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Chlorophyll Content Index and Yield Responses of Maize and Banana Plants under *Calliandra calothyrsus*, *Sesbania sesban* and *Leucaena diversifolia* Intercropping in Vihiga County, Kenya

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

High population has led to more demand for food. Subsequently, there is need to expand agricultural land. This has necessitated cutting down of trees. This has led to soil degradation. Nutrient depleted soils and poor cropping systems such as continuous cropping, have contributed to the declining yield, which is a major problem facing farmers in Western Kenya. Intercropping with agroforestry tree species can alleviate soil infertility problems and increase crop productivity through enhanced biological nitrogen fixation, growth and photosynthesis hence ensuring food security. However, intercropping with agroforestry trees may lead to competition for both above ground and below ground resources between crops and trees hence affect the physiology and yield of the component crops. Intercropping maize and bananas with agroforestry trees such as C*alliandra*

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calothyrsus, *Sesbania sesban* and *Leucaena diversifolia* have the potential to improve the physiology and productivity of both maize and bananas and as a result alleviate food insecurity. However, the influence of the agroforestry trees species on the physiology and yield of the maize and banana crops in an intercrop system is yet to be established. This study sought to investigate the influence of intercropping agroforestry tree species on maize and banana chlorophyll content index and yield. The field trials were set up at Maseno University farm in Vihiga County. Seeds of agroforestry trees were acquired from KEFRI – Muguga, planted in a seedbed and the seedlings raised in nurseries. Five months old Williams' variety tissue banana seedlings were obtained from KALRO-Thika. Hybrid maize seeds, H513 were bought from Kenya seed company Kitale. Banana holes were dug 90cm x 90cm x 60cm deep and 20 Kg of cow dung manure + 20 Kg of top soil + 200g of NPK fertilizer added before planting the banana at a depth of 0.3m for proper anchorage. Maize were planted at 0.75 m inter row by 0.3 m spacing. Randomized Complete Block Design with 3 replications and seven treatment levels (maize without fertilizer, maize banana *Calliandra calothyrsus*, maize banana *Leucaena diversifolia*, maize banana *Sesbania sesban*, maize-banana, banana monocrop and maize with fertilizer) were used. Fifteen maize and four banana plants in each treatment were sampled in a zigzag method and tagged for data collection. Data on maize and banana plant chlorophyll content and yield were determined. Chlorophyll content index parameters were measured using SPAD meter on the 3rd fully sun exposed leaf of the tagged plants. Data collected from the study was subjected to analysis of variance using GenStat statistical package. Treatment means were separated and compared using the Least Significant Difference (LSD). There were significant increases ($P \leq 0.05$) in chlorophyll content and yield under maize + banana + *sesbania sesban* (MBS) treatment. Bunch weight and finger length were significantly higher under MBS. These agroforestry trees enhanced chlorophyll content index and yield of maize and bananas. Therefore, intercropping of maize, banana and *Sesbania sesban* is recommended as it increases the yields of both maize and banana through improved chlorophyll content index. This study allows us to understand the interaction mechanisms of the crops of maize and banana with the three agroforestry tree species to resources.

Keywords: Intercropping; agroforestry; yield; chlorophyll content index; Sesbania sesban; Calliandra calothyrsus; Leucaena diversifolia; banana; maize; Vihiga county.

1. INTRODUCTION

1.1 Background of the Study

Vihiga is the third most populated county in Kenya after Nairobi and Mombasa with a population density of 1046 persons per km^2 on a land area of 563.8 km^2 and a total population of 590,013 [1]. This high population density coupled with declining food production has led to cutting down of trees to provide land for crop production. According to [2] the clearing of forests has led to loss of global forest cover estimated at 3.1% per year resulting to reduced soil fertility and crop yields [3]. The smallholder farmers are the major drivers to food security in sub Saharan African [4]. However, these farmers face the challenges of low soil nutrient fertility arising from monocropping and continuous cultivation without fallows resulting to low crop productivity [5]. Therefore, this calls for improved farming practices that can incorporate crop farming and tree growing in the limited land resource of Vihiga County.

Agroforestry trees may have an impact on crop productivity. This can be manifested in physiological responses of the crop plants such as chlorophyll accumulation and yield. In Western Kenya, information on the effects of intercropping trees to chlorophyll content index and yield responses of crop plants is yet to be demonstrated. Due to high population, planting of *Crotalaria grahamiana*, *Crotalaria paulina*, *Tephrosia vogelli* and *Tephrosia candida* fallows under farmer-managed conditions in Western Kenya has become popular in order to maximize their benefits of improving soil fertility and providing fuelwood at the same time on the limited land resource [6]. Despite reporting soil fertility improvement, other factors that affect crop development and productivity such as chlorophyll content index and yield are influenced by limited nutrient and water resources have not been reported. Competition for water will result to water stress to the plant cells and consequently leading to reduced cell expansion hence reduced plant crop productivity. Previously, agroforestry-farming systems has been practiced by smallholder farmers worldwide and proved beneficial [7]. In Western Kenya, *Calliandra calothyrsus* has been popularized for seed production and animal feeds by smallholder farmers [8]. For this reason, there is a growing interest to these tree species on farms as agroforestry to meet fodder, mitigate soil fertility and fuel demands [6]. However, their presence may directly affect resource sharing between food crops and trees. Despite the widespread adoption by farmers, no study has been done to investigate their effect on the crop physiological processes that have direct impact on the crop productivity.

Incorporation of *Calliandra calothyrus, Tithonia diversifolia*, *Senna spectabilis* and *Sesbania sesban* tree species has reported increased soil fertility and maize yield when planted along the farm boundaries in Western Kenya among smallholder farmers because of increased nutrient uptake through nutrient fixation [9] and [10]. However, the agroforestry tree species may have some effect on the competition for water and nutrients that may interfere with the physiological and yield responses of the associated crops. Despite the positive attributes of such trees to maize production, it remains unknown if similar results can be produced in the new farming practice where banana has been introduced. More so, no study has been done to establish physiological responses such as chlorophyll content index and yield within an intercrop involving maize and banana plants.

Total chlorophyll content is a valuable indicator of both potential primary productivity and general plant vigour [11]. Chlorophyll content in plants is affected by the availability of some key elements such as nitrogen and magnesium which are a subject of competition under agroforestry system. [12] reported significant increase in maize total chlorophyll under different intercropping systems involving maize and cowpeas compared to monocrop. [13] stated that leaf total chlorophyll of sweet basil were significantly increased under intercropping with aromatic tree plants. *Grevillea robusta* intercropped with maize have shown reduced total chlorophyll on maize in Trans Nzoia, Kenya [14]. The reduction in chlorophyll is because of competition for nutrients with the associated food crops.

Smallholder farmers in the Sub Saharan Africa region have practiced intercropping farming of cereals – legumes, cereal - grain [15]. [16] indicated that maize yields in the intercropping system increased in two fold compared to the monocropped maize after fourth year due to facilitation processes on macro nutrient uptake that enhanced maize grain filling. [17] established a substantial increase in yields of maize when intercropped with *Sesbania sesban* in southern Malawi. Contrarily, [18] and [19] reported reduced maize yields under Mucuna intercropping due to low biomass production. Higher maize produce has been reported when biomass of *Tithonia diversifolia*, *Calliandra calothyrsus* and *Leucaena diversifolia* are applied [20,21]. Maize grown following legume cover crops produced significantly higher yield than those without green manures mainly through benefits of higher amounts of N and P and partly through nutrient pumping from deeper layers [22]. In Western Kenya, increased yield have been reported up to 200% when tithonia biomass was applied [23,24]. Similarly, in central Kenya application of tithonia, *Calliandra callothyrsus* and *Leucaena diversifolia* biomass has been reported to increase maize yield [25, 26]. [27] demonstrated that use of organics could enhance efficiency of chemical fertilizers. [28] and [29] showed that combination of organic and inorganic nutrient sources result into interaction, enhanced management and increased fertilizer efficiency and higher yields. [30] reported higher grain yields of maize under application of organic and mineral fertilizers. Maize has been reported to increase by more than 300% when intercropped for more than four seasons with Gliricidia as opposed to monocropped maize [31].

[32] reported highest biomass in maize grown without hedgerows and nitrogen fertilizer, whereas under hedgerow showed the lowest biomass because of hedgerow plants competing for nutrients, water and light. Therefore, there is need for adoption of tree species that are complementary to food crops. In the sub-humid region of Embu, significant increase of maize yield was reported under *Calliandra calothyrsus* and *Leucaena diversifolia* pruned biomass application [25]. Rice yield increased when it was intercropped with fruit trees compared to monocrop rice [33]. The legume trees and green manure cover crops provide biomass that increased maize yields [31] and [34].

Growing crops with different maturation periods such as maize and banana crops can be adopted in agroecologies with growing seasons of variable length such as Vihiga County to exploit the occasional favourable season and to insure against total crop failure in case of unfavorable seasons [35]. Vihiga County is located in the same agro-ecological region facing climate change, food insecurity, high poverty index, declining soil fertility and land degradation courtesy of poor farming systems. It is thus necessary to adopt intercropping system of maize and banana, which are the main food crops that Western Kenya relies on with selected agroforestry trees species.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

Experiments in the field were carried out for two consecutive seasons from August 2018 to September 2019 at Maseno University farm in Vihiga County (00^o 00'15.5''S; 034^o 35'53.1''E; 1522 masl) of Western Kenya. The soils at the site have very low N, P, K, Ca and Mg amounts hence highly impoverished [36]. For instance, the Maseno soils are acidic with a pH of 4.65, and have low nutrient contents, that is N = 0.16%, P = 2.57 mg/kg, K = 46.8 mg/kg Ca = 105 mg/kg Mg = 22.3 mg/kg and Al = 1.88 meq/100g [37]. The chemical composition of cow dung manure used and the nutrient composition of the prunings of agroforestry trees used are shown on Table 1 and Table 2 respectively. The site receives a bimodal annual mean precipitation of 1750 mm, from August to November short rains and March to July long rains. The mean temperature during the study was 28.7 degrees Celsius with relative humidity of 40%. Maize, bananas, sorghum, millet, beans, cowpeas, cassava, sweet potatoes, groundnuts and finger millet are the commonly grown food crops in the region.

Table 1. Chemical composition of the cow dung manure used in the study (Source: Author).

pH(H_20)	N (g/kg)	P (g/kg)	K (g/kg)	Ca (g/kg)	Mg (g/kg)
9.6	12.8	1.78	1.14	3.47	1.36

Table 2. Nutrient composition of the agroforestry tree species used in the study (Source: Author)

	N	P	K	Ca	Mg
Calliandra calothyrsus	3.3	0.2	1.1	0.9	0.4
Leucaena diversifolia	3.8	0.2	1.8	1.4	0.4
Sesbania sesban	3.8	0.18	1.4	2.2	0.6

Map of the Study Area:

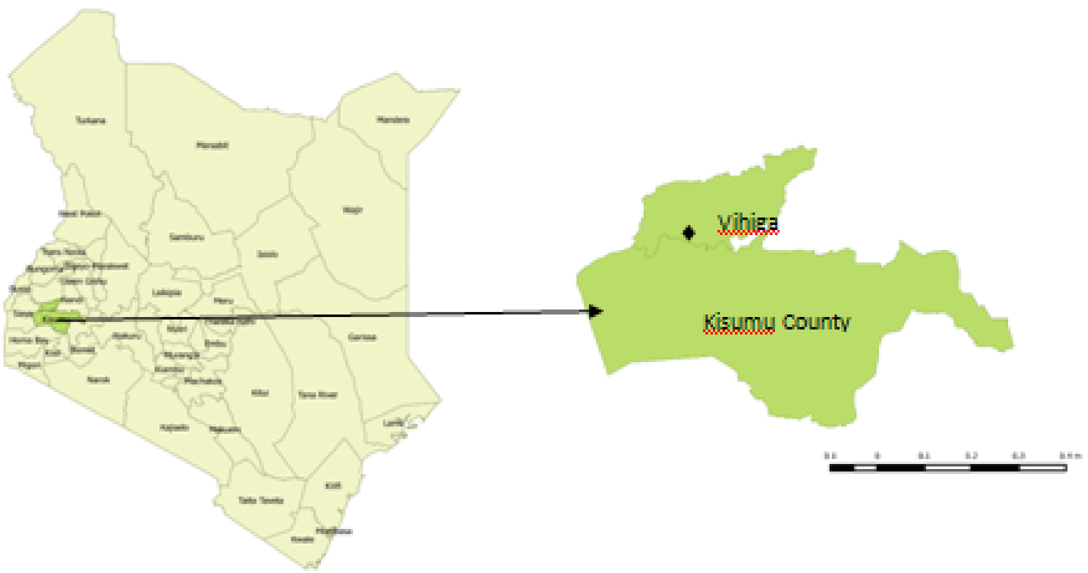

Fig. 1. Map showing the Vihiga study site at Maseno University farm Source, Google maps

2.2 Experimental Treatment and Design

Randomized complete block design experiment with seven treatments of maize + fertilizer (MF), maize + no fertilizer (M), banana monocrop (B), maize + banana + *Calliandra calothyrsus* (MBC), maize+ banana+ *Leucaena diversifolia* (MBL), maize+ banana+ *Sesbania sesban* (MBS) and maize + banana (MB) and three replications was laid. Seeds of agroforestry trees were purchased from KEFRI-Muguga, sown and raised in nurseries. When the agroforestry tree species seedlings were three months old, they were transplanted into the field at a spacing of 0.5 m by 3 m. The agroforestry tree species seedlings were then allowed to grow for three months before maize seeds were sown, to give them time to establish. Five months old, Williams' tissue banana variety from the green house were purchased from KALRO-Thika. Banana holes were dug at 0.9m by 0.9m by 0.6m deep and banana planted at a depth of 0.3m for proper anchorage. Under agroforestry, treatments a maximum of nine bananas plants were planted at a spacing of 3m by 3m while monocrop banana had a maximum of twelve banana plants with a spacing of 3m by 2.5m. In maize-banana plots, the banana spacing was 6m by 2.5m having a maximum of six banana plants. The bananas were planted three months prior planting maize. Hybrid seeds maize, H513 were obtained from Kenya seed company Kitale. The Maize was planted at a spacing of 0.75m by 0.3m for both inter-rows and intra-rows and NPK (13-40-13) fertilizer applied in the maize fertilizer plots. In maize plots alone, twelve rows were planted giving a maximum of 480 maize plants. The plots containing agroforestry trees, nine rows were planted in each plot giving a maximum of 216 maize plants. Two maize seeds were planted in each hole and thinned to one plant, one week after emergence. Gapping was done five days after emergence. The agroforestry trees were regularly pruned and the prunings applied between the maize and banana rows after every fourteen days. The shoot prunings of the three agroforestry tree species used in this study have been reported to have quality chemical properties of N, P, K, Mg and Ca (Table 2). Plot sizes measured 9 m by 12 m, holes for bananas were dug at a spacing of 2x2 feet and added 200 g NPK fertilizer 200 g of Nitrogen Phosphorus potassium (NPK) (N=14%, P=29%,K=6%, S=4%, Zn=0.1%, Cao=4%, B=0.1% and MgO= 1%) + 20 kg cow dung manure whose chemical composition was pH 9.6, N=12.8, P = 1.78, K = 1.14, Ca = 3.47 and Mg =1.36 + 20 kg of top soil before planting in the Banana [37]. Spacing of bananas in agroforestry treatments was 3 m x 3 m, monocropped banana 3 m x 2.5 m, maize and banana was 6m x 2.5m and 0.75m by 0.30 m in maize and 2 rows of banana x 4 within row in maize + banana+Agroforestry trees, [37].

Plate 1. The research plot at study site, Maseno University farm at tassling stage. (Source, Photo taken by researcher)

2.3 Determination of Total Chlorophyll Content

Chlorophyll content Index of the 3rd fully sun exposed leaf from the top was estimated non-destructively using a portable chlorophyll meter SPAD-502 meter, Minolta, Japan. Fifteen maize and four banana plants were tagged in each treatment for data collection and the average calculated. Chlorophyll content index was recorded at 28 days after planting (DAP) until the maize plants attained physiological maturity and bananas at 143 DAP and 360 DAP for 1st and 2nd season of banana plants at an interval of 28 days.

2.4 Determination of Yield and Yield Component Responses

2.4.1 Harvest yield for maize and banana

Eight middle rows of maize from each treatment were harvested and the maize weight determined with a spring balance. One fully matured banana per treatment was harvested and weighed.

2.4.2 Yield component responses

Total number of plants harvested were determined by physically counting the number of plants harvested from the eight middle rows from each treatment. The total number of maize with cobs, total number of maize without cobs, total number of rotten maize cobs and total number of fresh maize cobs were determined through physical counting and their numbers recorded for each treatment [38]. The banana bunch weight was determined using spring balance, number of hands and fingers per bunch were physically counted and recorded. The finger length was determined from five fingers randomly selected per hand in the bunch.

2.4.3 Determination of biomass production for the whole plant

Five maize plants were randomly selected from each treatment at plant harvest, uprooted and partitioned into different plant parts such as roots, stem, leaves, maize cob and maize grains. The roots were rinsed with tap water and immersed in a bucket of water to remove soil that had adhered to the root surfaces. The plant parts were oven dried at 72^0C to a constant weight. The dry weight was then determined using balance Denver instrument XL-3100, [38].

2.5 Data Analysis

Analysis of Variance (ANOVA) using Genstat statistical package version 15.2 was used to analyze the data. Fischers' protected LSD test at 95% confidence level was used to separate the means.

3. RESULTS

3.1 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Maize Total Chlorophyll Content (%)

There were significant differences ($p \le 0.05$) on the chlorophyll content for both seasons among the treatments (Table 3). There was a rise in the total chlorophyll content as the number of days after planting increased up to 56 DAP. The highest chlorophyll content was observed at 56 DAP compared to other days of measurement for both season 1 and 2. The lowest chlorophyll content was shown at 84 DAP. There was significant difference in MF at 56 DAP however, it was not significantly different from MBS and MBL. The least chlorophyll content was measured under monocrop maize without fertilizer application treatment. The MBL and MBS treatments performed better than the MBC with MBS posting the highest chlorophyll content throughout among the agroforestry treatments.

Though the maize with fertilizer treatment showed the highest total chlorophyll content, it was not significant to that of MBS treatment at 56 DAP during 2nd season. Maximum chlorophyll content was observed at 56 DAP in all treatments during the two seasons of study. There was a decline on the chlorophyll content at 84 DAP during the two seasons.

3.2 Effect of Intercropping Maize and Banana with Agroforestry tree Species on Banana Total Chlorophyll Content

The chlorophyll contents in the banana crop showed significant differences ($p \le 0.05$) under the MBS treatments at 199 DAT for the first season, though not significantly different from all the other treatments except under MB at 199 DAT (Table 4). There was minimal differences between the chlorophyll content under the agroforestry treatments. MBS measured higher banana chlorophyll content compared to the other treatments.

Table 3. Effect of intercropping maize and banana with agroforestry tree species on maize chlorophyll contents (μmol) during the first and second seasons

Seasons	Treatment	28 DAP	56 DAP	84 DAP
Season 1	M+B	37.1 c	43.5 c	32.9 b
	M+B+C	37.2 c	43.6 bc	32.3 b
	M+B+L	40.4 ab	48.0 abc	34.8 b
	M+B+S	40.3 ab	48.4 ab	35.3 b
	M+F	43.1 a	49.5 a	40.8 a
	M Alone	38.6 bc	46.9 abc	35.4 b
	LSD	**3.0**	**5.0**	**4.6**
Season 2	M+B	41.4 b	42.3 bc	39.4 ab
	M+B+C	37.1 c	40.3 c	34.7 b
	M+B+L	40.5 b	42.8 bc	36.9 b
	M+B+S	41.5 b	45.2 ab	39.4 ab
	M+F	46.8 a	48.0 a	45.5 a
	M Alone	40.2 b	41.5 bc	36.3 b
	LSD	**2.8**	**4.8**	**5.47**

Treatments with same letter along the columns are not significantly different according to LSD at p≤0.05. DAP-Days after Planting of maize

Significantly ($p \leq 0.05$), higher banana chlorophyll contents were observed only at 416 DAT under MBS treatments in the 2nd season (Table 4). However, this was not significantly different from the rest of the treatments except the MB and MBC treatments. Consistently high chlorophyll contents were observed in the MBS and the lowest chlorophyll content were under the B treatment during the days of measurement for both seasons. Despite high amount of chlorophyll content under MBS treatment, the difference with other treatments was minimal.

3.3 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Number of Maize Cobs Per Plot

The number of maize cobs per plot showed significant differences ($p \leq 0.05$) for both seasons. The maize under fertilizer application showed the highest number of maize cobs compared to the rest of the treatments however, MBS recorded significantly higher number of cobs compared to MBL, MB and M. The MBL had the least number of cobs among the treatments. During the second season, the number of maize cobs in MBS and MF treatment were highest, however they were not significantly different from each other. Maize cobs were lowest under MBL treatment during the first and second seasons among the agroforestry trees while maize banana intercrop and maize without fertilizer application reported least number of maize cobs in the second season. The 2nd season reported significantly higher number of maize cobs compared to season one.

3.4 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Maize Grain Yield Parameters

The number of maize rotten cobs, number of maize cobbed plants and maize total biomass did not show significant differences ($p \leq 0.05$) during the study (Table 5). In the 1st season, high number of maize rotten cobs were registered under the maize without fertilizer application with *Calliandra carlothyrsus* and *Sesbania sesban* treatments recording the lowest number of rotten cobs. Contrary to the 1st season, the 2nd season recorded the highest number of rotten cobs in with fertilizer application and in *Calliandra carlothyrsus* treatment recording the least number of rotten cobs. In both seasons, MBS and MBC recorded the lowest number of maize with rotten cobs.

The maize under fertilizer application treatment registered high number of cobbed maize plants during both seasons, but not significantly different to MBL and MBS during season 1 (Table 5). In the second season no significant differences were reported. The agroforestry trees treatments registered high number of cobbed maize plants with *Sesbania sesban* having the highest number and maize without fertilizer application having the least number of cobbed maize plants.

Table 4. Effect of intercropping maize and banana with agroforestry tree species on banana chlorophyll contents (µmol) during the first and second seasons

Seasons	Treatment	143 DAT	171 DAT	199 DAT
Season 1	B	53.8 a	49.2 a	52.9 ab
	M+B	53.2 a	54.1 a	51.3 b
	M+B+C	55.1 a	52.6 a	52.1 ab
	M+B+L	53.1 a	49.9 a	51.6 ab
	M+B+S	54.2 a	55.9 a	57.3 a
	LSD	**3.7**	**7.2**	**5.8**
	Treatment	**360 DAT**	**416 DAT**	**488 DAT**
Season 2	B	45.8 a	51.2 a	54.2 a
	M+B	49.8 a	49.5 bc	55.6 a
	M+B+C	48.4 a	48.5 c	53.3 a
	M+B+L	49.1 a	52.1 ab	55.7 a
	M+B+S	48.6 a	54.0 a	58.1 a
	LSD	**5.1**	**3.3**	**5.9**

Treatments with same letter along the columns are not significantly different according to LSD at p ≤ 0.05. DAT-Days after transplanting of bananas

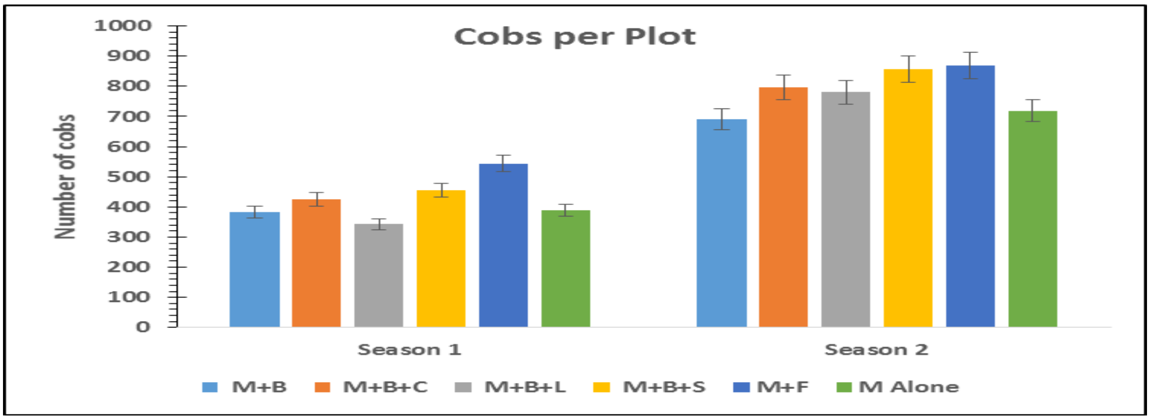

Fig. 2. Effect of intercropping maize and banana with agroforestry tree species on number of maize cobs per plot during the first and second seasons. Error bars indicate the SE at p≤0.05

The maize plant total biomass did not show significant differences (p≤0.05) among the treatments during the period of study (Table 5). The MBS treatments and the maize under fertilizer recorded the highest total biomass during the study period. During the 1st season, MB had the least total biomass and the maize without fertilizer application registered the least biomass in the 2nd season.

3.5 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Maize Grain Yield Parameters

Significant differences (p≤0.05) were recorded for both seasons, under *Sesbania sesban* and in maize under fertilizer treatments (Fig. 3). During season one, maize under MBS treatments and the maize under fertilizer recorded the highest grain yield amongst the treatments. In the second season, MBS and MF recorded significantly high grain yields. The MB, MBC, MBL and M recording the yields that was not significantly different from each other. Among the agroforestry trees, MBS recorded the highest grain yield followed by MBC and the least was under MBL treatments.

3.6 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Banana Bunch Weight

The MBS reported significantly higher (p≤0.05) bunch weight of bananas than all the treatments (Fig.4). The MBS had the heaviest bunch weight. Monocropped banana crop had the least bunch weight however; it was not significant to MB, MBL and MBC treatments. Banana bunch weight was significantly higher under MBS among the treatments.

Table 5. Effect of intercropping maize and banana with agroforestry tree species on maize yield parameters during the first and second season

Seasons	Treatment	Rotten Cobs	Cobbed Plants	Total Biomass
Season 1	M+B	6.3 a	88.0 a	1782.0 a
	M+B+C	2.3 a	90.0 a	1796.0 a
	M+B+L	6.3 a	137.7 a	1817.0 a
	M+B+S	3.0 a	138.3 a	2107.0 a
	M+F	4.0 a	170.3 a	2117.0 a
	M Alone	8.0 a	81.0 a	1797.0 a
	LSD	**6.3**	**48.9**	**1069.8**
Season 2	M+B	5.0a	73.0 a	931.0 a
	M+B+C	1.7 a	114.0 a	901.0 a
	M+B+L	3.0 a	106.0 a	847.0 a
	M+B+S	3.3 a	173.0 a	1146.0 a
	M+F	6.0 a	109.0 a	1057.0 a
	M Alone	4.3 a	73.0 a	784.0 a
	LSD	**4.9**	**112.9**	**577.0**

Treatments with same letter along the columns are not significantly different according to LSD at p≤0.05

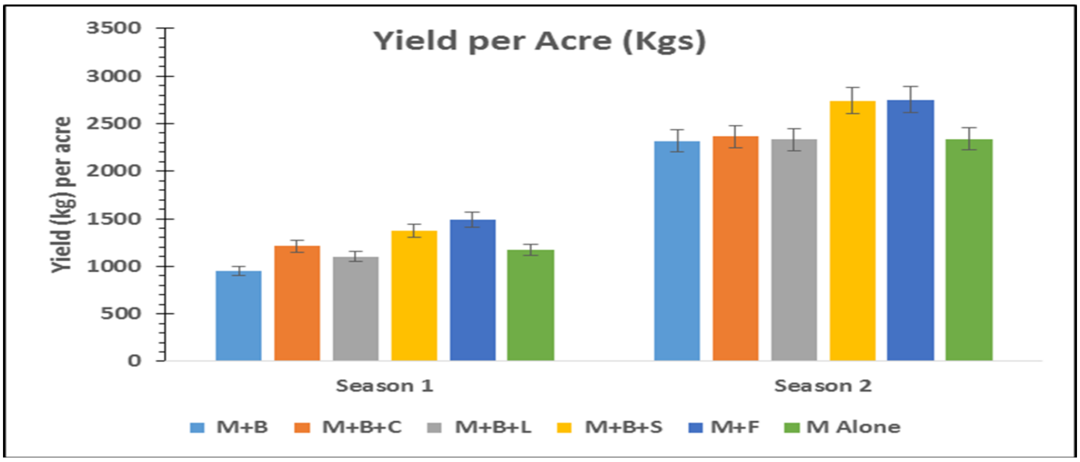

Fig. 3. Effect of intercropping maize and banana with agroforestry tree species on grain yield of maize per acre during the first and second seasons. Error bars indicate the SE at p≤0.05

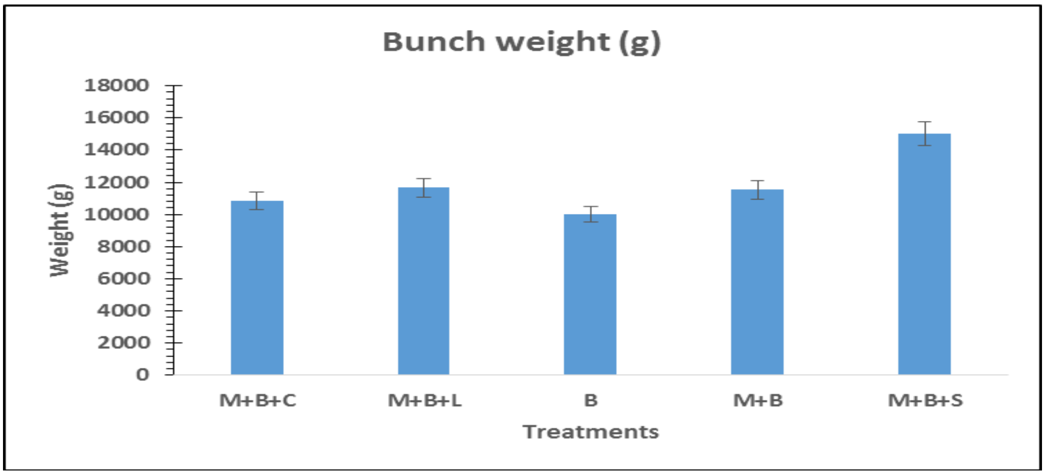

Fig. 4. Effect of intercropping maize and banana with agroforestry tree species on the bunch weight (g) of bananas at the harvest. Error bars indicate the SE at p≤0.05

3.7 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Banana Finger Length

Significant differences (p≤0.05) were observed on the banana finger length in MBS treatment in comparison to the other treatments (Fig. 5). Banana crops under MBS treatments produced significantly longest finger length of 20 cm while the B treatment had the shortest at 17 cm. Intercropping of banana crops with agroforestry trees produced longer fingers of bananas as compared to monocropped bananas.

3.8 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on the Number of Hands and Fingers Per Bunch of Banana

There were no significant difference in between the numbers of hands per bunch of the banana plants among the treatments (Fig. 6). The number of fingers per bunch showed significant differences (p≤0.05) where the highest was recorded on the MBS at 105 fingers while the lowest was recorded on the intercrop of MB and in the MBC at 84 fingers respectively (Fig. 6).

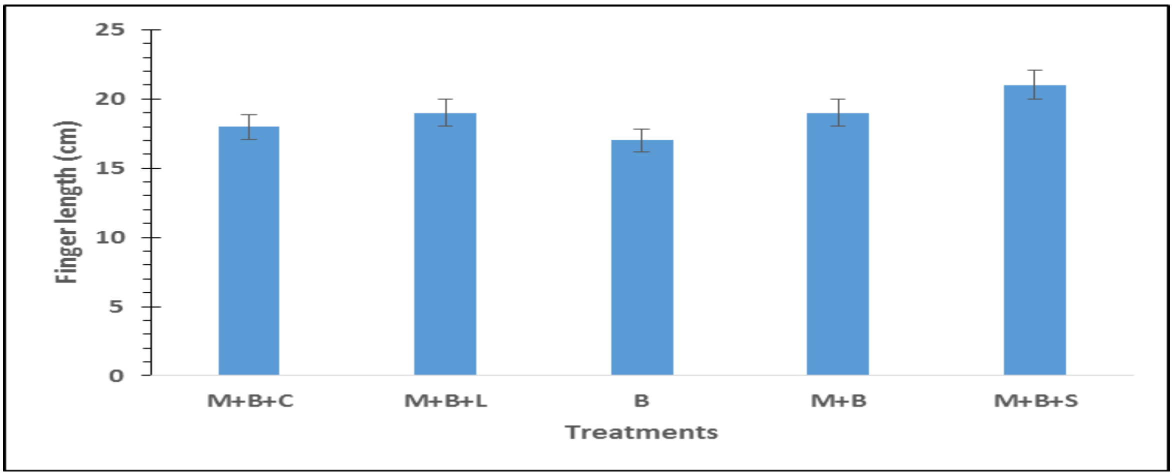

Fig. 5. Effect of intercropping maize and banana with agroforestry tree species on the finger length (cm) of bananas at harvest. Error bars indicate the SE at p≤0.05

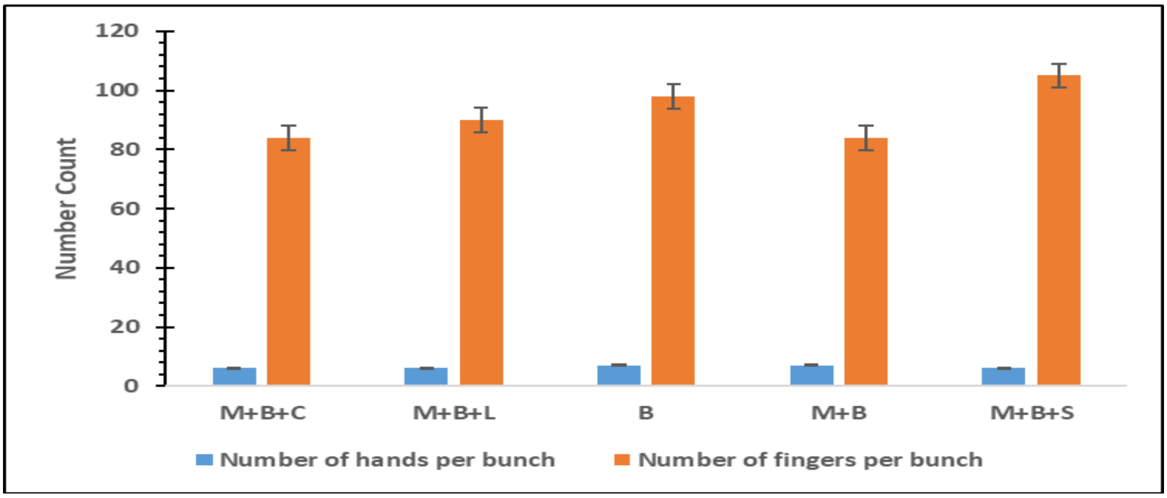

Fig. 6. Effect of intercropping maize and banana with agroforestry tree species on the number of hands per bunch and number of fingers per bunch of bananas at harvest. Error bars indicate the SE at p≤0.05

4. DISCUSSION

4.1 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Maize and Banana Total Chlorophyll Content

Total chlorophyll content showed significant differences among treatments during the study period for maize and for bananas at 199 DAT in season one and 416 DAT in the second season. MBS recorded the highest chlorophyll content than all the treatments in both maize and bananas. The maize under MBS and MF recorded minimal differences in chlorophyll content. The study outcomes are in agreement with those of [13] who found increased sweet basil chlorophyll in the intercrop with aromatic tree plants. However, the current findings of this study contradicts the earlier findings by [14] who reported reduced total chlorophyll content on maize in Trans Nzoia, Kenya. Since most smallholder farmers have limited access to mineral fertilizers and the negative environmental effects of the mineral fertilizer, *Sesbania sesban* may be a remedy to such farmers. Therefore, *Sesbania sesban* trees may have significant effect on the maize chlorophyll content and can be recommended to farmers who fail to afford the chemical fertilizers. The increased chlorophyll content recorded under MBS treatments may be attributed to the high amount of nitrogen added to the study soils through nitrogen fixation and decomposition of pruned biomass of the tree twigs and leaves [30]. The increased transpiration rate also increased the mineral nutrient uptake by the maize and banana crops. The decomposing prunings added magnesium, calcium and phosphorus which are also key elements in the chlorophyll formation.

4.2 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Banana Total Chlorophyll Content

The banana total chlorophyll content showed significant differences at 199 and 416 DAP in all treatments. The highest total chlorophyll content were reported under MBS treatments. The increased chlorophyll content under MBS treatments could be attributed to the faster decomposition of the *Sesbania sesban* plant materials that added more nutrients into the soil. The findings may also be attributed to the nutrient partitioning between the sesbania trees and the banana plants as the sesbania trees could have developed deep roots to utilize nutrients from the deep surfaces reducing nutrient competition with the banana crops. Since nitrogen is a component for chlorophyll synthesis, being made readily available increases the chlorophyll content. The findings are in agreement with those of [12] who reported high chlorophyll content in maize under maize-cowpeas-sweet basil intercrop. The results in *Sesbania sesban* can be attributed to its efficiency in the fixing of the nitrogen and the quality of the chemical composition of prunings added to the soil [30]. Similar findings were reported [13] in sweet basil in the intercropped with aromatic tree plants.

4.3 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Maize Yield

The number of maize cobs and maize yield per acre under the MBS and in the MF treatments recorded significant differences. Higher number of maize cobs recorded in the *Sesbania sesban* agroforestry intercrop was possibly due to improved nitrogen fixed by the nitrogen fixing plants and the decomposition of the tree prunings. Furthermore, the high amount of moisture within the MBS treatment could be the cause of increased yield as water availability to the plant is regarded as a key factor to crop productivity. The higher yields could also be attributed to higher nitrogen and phosphorus nutrients in the soils that were added through nitrogen fixation, mineralization and decomposition of the tree prunings [30]. The lower number of maize cobs in the monocropped maize without fertilizer and in banana maize intercrop could be due to minimal amount of nitrogen and phosphorus in the soils occasioned by little nutrient recycling. Phosphorus paucity constrained sink meristematic activities resulting to reduced photo-assimilate processing. The low concentration of root nitrogen content is an indicator of reduced uptake thus reduced grain filling and maturity. The results are in line with [17]; [19]; [20]; [30] and [31] who in their findings reported that, the cereal-legume intercrop or with agroforestry trees resulted to increased harvest.

Significant differences on the maize yield related parameters was only observed in the number of maize plants with cobs during the second season under MBS. The increase in number of maize plants with cobs and total biomass observed under intercropping can be attributed to increased nutrient supply through nitrogen fixation and as a result of twig and pruning decomposition. Generally, there were fewer number of rotten maize cobs under agroforestry treatments which could be attributed to the fact that trees acting as windbreakers which enabled plants to remain upright hence could not retain much moisture thus reducing rotting. The high productivity of maize in terms of fewer rotten maize cobs, high number of maize plants with cobs and high total biomass could also be due to the lower incidences of pests and diseases to maize under agroforestry systems [31]. The findings are in tandem with those of [31] and [34] who reported higher yields of maize and bananas under the intercrop with *Gliricidia sepium* and legume fallows.

4.4 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Banana Yield

The banana yield showed significant differences in the MBS treatment. MBS recorded significantly heavier bunch weight, longer fingers and number of fingers per bunch. The number of hands per bunch showed no significant differences in all the treatments. The yield parameters of bunch weight, finger length and number of fingers per bunch registered under bananas intercropped with *Sesbania sesban* might have been due to the increased nitrogen nutrient uptake resulting from the nitrogen fixation and the biomass added through the leafy biomass decomposition that added humus to soils. The decomposition of the agroforestry tree cuttings may have significantly influenced nitrogen, phosphorus, potassium, calcium and magnesium uptake by banana plants. Phosphorus could have led to increased meristematic tissues, increased photosynthetic rates, banana fruit filling and elongation of the banana fingers. The increased banana yield under agroforestry trees may be due to reduced disease and pests incidence on bananas and increased fertility status due to biomass addition from leguminous plants. The findings concurs with the previous results of [17]; [31] and [39].

5. CONCLUSION

The agroforestry trees affected the physiological aspects of the maize and banana plants through increased total chlorophyll content. *Sesbania sesban* increased total chlorophyll content in both maize and banana plants in comparison to other agroforestry trees. Agroforestry trees with intense ability to fix nitrogen and recycling of other essential macronutrients may lead to enhanced chlorophyll synthesis.

The intercrop of maize, bananas and *Sesbania sesban* trees resulted to higher yields, higher biomass, higher number of maize plants with cobs and fewer number of maize with rotten cobs. The maize and banana plants intercropped with *Sesbania sesban* trees had the highest growth rates, physiological, biochemical and yield parameters.

6. RECOMMENDATIONS

Higher maize and banana growth, biochemical, physiological and yield responses were recorded under *Sesbania sesban* tree species treatment. Therefore, *Sesbania sesban* can be recommended for intercropping with maize and banana for sustainable crop plant height, stem diameter, higher nutrient uptake, increased gas exchange, higher total chlorophyll and ultimately higher yields to farmers.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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