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Original Article

Evaluation of Alley Cropping with Selected Leguminous Multipurpose Tree Species on Maize Production and Soil Fertility at Abaya District, West Guji Zone, Southern Oromia, Ethiopia

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Alley Crop, Soil Fertility, Maize Yield, Leguminous Multipurpose Tree.

ABSTRACT

Agroforestry as a dynamic ecologically-based natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased socio-economic and environmental benefits. Among those, alley cropping is one of the agroforestry practices which is growing food crops between hedgerows of planted shrubs and trees, preferably leguminous species. A study was conducted to evaluate the contributions of alley cropping for improving maize yield and to evaluate the role of alley cropping for soil fertility improvement in the study area. Susbania sesban and Cajanus cajan trees/shrubs were selected for their potential to improve soil fertility (nitrogen fixing) and have other uses such as fodder. The experiment was designed with four treatments and laid out in randomized complete block design with three replications (block) along the slope gradient. The size of a sampling units (a plot) for each treatment were 20 m x 13 m and the distance between treatments (plots) was 2 m, while; the distance between blocks were 3 m. Alley crop was designed in doubled alley per study plot and the size of an alley crop was 20 m x 5 m. The selected variety of maize (Gibe 2) was sown between alleys of trees/shrubs with recommended spacing of 25 cm and 75 cm between plant and rows of maize respectively. Soil samples were collected and analyzed to evaluate the change made to soil fertility improvement. As a result, a significant difference among arrangements of maize alley cropping in grain yield was observed at ($P<0.001$). The highest total grain yield was obtained from maize sown with recommended fertilizer (5.16 ton/ha) in 2018 cropping season and maize grown in between alley of Cajanus cajan (4.33 ton/ha) in 2019 cropping season. The soil chemical properties under the alleys plots improved compared to control plots. Positive changes in the soil fertility in terms of soil organic C, total N, soil pH, available K, and exchangeable Ca, Mg and CEC of the top soil layer were detected in alley cropping system. Tree/shrub species of Cajanus cajan seemed to be better than Susbania sesban in improving soil health. Accordingly, it is recommended to grown maize with recommended application of fertilizer and in between alleys of Cajanus cajan tree/shrub species as it has multipurpose importance.

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INTRODUCTION

Agroforestry, growing of multipurpose trees along with agricultural crops and rearing of animals has been an important soil conservation practice. Thus, agroforestry systems are believed to increase or at least maintain the organic matter level of soils mainly through litter fall (Young, 1989). Cultivation of trees and agricultural crops in intimate combination with one another is an ancient practice that farmers have used throughout the world. Traditional agroforestry systems are common and major features of land use systems in the tropics. Particularly in sub-Saharan countries farmers consider trees as an integral part of agriculture, which helps them to overcome many land use problems and constraints (Nair, 1993). Current thinking places Agroforestry as a dynamic ecologically-based natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased socio-economic and environmental benefits (Garrity *et al*., 2006).

The major components of agroforestry systems are trees or shrubs (woody perennials, including bamboos) deliberately retained or planted on the farmland; agricultural crops, including food and 'cash' crops (some of which are herbaceous annuals or perennials); and livestock. In an Agroforestry system, the trees and shrubs provide a variety of products, some of which are consumed by the farming family or sold for cash, and a variety of services that benefit the crops, livestock, or the landscape (Garrity *et al*., 2006). In this way, integration of trees and shrubs in crop and livestock production systems can transform the rural landscape, and also improves farmers' livelihood. Among those, alley cropping is one of the agroforestry practices which have paramount advantages.

Alley cropping is broadly defined as the planting of two or more sets of single or multiple rows of trees or shrubs at wide spacing's, creating alleys within which agricultural, horticultural or forage crops are cultivated (Gold *et al*., 2013). This approach is sometimes called intercropping and multi-cropping. Alley cropping provides the opportunity to grow wood or other tree products while providing an annual income through the production of the companion crops. Generally, Alley cropping diversifies farm enterprises by providing short-term cash flow from annual crops while also providing medium to long term products from the woody components; reducing soil erosion from wind and water; reducing erosion on slopping cropland; improving crop production by slowing wind speed and reducing wind erosion; modifying the crop microclimate with similar effects to that of windbreaks;

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reducing damage from insect pests by reducing crop visibility, diluting pest hosts due to plant diversity, interfering with pest movement, and creating habitat more favorable to beneficial insects and enhancing wild life habitat and aesthetics (Gold *et. al*., 2013).

Alley cropping is a promising agroforestry technology for the humid and sub humid tropics, which is growing food crops between hedgerows of planted shrubs and trees, preferably leguminous species (Nair, 1992). The hedges are pruned periodically during the crop's growth to provide biomass (which, when returned to the soil, enhances its nutrient status and physical properties) and to prevent shading of the growing crops. The underlying scientific principle of this technology is that, by continually retaining fast-growing, preferably nitrogen fixing, trees and shrubs on crop-producing fields, their soil-improving attributes (such as recycling nutrients, suppressing weeds, and controlling erosion on sloping land) is create soil conditions similar to those in the fallow phase of shifting cultivation (Atta-Krahetal, 1985). This means, soil under alley cropping was higher in organic matter and nitrogen content than soil without trees. From an eight-year alley cropping trial conducted in southern Nigeria on a sandy soil, using *Lucinia leucocephala* pruning's only, *maize* yield could be maintained at a "reasonable" level of 2t ha^{-1}, as against 0.66tha^{-1}without *Leucaenia* pruning's (Kang *et al*., 1981).

Nowadays, crop cultivation is undertaken in West Guji in which rainfall is erratic and soil erosion is common. Even though West Guji is highly degraded, currently different soil and water conservation activities have been practiced on degraded lands. However, for the mid highland areas little attention has been given to improve the soil fertility of agricultural land. Therefore, alley cropping agroforestry practice has optional to reduce soil erosion so as to; improve soil fertility, improve crop production and improve trees/shrubs products simultaneously on agricultural land. Thus, this study was designed to evaluate the contribution of alley cropping for improving maize yield and to evaluate the role of alley cropping for soil fertility improvement in the study area.

Objectives

The objectives of the study were

- To evaluate the role of alley cropping for soil fertility improvement.
- To evaluate the contribution of alley cropping for improving maize yield.

MATERIALS AND METHODS

Description of the Study Areas

The study was conducted at Abaya District, West Guji Zone, Southern Oromia. Abaya district is found in southern Ethiopian rift valley with 365 km away from Addis Ababa. The study area lies between 06°43'520"N to 038°25'425"E, at altitude of 1442 m a.s.l. Abaya area receive annual rain fall ranging from 700 mm to 1000 mm which reaches its pick in June. The activity was conducted at Abaya sub-station of Yabello Pastoral and dryland Agriculture Research Center for the last five years.

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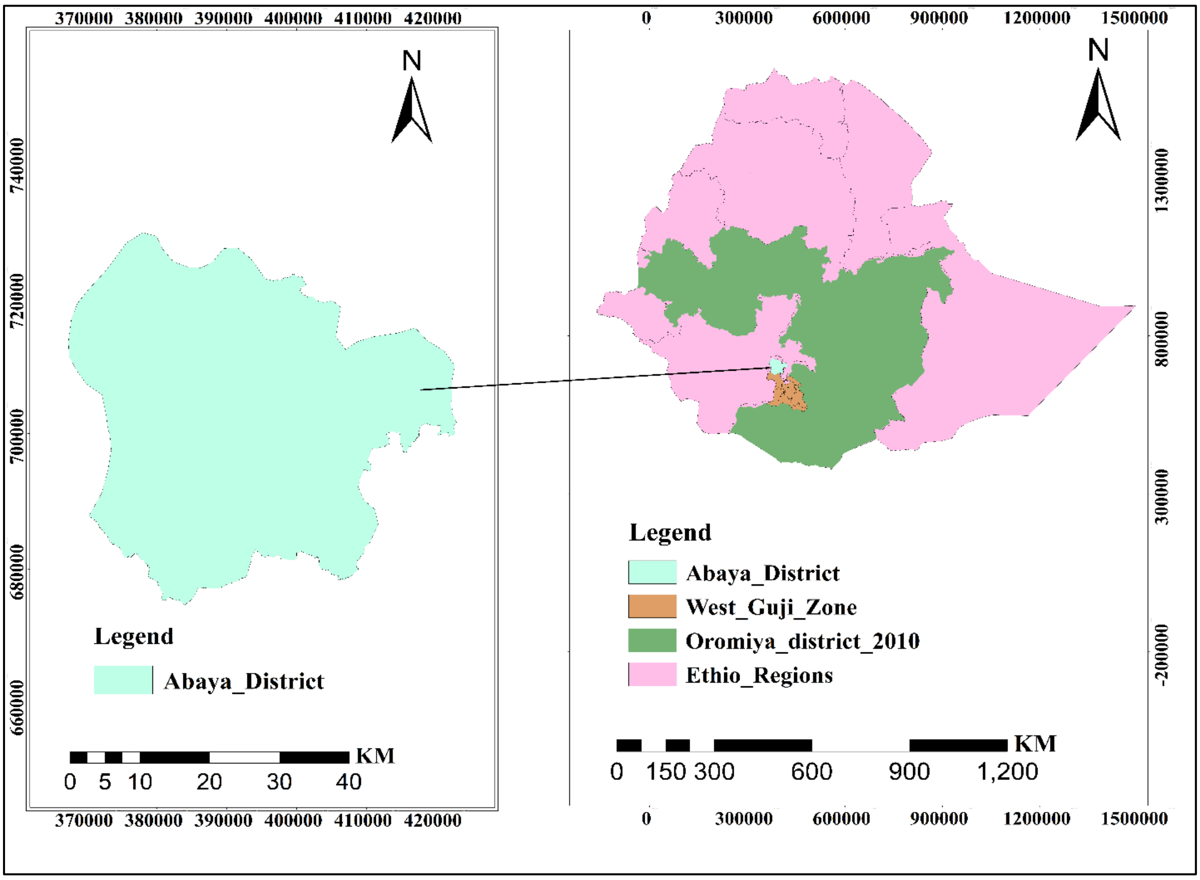
Figure 1: Map of the study area



Methods

Selection of Trees/Shrubs and Crops

Susbania sesban and *Cajanus cajan* were selected for the alley cropping study. These trees/shrubs were selected for their potential to improve soil fertility (nitrogen fixing) and have other uses such as fodder. Crop type which is dominantly producing in the study area and suitable for alley cropping was selected. Accordingly, maize is the major crop produced in Abaya district of West Guji Zone (Borana Agricultural office, 2013). Based on this, the recommended pioneer Gibe 2 maize (*Zea maize*) varieties for Abaya was used. Accordingly, the selected alley crop *Zea maize* will be sown in between single species of *Susbania sesban*, *Cajanus cajan*, with recommended rate of fertilizer and plot with no tree/shrub (sole maize) which was used as control.

Treatments and Experimental Design

The experiment was designed with four treatments (*Table 1*). The treatments were *Susbania sesban* with maize alley cropping, *Cajanus cajan* with maize alley cropping, maize sowing with recommended rate of fertilizer and control/sole maize (maize sowing without inorganic fertilizer and fertilizer trees). The experiment was laid out in randomized complete block design with three replications (blocks) along the slop gradient. The size of a sampling units (a plot) for each treatment were 20 m x 13 cm and the distance between treatments (plots) was 2m, while; the distance between blocks were 3 m (*Figure 2*).

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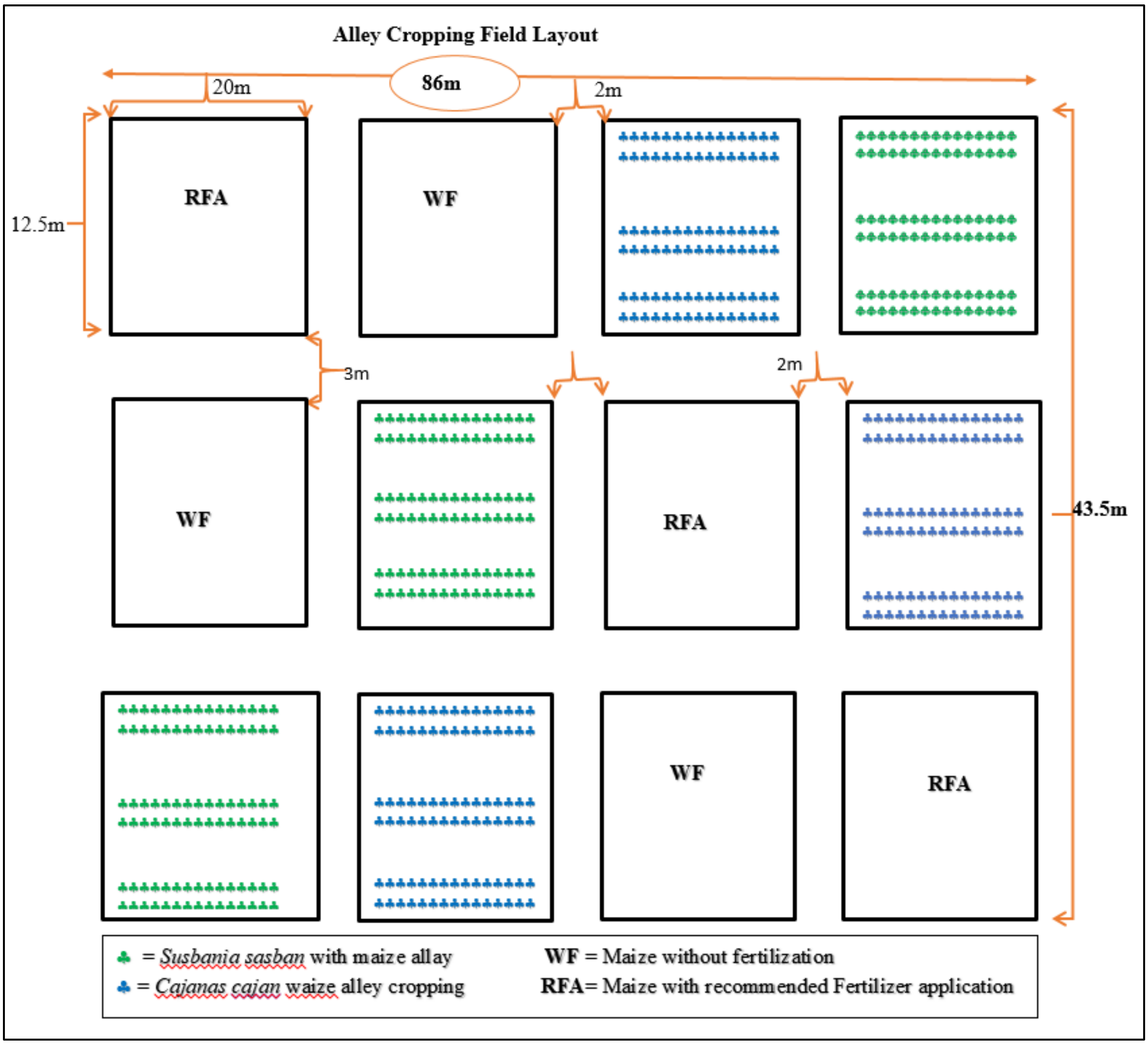
Table 1: Treatment combinations

Treatment code	Description of treatments
1	*Susbania sesban + Zea maize*
2	*Cajanus cajan + Zea maize*
4	Sole *Zea maize* (no fertilizer)
5	*Zea maize* with recommended fertilizer

Figure 2: Scheme of the arrangement/design and field layout of cultivation the experiment



Establishment and Arrangement of Trees Rows

The selected alley trees/shrubs species were raised in nursery and transplanted in double rows arrangements to the experimental area as double rows allow maximum utilization of space for companion crops (Gold *et. al.*, 2013). Spacing of 0.5 m between plants and 1 m between rows for *Susbania sesban and Cajanus cajan* while 5 m spacing was used between each alley of trees/shrubs. Throughout the study years' trees/shrubs component was permanently kept and protected from wildlife and livestock interference and, maize was sown every year during main rainy seasons.

Alley Crop Arrangement

Land preparation was done using tractor before the establishment of the treatment and oxen plow after the establishment of the treatment. Alley crop was designed in doubled alley per study plot and the size of an alley crop was 20 m x 5 m. The selected variety of maize (Gibe 2) was sown between alleys of trees/shrubs with recommended spacing of 25 cm and 75 cm between plant and

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rows of maize respectively. In plots of recommended fertilizer and sole maize (non-fertilizer) treatments, maize was also sown in rows with the recommended spacing of 25 cm and 75 cm between plant and rows of maize respectively.

Soil Sampling Techniques and Laboratory Analysis

Soil samples was purposively taken from the four corners and center of each experimental plot 45 days after sowing the test crop by soil auger and core sampler and mixed to make a composite soil sample. Accordingly, the soil samples were collected from each treatment and replications separately. Then, the composite soil samples were prepared for laboratory analysis and sent to Batu Soil Research Center and analyzed using standard methods. Accordingly, the soil samples taken by core samplers was oven dried at 105 ^{o}C for 24 hours to calculate the soil bulk density and moisture content. EC was analyzed in water suspension with soil to water ratio 1:25 by electro conductivity meter method, PH in water suspension with soil to water ratio 1:25 by PH meter, TN by Kjeldhal Method (1965), Av.P by Olsen method, Av.K using Ammonium acetate (1MNH4OAC), CEC by Ammonium Acetate (1 M NH4OAC), Exch. Na & K using flame photometer, Exch.Ca & Mg using EDTA titration, OC using Walkley black and Texture was analyzed using Bouycos hydrometer method.

Management Practices

The trees/shrubs species were pruned periodically and mulched on alleys and necessary management techniques will be timely carried out.

Data Collected

Data recorded during the course of the experiment were, agronomic data: (plant height, hundred seed weight, grain yield, cob diameter and cob height) and soil data (soil data (EC, pH, T. N, Av.p, Av.K, CEC, Ca, Mg, Ex.Na, Ex.K and OC).

Statistical Data Analysis

Data were subjected to analysis of variance following a procedure appropriate to the design of the experiment (N.R.DAS, 2008) using SAS statistical software. The treatment means that were significantly different at 5% level of significance were separated using Duncan and LSD tests.

The Model is:

$$Y_{ij} = \mu + \beta_i + \tau_j + \epsilon_{ij}$$

$$i = 1, 2, \ldots, n; \ \ j = 1, 2, \ldots, k$$

Where: $x_{(ij\ )}$ is a typical value from the overall population; μ is an unknown constant; β_i represents a block effect reflecting the fact that the experimental unit fell in the i^{th} block; τ_i represents a treatment effect, reflecting the fact that the experimental unit received the j^{th} treatment; ϵ_{ij} is a residual component representing all sources of variation other than treatments and blocks.

RESULTS AND DISCUSSIONS

The analysis of variance indicated that maize yield and yield components were significant differences among treatments under study. The analysis of variance showed there was significant treatments and year's interaction effect on maize yield and cob diameter (*Table 2*).

Table 2: Mean square value of yield and yield related parameters of maize alley cropping from combined analyses of variance over two years at Abaya district in 2018 and 2019 EC.

Source of variations	DF	PH (cm)	GY (ton/ha)	HSW	CD (cm)	CH (cm)
Replications	2	46.34ns	0.11ns	6.45ns	0.02ns	5.55*
Treatment	3	3203.44**	12.37***	9.02ns	0.32***	46.56***
Year	1	3203.51*	0.05*	18.32*	0.014ns	0.23ns
Treatment*Year	3	270.76ns	3.29***	5.90ns	0.09*	4.34ns
Error	14	629.07	0.10	2.91	0.02	1.52
CV		13.61	12.08	5.64	2.94	8.35
Mean		184.30	2.66	30.28	4.82	14.77

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Plant height: The arrangements of different alley cropping system were found highly significant at ($p < 0.001$) on mean plant height of maize. The tallest mean plant height (216.6 cm) of maize was observed from maize sown with recommended fertilizer rate while the lowest plant height was observed for maize sown in between alley of *Susbania sesban* (162.72 cm).

Hundred seed weight: No significant difference was observed for mean hundred seed weight among maize grown under different arrangements. However, the highest hundred seed weight was observed for maize sown with recommended fertilizer (31.83 gm) while the lowest hundred seed weight was observed for sole maize cropping system (29.00 gm).

Grain yield (GY): Combined analysis of variance over years showed a significant difference among arrangements of maize alley cropping in grain yield at ($P < 0.001$). The highest grain yield was observed for a maize sown with a recommended fertilizer (4.22 ton/ha) while the lowest grain yield of maize was observed for maize grown in between alley of *Susbania sesban* (1.55 ton/ha) (*Table 3*). The highest total grain yield was obtained from maize sown with recommended fertilizer (5.16 ton/ha) in 2018 cropping season and maize grown in between alley of *Cajanus cajan* (4.33 ton/ha) in 2019 cropping season while the lowest total grain yield was obtained from maize sown in between alley of *Susbania sesban* (1.17 ton/ha) in 2018 and sole maize cropping (1.28 ton/ha) in 2011 cropping season (*Table 3*). Phiri *et al*., (1999) reported that alley cropping of *sesbania* with maize increased maize grain yield, as compared to unfertilized sole maize in two of three years. Thus, the mean grain yield of maize sown with recommended fertilizer was decreased in 2019 as compared with grain yield of 2018 cropping season. This might be due to maize sown for a second cropping season in a row on the same plot which decreases soil micronutrients while the mean grain yield of maize was increased in 2019 for maize grown in between alleys of *Cajanus cajan* as it starts releasing soil nutrition's and biomass transfer of the shrubs to the experimental plots. That means, the yield increment was depending on the soil micronutrients that crops gains from the soil due to alley shrubs biomass transfer to the soil and/or application of recommended fertilizer. This finding related with the finding showed maize yield increased with the increase in N level applied to plots irrespective of added fresh pruned materials (Abiar *et. al*., 2009).

Cob diameter: The analysis of combined variance data showed a significance difference among different arrangements of maize alley cropping at $p < 0.001$ (*Table 2*). The highest cob diameter was recorded from maize sown with recommended fertilizer rate (5.03 cm), while the lowest cob height was recorded from maize grown in alleys of *Susbania sesban* (4.61 cm) (*Table 3*).

Cob height: Analysis of variance showed a significance difference among treatments in cob height for both years at ($p < 0.001$) (*Table 2*). The highest cob height was obtained from maize sown with recommended fertilizer (18.03 cm) while the lowest cob height was recorded from maize grown in alleys of *Susbania sesban* (13.46 cm) (*Table 3*). This implies that, the number of cob height of maize decreases as compared to sole maize and maize sown with recommended fertilizer. This might be due to the synergistic effect of the crops and alley shrubs was changed to compete for the limited availability of moisture in the area since moisture stress is the main problem in the study area.

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Table 3: Mean value of yield and yield related parameters of maize alley cropping from combined analyses of variance over two years at Abaya district in 2018 and 2019 EC.

Treatments	PH	GY (ton/ha)	HSW	CD (cm)	CH (cm)
Zea maize with recommended fertilizer	216.64a	4.22a	31.83a	5.03a	18.03a
Cajanus cajan + Zea maize	182.93b	3.54b	30.62ab	5.01a	15.91b
Sole *Zea maize (no fertilizer)*	174.93b	1.34c	29.00b	4.64b	11.67d
Susbania sesban + Zea maize	162.72b	1.55c	29.67ab	4.61b	13.46c
Mean	13.61	12.08	5.64	2.94	8.35
CV	184.30	2.66	30.28	4.82	14.77

In general, the maize grain yield and yield component was highest under recommended fertilizer cropping followed by *Cajanus cajan* alley cropping and *Susbania sesban* alley cropping and, lowest under control treatment. The increase of maize yield within *Cajanus cajan* alley cropping with maize related with the finding by Rosecrance *et. al*., (1992) showed additions of pruning from hedge rows of leguminous trees were able to support maize grain yields at about 1800 kg/ha for two consecutive cropping seasons, while control plot yields averaged less than 600 kg/ha.

Soil Properties

The results of the soil properties after the alley cropping experiment stablished are shown in *Table 5* and *Table 6*. The soil organic carbon content from the *Susbania sesban* and *Cajanus cajan alley cropping plots* and fertilizerd plots was significantly different from sole maize (no fertilizer) plots. In non-fertilizer (control) plots the soil organic carbon content was lowest than others experimental plots. The average soil organic carbon content of *Susbania sesban plot, Cajanus cajan plot* and fertilized plots even though not statistically significantly different, it was greatest in *Susbania sesban* plots followed by *Cajanus cajan* plot (*Table 6*). The result obtained in this study agreed with the report of Atta-Krah (1986), that soils under alley cropping system were higher in organic matter and N than soils without hedgerow tree. The soil organic carbon content of experimental plots was not significantly different statistically; however, it was increased with time in *Susbania sesban* and *Cajanus cajan* plots, and it was decreased with time in fertilized and control non-fertilized (control) plots (*Table 6*). The result obtained agreed with a study found that the plant nutrients were gradually built up in the alley cropping system plots than in the fertilizer and control (Okonkwo *et al.,* 2009).

Similar to soil organic carbon content, the % of soil total nitrogen (TN) content of the treatments was significantly different. It was lowest in non-fertilized (sole maize) plots compared to others experimental plots. The soil total nitrogen (TN) content of *Cajanus cajan and Susbania sesban alley cropping plots* and fertilized plots were not significantly different (*Table 5*).

Despite the TN content of the experimental plots were not significantly different along study years, the *Cajanus cajan* and *Susbania sesban* plots maintained improved TN contents compared to fertilized and non-fertilized (control) plots (*Table 6*). This result therefore, indicated that incorporated pruning of the legume trees alley cropping improved the total nitrogen contents of the soil. This finding agreed with a study by Okonkwo *et al.,* (2009) which showed that the total nitrogen (N) content increased in the alley plots over time with continuous addition of pruning from the hedgerow trees.

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Table 4: Mean value of yield and yield related parameters of maize alley cropping at Abaya district during 2018 and 2019 cropping season.

Treatments	Year	Mean ± Standard error				
		PH (cm)	GY (t/ha)	HSW (gm)	CD (cm)	CH (cm)
Cajanus cajan + Zea maize	2018	166.67±14.48[cd]	2.75±0.19d	28.67±0.99g	4.91±0.08ab	14.76±0.71bcd
	2019	199.19±14.48[abc]	4.33±0.19b	32.57±0.99abcd	5.11±0.08a	17.06±0.71a
Zea maize with recommended fertilizer	2018	210.67±14.48[ab]	5.16±0.19a	30.34±0.99bcdefg	5.15±0.08a	18.53±0.71a
	2019	222.62±14.48[a]	3.28±0.19cd	33.31±0.99a	4.91±0.08ab	17.53±0.71a
Sole Zea maize (no fertilizer)	2018	169.33±14.48[bcd]	1.39±0.19fgh	28.93±0.99fg	4.67±0.08cde	12.35±0.71ef
	2019	180.52±14.48[abcd]	1.28±0.19gh	29.07±0.99efg	4.61±0.08de	10.99±0.71f
Susbania sesban + Zea maize	2018	144.33±14.48[d]	1.17±0.19h	29.68±0.99cdefg	4.46±0.08e	13.04±0.71def
	2019	181.1±14.48[abcd]	1.94±0.19e	29.67±0.99defg	4.75±0.08bcd	13.87±0.71cde

Table 5: Mean soil chemical properties of experimental plots

	%	%	ppm		pH	meq/ 100g soil				mmhos/
Treatments	OC	TN	AvK	AvP		Ex. K	Ca	Mg	CEC	EC
Cajanus cajan + Zea maize alley cropping	1.60 [a]	0.16[a]	299.72 [a]	2.01 [a]	6.03 [a]	1.045[a]	8.51 [a]	5.38 [a]	13.01 [a]	0.18[a]
Zea maize + with recommended fertilizer rate	1.53 [a]	0.14[a]	289.00 [a]	2.30 [a]	5.68 [b]	1.03[a]	7.59 [a]	3.96 [b]	12.74 [a]	0.15[ab]
Susbania sesban + Zea maize alley cropping	1.73 [a]	0.15[a]	288.22 [a]	2.26 [a]	5.83 [ab]	0.96[a]	7.13 [ab]	4.28 [b]	12.79 [a]	0.15[bc]
Non-fertilizer (control)	1.16 [b]	0.10[b]	229.78 [b]	1.73 [a]	5.82[ab]	0.91[a]	5.83 [b]	2.89 [c]	11.42 [a]	0.12[c]
LSD (0.05)	0.36	0.03	41.41	0.92	0.34	0.13	1.63	0.83	1.94	0.03
CV (%)	24.82	22.66	15.38	45.68	5.93	13.49	23.11	20.74	3.36	19.22

OC= Organic carbon; T.N= Total Nitrogen, EC= Electro conductivity, Ex.K = Exchangeable Potassium, .Ca & Mg = Exchangeable Calcium & magnesium, Av. P = Available Phosphorus, CEC = Cation exchangeable capacity

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Table 6: Mean of Soil Properties of along the study years (2018, 2019, 2021)

Treatments	Study Year	% OC	% TN	mmhos/ cm EC	ppm		pH	meq/ 100g soil			
					AvK	Avp		CEC	Ca	Mg	Ex. K
Cajanus cajan + Maize alley cropping	Year I	1.39^{abcd}	0.16^{ab}	0.16^{abcd}	207.50^{cde}	1.72^{b}	5.58^{b}	12.33^{abc}	9.13^{a}	4.23^{bc}	0.77^{efg}
	Year II	1.60^{abcd}	0.16^{ab}	0.19^{a}	264.33^{bc}	2.43^{ab}	6.13^{ab}	15.23^{a}	8.50^{abc}	5.50^{ab}	0.95^{de}
	Year III	1.80^{ab}	0.16^{ab}	0.19^{a}	427.33^{a}	1.87^{ab}	6.38^{a}	11.47^{bc}	7.90^{abc}	6.40^{a}	1.43^{b}
Recommended fertilizer rate	Year I	1.58^{abcd}	0.14^{abcd}	0.15^{abcde}	164.17^{de}	2.57^{ab}	5.76^{b}	13.07^{ab}	8.80^{ab}	2.93^{cd}	0.59^{g}
	Year II	1.54^{abcd}	0.13^{abcd}	0.15^{abcde}	228.50^{bcde}	2.59^{ab}	5.54^{b}	13.07^{ab}	6.87^{abcd}	3.23^{cd}	0.83^{ef}
	Year III	1.47^{abcd}	0.16^{ab}	0.17^{abc}	474.33^{a}	1.74^{b}	5.75^{b}	12.10^{abc}	7.10^{abcd}	5.70^{a}	1.68^{a}
Susbania sesban + Maize alley cropping	Year I	1.48^{abcd}	0.13^{abcd}	0.12^{de}	222.50^{bcde}	3.46^{a}	5.67^{b}	11.97^{abc}	8.50^{abc}	3.57^{c}	0.68^{fg}
	Year II	1.74^{abc}	0.14^{abc}	0.18^{ab}	234.67^{bcd}	1.81^{b}	5.79^{b}	12.10^{abc}	6.20^{bcd}	3.90^{c}	0.89^{ef}
	Year III	1.98^{a}	0.18^{a}	0.15^{abcde}	407.50^{a}	1.51^{b}	6.02^{ab}	14.30^{ab}	6.70^{abcd}	5.38^{ab}	1.32^{bc}
Non-fertilizer (control)	Year I	1.34^{bcd}	0.11^{bcd}	0.10^{e}	158.17^{e}	1.79^{b}	5.85^{ab}	12.40^{abc}	6.83^{abcd}	2.00^{d}	0.70^{fg}
	Year II	1.16^{cd}	0.10^{cd}	0.14^{bcde}	248.83^{bc}	2.04^{ab}	5.74^{b}	12.53^{abc}	5.83^{cd}	3.00^{cd}	0.88^{ef}
	Year III	0.99^{d}	0.09^{d}	0.13^{cde}	282.33^{b}	1.35b	5.88^{ab}	9.34^{c}	4.83^{d}	3.68^{c}	1.16^{cd}
LSD (0.05)		0.63	0.05	0.05	71.72	1.60	0.58	3.35	2.83	1.44	0.22
CV (%)		24.82	22.66	19.22	15.38	45.68	5.93	15.95	23.11	20.74	13.49

OC= Organic carbon; T.N= Total Nitrogen, EC= Electro conductivity, Ex.K = Exchangeable Potassium, .Ca & Mg = Exchangeable Calcium & magnesium, Av. P = Available Phosphorus, CEC = Cation exchangeable capacity

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The level of available P was not significantly different both among treatments and along the study years statistically; however, it was lowest in non-fertilized (control) plots compared to other experimental plots (*Table 5*). This might be due to no variations in soil pH of the experimental plots. Larsen (1995) reported that maximum phosphate availability is obtained when the soil pH is maintained in the range from 6 to 7. Low soil PH found in fertilized plots. Thus, continuous cultivation and long-term application of inorganic fertilizers led to low soil pH.

The available K was significantly different among the treatments; while the exchangeable K content was non-significant however it was lower in non-fertilizer (control) treatment compared to other treatments (*Table 5*). The available K was lowest in non-fertilized (control) plots (229.78 ppm) compared to of *Cajanus cajan*, *Susbania sesban* and fertilized plots. This finding related with the findings of Jannatul *et al.*, (2019) showed the exchangeable K content was lower in control treatment compared to agroforestry treatments. Crop removal and losses through runoff may be attributed the lowest exchangeable K in control plot. Moreover, no K added to this plot through pruned materials, whereas, the increase in exchangeable K in plots with tree species was probably due to the return of K via tree pruning and leaf litter fall to the soil surface (Miah *et al.*, 1997). The available K was significantly different along the study years; it was showed significant increase in ally cropping and fertilized plots (*Table 6*).

There were significant different in levels of soil Mg and Ca contents among the treatments. The levels of soil Mg and Ca contents were lowest in non-fertilized (control) plots and were 20.74 and 23.11 meq/ 100g soil respectively. The Mg contents of soil showed an increasing trend in alley cropping agroforestry treatments and fertilized plots; whereas, Ca contents showed an irregular fashion (*Table 6*). The variations of CEC of the soil among the treatments were not so different; on the other hand, the EC was significantly different and lowest in control treatment plots

CONCLUSIONS AND RECOMMENDATIONS

This study concluded that, alley cropping system had significantly affected maize grain yield. Thus, a significant difference among arrangements of maize alley cropping in grain yield was observed at ($P < 0.001$). Consequently, maize cropping with a recommended fertilizer had significantly higher grain yield at ($P < 0.001$) than maize cropping between alleys of *Cajanus cajan*, *Susbania sesban* and sole maize cropping. Accordingly, the highest total grain yield was obtained from maize sown with recommended fertilizer (5.16 ton/ha) in 2018 cropping season and maize grown in between alley of *Cajanus cajan* (4.33 ton/ha) in 2019 cropping season. Based on this, the study confirmed that, growing crops with recommended fertilizer application and in between alley of *Cajanus cajan* was preferable than growing maize in between alleys of *Susbania sesban* and sole maize cropping. Even though, the maize yield grown in between alleys of *Cajanus cajan* was lower than maize sown with that of recommended fertilizer application, *Cajanus cajan* has many additional importance (uses for fodder, soil improving through recycling nutrients and controlling erosion on sloping land). From the soil chemical properties point of view, it may be concluded that alley cropping practices has high contribution in soil amendments. The pruning of the legume species incorporated into the soil and dead roots were gradually built-up soil nutrients. Accordingly, it is recommended to grown maize with recommended rate of fertilizer application and in between alleys of *Cajanus cajan* trees/shrubs species as it has multipurpose benefits. Further study is need on combinations of fertilizer trees and inorganic fertilizers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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