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Growth, chlorophyll content and yield of maize and banana plants in an agroforestry system in Kisii County, Kenya

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ABSTRACT

Diverse tree species when employed in agroforestry systems may serve as an alternative to increasing soil fertility through nitrogen fixation. However, it is not clearly known how intercropping maize and banana with *Sesbania sesban*, C*alliandra callothyrsus* and *Leucaena diversifolia* may affect growth of maize and banana. The purpose of this study was to evaluate the effect of intercropping agroforestry trees species with maize and banana on the growth, chlorophyll content and yield of maize and banana. Field experiment was laid out at Kenya Agricultural Livestock and Research Organization farm (KALRO) located in Kisii County. The Williams varieties of banana of the same age were obtained from KALRO -Thika and Hybrid seed maize, H513 obtained from Kenya seed company, Kisumu. The agroforestry tree seedlings were spaced: 0.5m by 1m, 0.9m by 0.9m by 0.6m deep and 0.3m by 0.75m between banana and maize respectively. Three replicates were used with seven treatments of Pure maize, pure banana, maize-banana-Calliandra, maize-banana-Leucaena, maize-banana-sesbania, maize-banana and maize-fertilizer, all in a randomized complete block design. Data on maize growth and chlorophyll content was collected at intervals of 2 weeks which commenced 30 days after planting while yield was determined at the end of growing seasons. Data was subjected to the Analysis of Variance. Maize plants and banana that were intercropped with *Sesbania sesban* had significantly ($P \leq 0.05$) highest growth, chlorophyll content and yield compared to other treatments. Therefore, Sesbania sesban is recommended as a suitable agroforestry tree species for intercropping with maize and bananas.

Contribution/Originality: This study is one of very few studies conducted in Kisii county, Kenya to evaluate the effect of intercropping *Sesbania sesban*, C*alliandra callothyrsus* and *Leucaena diversifolia* on growth, chlorophyll content and yield of maize and bananas.

1. INTRODUCTION

Smallholder farmers are the most important food security stakeholders in Sub-Saharan Africa (SSA), who mainly practice subsistence agriculture characterized by low plant growth and productivity due to soil nutrient depletion [1]. Integrated farming system such as agroforestry is regarded to promote sustainable farming in the region [2]. For instance, Birhane, et al. [3] reported that *Sesbania sesban* improved soil fertility, overall plant growth and yield. Although intercropping with agroforestry trees is being promoted for nutrient restoration in depleted soils through nitrogen fixation, maize and banana may be affected by competition for water and nutrients

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from agroforestry trees impacting negatively on their growth. However the use of agroforestry system is limited in Kisii County, evidenced by lack of documentation on how intercropping maize and banana with selected agroforestry trees impacts on growth of maize and banana. Chlorophyll is also an important photosynthetic pigment to maize and banana plants, largely determining photosynthetic capacity and hence plant growth [4]. When considering on the importance of Chlorophyll for photosynthesis, plants in the natural community should optimize light absorption and photosynthesis by adjusting the content and ratios of chlorophyll to enhance growth and survival at the long-term evolutionary scale [5]. However, due to limited use of agroforestry system, it is still unknown if intercropping with selected agroforestry trees such as *Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolia* can impact on maize and banana chlorophyll content in Kisii County.

Estimates have placed maize's yield gap in Sub Saharan Africa at 20% and have projected that the average yield needs to increase at an annual rate of 2% by 2050 in order to feed the growing population [6]. Additional to maize, banana is also a key crop in Kisii County grown for both subsistence and commercial use under an area of 82,518 ha [7]. Banana having a shallow root system spread on top of the soil, it's a heavy feeder of nutrients and its growth and fruit production need proper manuring and fertilizer application for potential yields [8]. Consequently, poor soil fertility as a result of monocropping has emerged as one of the greatest biophysical constraint to increasing agricultural productivity hence threatening food security in Sub-Saharan Africa [9]. Moreover, majority of these farmers lack financial resources to purchase sufficient amount of mineral fertilizers to replace soil nutrients removed through harvested crop products and through loss by runoff, leaching and gas form [10]. Maintaining yields calls for detailed assessment of limiting nutrients and the adoption of integrated soil fertility management (ISFM) practices for long-term productivity and profitability of the system [11]. However, this has not been determined in Kisii County. There was therefore need for intercropping maize and banana with agroforestry trees in Kisii region which may improve growth, chlorophyll content and yield of maize and banana and reduce food insecurity. The objective of this study was to determine growth, chlorophyll content and yield of Maize and banana plants in an agroforestry tree intercrop system in Kisii County.

2. MATERIALS AND METHODS

2.1. Study Site and Experimental Design

The study was carried out at Kenya Agricultural Livestock and Research Organisation farm (KALRO) located in Kisii County (Figure 1), which is characterized by very small landholdings, ranging from 0.2 Ha to 2.1 Ha (0.5 acres-5.18 acres) of land. The region enjoys a highland climate found in latitude 0º 40' 0.00'' N and longitude 34º 45' 0.00'' E. Kumba [12] the area receives rainfall all year round, thanks to its positioning in the Lake Victoria basin and the densely foliaged Kisii highlands [13].

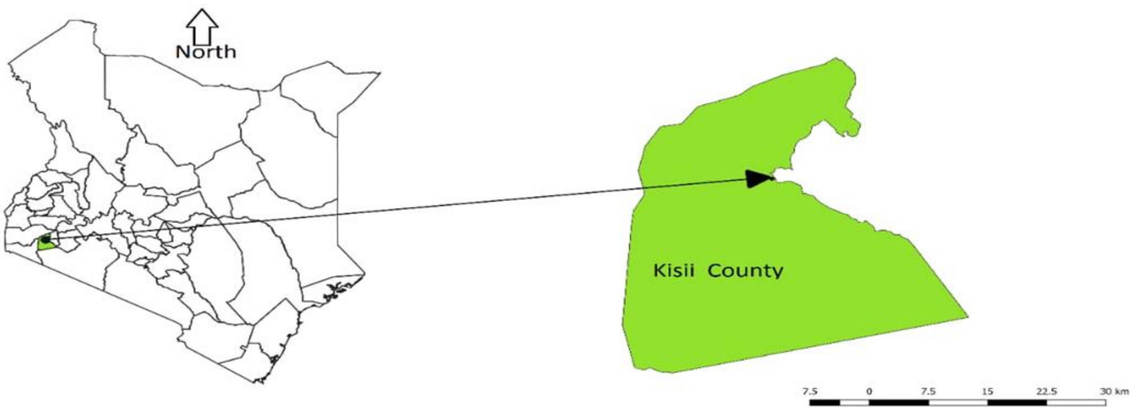

Figure 1. Shows a map of Kenya and Kisii County, study site, Kisii KALRO.

Source: Google map.

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The temperatures are highest on average in February, at around 20.6 °C. In July, the average temperature is 18.5 °C [14]. About 75% of the area has red volcanic soils which are deep in organic matter which offer opportunities for farming, the rest being clay soils which have poor drainage, red loams and sandy soils [15].

Williams varieties of banana were obtained from KALRO in Thika and Hybrid seed maize, H613 were obtained from Kenya seed company, Kisumu. Certified agroforestry tree seeds were purchased from Kenya Forestry Research Institute (KEFRI), Muguga and were sown in a nursery that was watered daily and later transplanted to the respective plots after two months. Agroforestry trees were planted in rows of spacing of 0.5m by 1m. Banana holes were dug 0.9m by 0.9m by 0.6m deep. 20kg of cow dung manure, 20kg of topsoil and 200g of NPK (nitrogen, phosphorus and potassium) fertilizer was applied into each banana hole. Banana spacing was 3m by 2.5m in pure banana stands, 6m by 2.5m in maize banana intercrops and maize spacing 0.75m by 30cm. Three replicates were used with seven treatment levels of Pure maize (M), pure banana (B), maize-banana-caliandra (MBC), maize-banana-leuceana (MBL), maize-banana-sesbania (MBS), maize-banana (MB) and maize-fertilizer (MF) all in a randomized complete block design (RCBD). *Sesbania sesban*, C*alliandra callothyrsus* and *Leucaena diversifolia* were maintained through pruning at three weeks interval. Leafy prunings from the three agroforestry tree species were applied in between the maize and banana rows after pruning.

2.2. Measurement of Parameters

2.2.1. Growth Parameters

2.2.1.1. Plant Height

Plant height of maize and banana plants were measured from the soil level at the stem base to the shoot apex of the plant using a piece of wood calibrated using a metre rule up to 4 metres. Measurement commenced after 4 weeks of maize planting and 16th week of banana growth respectively. Maize and banana measurements were carried out at intervals of two weeks. Thirty maize and four banana plants per replicate per treatment were randomly sampled and tagged for measurement up to physiological maturity.

2.2.1.2. Leaf Number

Leaf number was determined by counting the number of leaves on maize and banana plants per treatment per replicate. Measurement commenced after 4 weeks of maize planting and 16th week of banana growth respectively. Maize and banana leaf count was carried out at intervals of two weeks. Thirty maize and four banana plants per replicate per treatment were randomly sampled and tagged for measurement up to physiological maturity.

2.2.1.3. Leaf Area

Leaf area of maize and banana plants were determined using a tape measure. The measurements were taken with the procedure, $A_L=0.73(L_L \text{ X } W_L)$, where A_L is the leaf area, L_L is the leaf length, and W_L is the maximum width measured for each leaf on each plant. Measurement commenced after 4 weeks of maize planting and 16th week of banana growth respectively. Maize and banana measurements were carried out at intervals of two weeks. Thirty maize and four banana plants per replicate per treatment were randomly sampled and tagged for measurement up to physiological maturity.

2.3. Chlorophyll Content

Chlorophyll content of maize and banana plants was estimated using a portable chlorophyll meter (SPAD - Soil Plant Analyses Development tool, -502, Konica Minolta Company, Tokyo, Japan). This was achieved by clamping SPAD chlorophyll meter to the third youngest and exposed leaf on thirty maize and four bananas and the average calculated. Measurement commenced after 4 weeks of maize planting and 16th week of banana growth respectively. Maize and banana chlorophyll content determined at intervals of two weeks up to physiological maturity.

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2.4. Harvest Yield

Maize cobs from eight middle rows per replicate per treatment were harvested and weight determined using a spring balance and recorded. Five maize cobs were sampled out and shelled and fresh weight of the grains determined by analytical balance machine model, SKS 4520, Shimadzu-Japan. Maize grain yield was calculated using the ear fresh weight, and the adjusted moisture content percentage (from 10 to 15%) as described by Ngoune Tandzi and Mutengwa [16].

$$\text{Grain yield (t/ha)} = \frac{\text{(Fresh ear weight (kg/plot)} \times 10 \times (100 - MC) \times 0.8)}{(100 - \text{adjusted MC}) \times \text{Plot Area}}$$

In this case, fresh ear weight is in kg, moisture content (MC) of grains and adjusted MC in percentage (%), 0.8 is the shelling coefficient, and the harvested plot area is in m^2.

Banana yield measurement (bunch weight) was taken at the time of harvest. Four banana stems that were randomly tagged in each treatment were selected for harvesting. Bunch weight was determined using spring balance model, PCE-CS 300, Shimadzu-Japan.

2.5. Data analysis

Data obtained from the study was subjected to Statistical Analysis System (SAS) version 9.1, to determine whether there were any significant effects among the treatments. Means that were considered significantly different were separated using least significant difference (LSD) at $p \leq 0.05$.

3. RESULTS

3.1. Maize Height

Maize plant height showed significant differences ($P \leq 0.05$) among treatments Table 1. At week 12 maize recorded significantly taller plants in MF treatment followed by MBS, MBC, MBL, M and lowest in MB for both short and long rain season.

Table 1. Shows the effect of intercropping maize and banana with *Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolia* on maize plant height for short and long rain seasons.

Short rain season- August to December 2018							
Parameter	**Intercropping**	**WK 4**	**WK 6**	**WK8**	**WK10**	**WK12**	**Overall mean**
Maize plant Height (cm)	MF	44.87a	80.00a	92.67a	171.87a	235.20a	124.92a
	MBS	42.80b	75.50b	95.13a	168.70b	229.93b	122.41b
	MBC	39.23c	72.77c	91.80a	162.50c	219.90c	117.24c
	MBL	36.23d	70.90d	87.17ab	156.73d	214.93d	113.19d
	M	33.10e	66.17e	79.80b	151.43e	210.10e	108.12e
	MB	32.13f	61.07f	67.50c	145.90f	203.80f	102.08f
	lsd (0.05)	0.55	1.68	8.34	1.61	2.69	2.18
Long rain season- April- August 2019							
Parameter	Intercropping	WK 4	WK 6	WK8	WK10	WK12	Overall mean
Maize plant height	MF	47.20a	83.93a	101.57a	176.60a	240.30a	129.92a
	MBS	45.83b	80.57b	95.47b	173.67b	235.57b	126.22b
	MBC	41.63c	74.53c	95.33b	168.13c	218.87c	119.70c
	MBL	38.23d	72.80d	89.63c	159.70d	216.63d	115.40d
	M	35.13e	66.60d	84.33d	153.23e	211.27e	110.11e
	MB	30.87f	60.07e	79.50e	147.27f	206.90f	104.92f
	lsd (0.05)	0.71	1.45	3.62	1.66	1.21	2.18

Note: Means with the same letter down the column are not significantly different at $P \leq 0.05$.
Pure maize (M), Pure banana (B), Maize-banana-caliandra (MBC), Maize-banana-leuceana (MBL), Maize-banana-sesbania (MBS), Maize-banana (MB) and Maize-fertilizer (MF).

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3.2. Maize Leaf Number

Maize leaf number showed significant differences (P≤0.05) among treatments Table 2. At week 12, maize recorded significantly higher leaf number in MF treatment followed by MBS, MBC, MBL, treatments that were not significantly different (P≥0.05) from each other. Moreover, M and MB treatments recorded lowest leaf numbers that were not significantly different (P≥0.05) from each other for both short and long rain season.

Table 2. Shows the effect of intercropping maize and banana with *Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolia* on maize leaf number for short and long rain seasons.

Short rain season August to December 2018							
Parameter	**Intercropping**	**WK 4**	**WK 6**	**WK8**	**WK10**	**WK12**	**Overall mean**
Maize leaf number	MF	7.10a	8.20a	11.20a	12.93a	13.67a	10.62a
	MBS	6.57b	7.40b	9.70b	10.47b	12.53b	9.33ab
	MBC	6.53b	7.33b	9.60b	10.40b	12.47b	9.27ab
	MBL	6.50b	7.47b	9.63b	10.33b	12.46b	9.28ab
	M	6.00c	6.30c	7.73c	9.37c	10.60c	8.00b
	MB	5.90c	6.50c	7.67c	9.40c	10.67c	8.03b
	lsd (0.05)	0.26	0.26	0.32	0.28	0.77	1.78
Long rain season April to August 2019							
Parameter	Intercropping	WK 4	WK 6	WK8	WK10	WK12	Overall mean
Maize leaf number	MF	8.20a	10.40a	12.27a	13.70a	14.83a	11.88a
	MBS	7.37b	8.30b	10.23b	10.97c	12.56b	9.89b
	MBC	7.33bc	8.17b	10.33b	11.43b	12.57b	9.97b
	MBL	7.13c	8.20b	10.40b	11.43b	12.60b	9.95b
	M	6.07d	6.87c	8.10c	9.86d	11.10c	8.40b
	MB	6.10d	6.83c	8.10c	9.67d	10.90c	8.32b
	lsd (0.05)	0.22	0.23	0.32	0.46	0.24	1.78

Note: Means with the same letter down the column are not significantly different at P≤0.05.
Pure maize (M), Pure banana (B), Maize-banana-caliandra (MBC), Maize-banana-leuceana (MBL), Maize-banana-sesbania (MBS), Maize-banana (MB) and Maize-fertilizer (MF).

3.3. Maize Leaf Area

Maize leaf area showed significant differences (P≤0.05) among treatments Table 3. At week 12, maize recorded significantly higher leaf area in MF treatment followed by MBS, MBC, MBL, treatments that were not significantly different (P≥0.05) from each other. Moreover, M and MB treatments recorded lowest leaf area that were not significantly different (P≥0.05) from each other for both short and long rain seasons.

Table 3. Shows the effect of intercropping maize and banana with *Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolia* on maize leaf area for short and long rain seasons.

Short rain season August to December 2018							
Parameter	**Intercropping**	**WK 4**	**WK 6**	**WK8**	**WK10**	**WK12**	**Overall mean**
Maize leaf area (Cm^2)	MF	95.10a	171.07a	378.00a	795.17a	676.87a	423.24a
	MBS	91.17b	168.00b	373.33b	788.53b	670.87b	418.38b
	MBC	90.57bc	167.70b	373.83b	787.47b	670.46b	418.01b
	MBL	90.13c	167.03b	373.13b	788.50b	671.10b	417.98b
	M	88.20d	160.37c	369.93c	776.03c	665.50c	412.01c
	MB	88.17d	160.33c	369.97c	775.90c	665.27c	411.93c
	lsd (0.05)	0.79	1.12	1.41	1.96	1.99	2.81
Long rain season April to August 2019							
Parameter	Intercropping	WK 4	WK 6	WK8	WK10	WK12	Overall mean
Maize leaf area (Cm^2)	MF	98.07a	174.97a	380.27a	798.83a	680.13a	426.45a
	MBS	93.10b	172.16bc	375.63b	794.47b	676.47b	422.37b
	MBC	93.66b	171.87c	375.17b	794.63b	674.63b	328.83d
	MBL	93.67b	173.37b	374.97b	795.57b	674.47b	422.41b
	M	89.43c	167.10d	374.10b	785.46c	670.90c	417.40c
	MB	88.83c	166.43d	372.23c	785.40c	670.83c	416.74c
	lsd (0.05)	1.19	1.46	1.76	2.27	3.30	3.56

Note: Means with the same letter down the column are not significantly different at P≤0.05.
Pure maize (M), Pure banana (B), Maize-banana-caliandra (MBC), Maize-banana-leuceana (MBL), Maize-banana-sesbania (MBS), Maize-banana (MB) and Maize-fertilizer (MF).

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3.4. Banana Height

At week 25 of banana planting, MBS treatments had higher banana heights followed by MBL, MBC, B and lowest in MB treatment Table 4 . However, there was no significant difference among the treatments.

Table 4. Shows the effect of intercropping maize and banana with *Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolia* on banana height for short and long rain seasons.

Short rain season-August to December							
Parameter	**Intercropping**	**WK 17**	**WK 19**	**WK 21**	**WK 23**	**WK 25**	**Overall mean**
Banana height (cm)	MBS	58.00a	89.97a	112.02a	129.97a	151.33a	108.26a
	MBC	58.00a	90.00a	112.01a	130.22a	150.04a	108.05a
	MBL	58.00a	90.00a	112.21a	130.03a	150.09a	108.07a
	B	57.37a	89.66a	111.30a	129.33a	149.30a	107.39a
	MB	57.33a	89.00a	111.33a	129.27a	149.33a	107.25a
	lsd (0.05)	2.31	5.59	7.13	2.84	3.18	3.04
Long rain season- April to August							
Parameter	Intercropping	WK 52	WK 54	WK 56	WK 58	WK 60	Overall mean
Banana height (cm)	MBS	214.70a	235.00a	250.12a	269.73a	294.30a	252.77a
	MBC	215.51a	235.24a	250.00a	269.96a	295.04a	253.15a
	MBL	215.22a	235.03a	250.07a	270.06a	294.96a	253.07a
	B	215.03a	234.63a	249.36a	269.63a	294.33a	252.60b
	MB	214.63a	234.67a	250.03a	270.00a	294.93a	252.85a
	lsd (0.05)	1.19	1.46	1.76	2.27	3.30	3.04

Note: Means with the same letter down the column are not significantly different at P≤0.05.
Pure maize (M), Pure banana (B), Maize-banana-caliandra (MBC), Maize-banana-leuceana (MBL), Maize-banana-sesbania (MBS), Maize-banana (MB) and Maize-fertilizer (MF).

3.5. Banana Leaf Number

At week 25 of banana planting, MBC treatments had higher banana leaf number followed by MBS, MBL, B and lowest in MB treatment Table 5 . However, there was no significant difference (P≥0.05) among the treatments.

Table 5. Shows the effect of intercropping maize and banana with *Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolia* on banana leaf number for short and long rain seasons.

Short rain season-August to December 2018							
Parameter	**Intercropping**	**WK 17**	**WK 19**	**WK 21**	**WK 23**	**WK 25**	**Overall mean**
Banana leaf number	MBS	9.80a	10.28a	11.33a	12.30a	13.33a	11.41a
	MBC	9.77a	10.27a	11.35a	12.33a	13.36a	11.42a
	MBL	9.81a	10.24a	11.32a	12.28a	13.31a	11.39a
	B	9.73a	10.20a	11.30a	12.23a	13.29a	11.35a
	MB	9.30a	10.23a	11.16a	12.26a	13.20a	11.23a
	lsd (0.05)	0.13	0.31	0.34	0.27	0.22	2.20
Long rain season- April to August 2019							
Parameter	Intercropping	WK 52	WK 54	WK 56	WK 58	WK 60	Overall mean
Banana leaf number	MBS	14.30a	14.83a	15.17a	15.43a	15.86a	15.12a
	MBC	14.33a	14.82a	15.20a	15.47a	15.83a	15.13a
	MBL	14.36a	14.80a	15.20a	15.46a	15.80a	15.12a
	B	14.20a	14.73a	15.13a	15.37a	15.81a	15.05a
	MB	14.23a	14.75a	15.10a	15.45a	15.76a	15.06a
	lsd (0.05)	0.18	0.15	0.18	0.19	0.20	2.70

Note: Means with the same letter down the column are not significantly different at p≤0.05.
Pure maize (M), Pure banana (B), Maize-banana-caliandra (MBC), Maize-banana-leuceana (MBL), Maize-banana-sesbania (MBS), Maize-banana (MB) and Maize-fertilizer (MF).

3.6. Banana Leaf Area

Intercropping treatments had no significant (P≥0.05) effect on banana leaf area according to their respective treatments, except for week 54 of banana growth which showed significant differences (P≤0.05) among treatments Table 6. At week 54 of the long rain season, MBC and MB had significantly (P≤0.05) higher banana leaf area while MBS, MBL and B had lower banana leaf area though not significantly different (P≥0.05).

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Table 6. Shows the effect of intercropping maize and banana with a*Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolias* on banana leaf area for short and long rain seasons.

Short rain season- August to December 2018							
Parameter	**Intercropping**	**WK 17**	**WK 19**	**WK 21**	**WK 23**	**WK 25**	**Overall mean**
Banana leaf area (cm^2)	MBS	1409.46a	1556.13a	2156.53a	2509.06a	2710.03ab	2068.42a
	MBC	1408.43a	1556.93ab	2154.90a	2509.93a	2709.96ab	2068.03a
	MBL	1408.13a	1558.36a	2156.40a	2510.00a	2711.73a	2068.92a
	B	1408.16a	1556.96ab	2155.46a	2509.86a	2710.06ab	2068.10a
	MB	1408.53a	1557.00a	2154.93a	2508.60a	2710.06ab	2067.82a
	lsd (0.05)	2.35	1.85	2.30	2.47	2.15	2.70
Long rain season- April to August 2019							
Parameter	Intercropping	WK 52	WK 54	WK 56	WK 58	WK 60	Overall mean
Banana leaf area (cm^2)	MBS	5880.33a	6078.86b	6169.90a	6249.83a	6458.10a	6167.40a
	MBC	5878.80a	6084.10a	6170.80a	6250.36a	6458.73a	6168.56a
	MBL	5879.86a	6079.33b	6171.93a	6250.90a	6459.63a	6168.33a
	B	5878.50a	6080.03b	6172.53a	6249.83a	6459.30a	6168.04a
	MB	5879.20a	6081.16a	6172.13a	6250.60a	6459.73a	6168.56a
	lsd (0.05)	3.77	3.84	3.42	3.46	2.70	2.93

Note: Means with the same letter down the column are not significantly different at p≤0.05.
Pure maize (M), Pure banana (B), Maize-banana-caliandra (MBC), Maize-banana-leuceana (MBL), Maize-banana-sesbania (MBS), Maize-banana (MB) and Maize-fertilizer (MF).

3.7. Maize Chlorophyll Content

Maize chlorophyll content was significantly different (P≤0.05) and higher in MF followed by MBS, MBC, MBL, M and lowest in MB Table 7. The trend was same for all the weeks and the two seasons of data collection except for week 12 of long rain season where chlorophyll content in MF, MBS and MBC was significantly different (P≤0.05) while MBC and MBL had lower chlorophyll content though no significantly different (P≥0.05). M and MB treatments had the lowest chlorophyll content which were not significantly different (P≥0.05) from each other. Generally, MBS treatment had significantly higher chlorophyll content among the agroforestry tree treatments.

Table 7. Shows the effect of intercropping maize and banana with *Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolia* on maize chlorophyll content for short and long rain seasons.

Short rain season August to December 2018							
Parameter	**Treatment**	**WK 4**	**WK 6**	**WK 8**	**WK 10**	**WK 12**	**Overall mean**
Maize chlorophyll content (SPAD values)	MF	42.57a	45.27a	48.77a	50.63a	49.60a	47.37a
	MBS	40.53b	44.40b	47.33b	49.10b	48.43b	45.96a
	MBC	38.00c	40.60c	43.17c	46.00c	44.77c	42.51b
	MBL	36.80d	39.10d	40.23d	44.30d	43.60d	40.81bc
	M	35.40e	37.97e	39.50e	42.97e	41.20e	39.41c
	MB	34.13f	35.93f	38.90f	40.33f	39.76f	37.81c
	lsd (0.05)	0.40	0.33	0.37	0.44	0.59	3.08
Long rain season April to August 2019							
Parameter	Treatment	WK 4	WK 6	WK 8	WK 10	WK 12	Overall mean
Maize chlorophyll content (SPAD values)	MF	45.90a	47.07a	50.03a	54.67a	52.87a	50.11a
	MBS	44.10b	45.60b	48.53b	53.10b	50.40b	48.35ab
	MBC	40.53c	43.10c	47.20c	52.10c	48.73c	46.33bc
	MBL	38.77d	42.33d	46.03d	49.90d	48.27c	45.06cd
	M	37.83e	39.50e	43.40e	47.90e	46.20d	42.97de
	MB	35.03f	38.50f	42.03f	46.93f	45.63d	41.62e
	lsd (0.05)	0.35	0.40	0.51	0.36	0.96	2.81

Note: Means with the same letter down the column are not significantly different at P≤0.05.
Pure maize (M), Pure banana (B), Maize-banana-caliandra (MBC), Maize-banana-leuceana (MBL), Maize-banana-sesbania (MBS), Maize-banana (MB) and Maize-fertilizer (MF).

3.8. Banana Chlorophyll Content

At week 25 of banana planting, MBC treatments had higher banana chlorophyll content followed by MBS, MBL, MB and lowest in B treatment Table 8. However, there was no significant difference (P≥0.05) among the treatments.

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Table 8. Shows the effect of intercropping maize and banana with *Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolia*on banana chlorophyll content for short and long rain seasons.

Short rain season August to December 2018							
Parameter	**Treatment**	**WK 17**	**WK 19**	**WK 21**	**WK 23**	**WK 25**	**Overall mean**
Banana chlorophyll content (SPAD values)	MBS	41.70a	43.33a	44.46a	45.31a	46.53a	44.27a
	MBC	41.66a	43.35a	44.50a	45.33a	46.58a	44.28a
	MBL	41.70a	43.30a	44.53a	45.36a	46.51a	44.28a
	M	41.53a	43.20a	44.33a	45.28a	46.36a	44.14a
	MB	41.63a	43.22a	44.48a	45.27a	46.40a	44.20a
	lsd (0.05)	1.24	0.65	0.99	0.77	0.93	2.70
Long rain season April to August 2019							
Parameter	Treatment	WK 52	WK 54	WK 56	WK 58	WK 60	Overall mean
Banana chlorophyll content (SPAD values)	MBS	56.30a	57.16a	58.28a	59.06a	58.61a	57.88a
	MBC	56.36a	57.29a	58.17a	59.10a	58.53a	57.89a
	MBL	56.27a	57.22a	58.20a	59.20a	58.60a	57.90a
	M	56.23a	57.06a	58.10a	59.00a	58.58a	57.79a
	MB	56.25a	57.10a	58.03a	59.03a	58.50a	57.78a
	lsd (0.05)	0.35	0.40	0.51	0.36	0.96	3.04

Note: Means with the same letter down the column are not significantly different at p≤0.05.
Pure maize (M), Pure banana (B), Maize-banana-caliandra (MBC), Maize-banana-leuceana (MBL), Maize-banana-sesbania (MBS), Maize-banana (MB) and Maize-fertilizer (MF).

3.9. Maize Yield

Maize yield per hectare was significantly different (P≤0.05) across all treatments and for both short and long rain seasons Table 9 . MF treatment had the highest maize yield per hectare followed by MBS, MBC, MBL, M and lowest in MB treatment. The trend was observed for both short and long rain season. Generally, MBS treatment had significantly higher maize yield per hectare among the agroforestry tree treatments.

Table 9. Shows the effect of intercropping maize and banana with *Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolia* on maize yield for short and long rain seasons.

Intercropping	**Short rain season- August to December 2018**	**Long rain season-April to August 2019**
	Yield (t/ha)	**Yield (t/ha)**
MF	3.16a	5.26a
MBS	2.76b	4.13b
MBC	2.44c	3.31c
MBL	2.26d	2.93d
M	2.12e	2.60e
MB	1.42f	1.01f
lsd (0.05)	0.06	0.08

Note: Means with the same letter down the column are not significantly different at P≤0.05.
Pure maize (M), Pure banana (B), Maize-banana-caliandra (MBC), Maize-banana-leuceana (MBL), Maize-banana-sesbania (MBS), Maize-banana (MB) and Maize-fertilizer (MF).

3.10. Banana Yield

Banana yield was significantly different (P≤0.05) among treatments Table 10.

Table 10. Shows the effect of intercropping maize and banana with *Calliandra callothyrsus*, *Sesbania sesban* and *Leucaena diversifolia* on banana yield for short and long rain seasons.

Intercropping	**Long rain season-April to August 2019**
	Banana bunch weight (Kg)
MBS	28.50a
MBC	24.83b
MBL	21.33c
B	18.00d
MB	16.70d
lsd (0.05)	1.47

Note: Means with the same letter down the column are not significantly different at P≤0.05.
Pure maize (M), Pure banana (B), Maize-banana-caliandra (MBC), Maize-banana-leuceana (MBL), Maize-banana-sesbania (MBS), Maize-banana (MB) and Maize-fertilizer (MF).

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MBS treatment had the highest bunch weight followed by MBC, MBL, B and lowest in MB treatment. Agroforestry tree treatments had higher banana yield and best performance in MBS treatment. During the first season of banana of planting data on banana yield was not taken since the banana plants had not matured yet.

4. DISCUSSION

The agroforestry trees were found to increase maize height with higher maize plants recorded in *Sesbania sesban* as compared to those treatments without the agroforestry trees except for fertilized maize. Even though the fertilizer plots were seen to produce positive results, it has however been earlier reported to have significant pollution effects on the environment [17] prompting the adoption of environmentally friendly technologies like intercropping. The findings are in agreement with those of Asekabta [18] who indicated that provision of adequate nitrogen in agroforestry tree intercrops extends vegetative growth period of maize and this increases the photosynthesis duration and partitioning of photo assimilates to stems which in turn positively impacts on maize plant heights. The positive increase in maize height in agroforestry treatments may be attributed the rapid and stable supply of essential nutrients such as nitrogen through biological nitrogen fixation which enhanced rapid growth compared to other treatments like sole maize and maize- banana intercrops which depended solely on already nutrient depleted soils.

There was a general increase in maize leaf number in agroforestry tree intercrops with higher leaf number observed in *Sesbania sesban*. The results are in agreement with Flagot [19] who indicated that intercropping with agroforestry trees consistently resulted in luxuriant growth of plant leaves, which is an indicator for improved photosynthesis. The increase in maize leaf number under nitrogen fixing tree intercrops may be attributed to improved uptake of nutrients through biological nitrogen fixation offered by *Sesbania sesban*, *Leucaena diversifolia* and *Calliandra calothyrsus* for proper growth and development of plants. Maize grown in poor soils has numerous deficiency symptoms that lead to poor growth of plants especially the leaves [20]. This was observed in sole maize and maize-banana treatments which recorded low number of leaves that were significantly different from other treatments.

There was a general increase in maize leaf area in agroforestry tree intercrops with higher leaf area recorded in *Sesbania sesban* treatments. The findings are in agreement with Asekabta [18] who indicated that intercropping maize with *Glycine max* resulted in appreciable enlargement of the unit area covered by the maize leaves. The increase in leaf area in nitrogen fixing tree plots can be attributed to steady supply of nitrogen nutrients through biological nitrogen fixation and decomposition of leafy prunings which enhanced maize plant leaf area compared to sole maize and maize- banana treatments which depended solely on already nutrient depleted soils.

However, intercropping had no significant effect on banana height, leaf number and leaf area suggesting that land use efficiency may be increased by incorporating food and or fodder legumes into banana cropping system but take care of the shading effect and mineral competition through pruning of banana to allow light interception and also increase banana to banana spacing to reduce on crop - banana competition.

There was a general increase in maize chlorophyll content in agroforestry tree intercrops with higher chlorophyll content recorded in *Sesbania sesban* treatments. The results are in agreement with those of Nasar, et al. [21] who indicated that maize–soybean intercropping increased the chlorophyll content of the maize crop compared to monocropping. Similar findings were reported by Ahmad, et al. [22] who indicated that chlorophyll content under maize- agroforestry tree intercropping conditions highly increases chlorophyll concentration in the maize leaves compared with monocropping conditions. The increase in chlorophyll content in intercrops could be attributed to the nitrogen fixation and decomposition of leafy prunnings in the respective plots which provided essential nutrients such as nitrogen, calcium and magnesium that plays a major role in the synthesis of chlorophyll molecules in the chloroplasts. However, previous study by Ong, et al. [23] contradicts the current findings indicating that intercropping maize with *Grevillea robusta* significantly reduced SPAD values in maize compared to

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control treatments, a fact that was attributed to light interception by the trees, which decreased chlorophyll concentrations due to shading. However, no significant difference was observed in chlorophyll concentration in banana plants in intercrop setting or monocrop setting. This suggested that the biological nitrogen fixation by agroforestry trees into soil and decomposition of leafy biomass from pruned agroforestry trees released minerals such as nitrogen and magnesium in lower quantities that could not exhibit significant differences in banana chlorophyll content, bearing in mind that bananas are heavy feeder plants, even though the rates of mineral acquisition were not determined.

Maize yield was observed to increase under nitrogen fixing tree intercrops with higher yield recorded in *Sesbania sesban* treatments while unfertilized plots and those that were not under intercropping had the lowest maize yield. Generally, maize fertilizer treatments had the highest maize yield. However the detrimental effects of fertilizer use and poverty among farmers limits its use as discussed earlier. Increased maize yield in agroforestry treatments is in agreement with Meijer, et al. [24] who indicated that fertilizer trees including *Gliricidia sepium*, intercropped or in improved fallows, have been shown to increase maize yield over current farmer practice across sub-Saharan Africa, but with different performance across soil types and ecological zones. The increase in maize yield in agroforestry treatments could be attributed to fertility improvement as a result of agroforestry tree coppices related to various mechanisms such as biological N fixation, pumping up or retrieval of nutrients from lower soil horizons and interception of nutrients that would otherwise be lost through leaching and surface runoff and release of nutrients during litter and root decomposition. Similar findings were reported by Selim [25] who found that nitrogen, phosphorus, potassium, calcium and magnesium uptake are enhanced by deep rooted leguminous trees that enhances pulling up of nutrients from below ground to maize crop rhizosphere increasing maize yield.

Banana yield was observed to increase under nitrogen fixing tree intercrops with higher yield recorded in *Sesbania sesban* treatments while unfertilized plots and those that were not under intercropping had the lowest maize yield. The increase in banana yield in agroforestry treatments may be attributed to low levels of pests and diseases on bananas grown in agroforestry systems as previously described by Deltour, et al. [26]. The high yield potential observed in agroforestry trees can be attributed to the release of volatile compounds which play an important role in plant defense against microbial pathogens and pest attack and in turn increase banana yield as reported by Takabayashi [27].

5. CONCLUSION

Intercropping with agroforestry tree species had a positive influence on maize growth, maize and banana chlorophyll content and yield. Best performance was observed in Maize-*Sesbania sesban* intercrop.

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