systems are financially attractive than maize mono-cropping. Therefore, in southern Ethiopia, integrating *Moringa stenopetala* with maize intercropping, in their farming systems is a feasible option to generate income and other benefits derived from planted *Moringa* trees.

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