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Growth and Gas Exchange Responses of Maize and Banana Plants in an Intercrop with Agroforestry Tree Species in Vihiga County, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author SDW designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors SDW, MMD, SAP and OGD reviewed the study design and all drafts of the manuscript. Author SDW managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Agroforestry trees have been reported to improve soil fertility through nitrogen fixation, coupled with leaves and twig decomposition. High human population pressure in Vihiga County has led to reduced land area under farming. This has resulted into increased demand for food and consequently forced smallholder farmers in the region to carry out poor farming practices such as continuous cultivation and clearing of trees to avail more land for crop production. The poor farming practices have occasioned severe land degradation, climate change and reduced farm productivity. However, it is not known how intercropping maize and banana with *Sesbania sesban*, C*alliandra calothyrsus* and *Leucaena diversifolia* impacts on the growth and gas exchange parameters of maize and banana. The objective of this study was to determine the effect of intercropping agroforestry tree species with maize and banana on maize and banana height, leaf area, number of leaves, stem diameter, intercellular Carbon (IV) oxide concentration, transpiration rate and net

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photosynthesis in Vihiga County. The study was conducted at Maseno university farm located in Vihiga County in Kenya. The Williams varieties of banana of the same age were obtained from KALRO-Thika. Seeds of selected agroforestry trees were obtained from KEFRI – Muguga, planted in a seedbed and the seedlings raised in nurseries before being transplanted in the study plots. Hybrid maize seed (H513) was purchased from an agrovet. Banana holes were dug 2x2 feet, 20 Kg of decomposed cow dung manure + 20 Kg of top soil + 200g of NPK fertilizer added in each banana hole before planting. A Randomized Complete Block Design (RCBD) with 3 replications was used with seven treatment levels of unfertilized Maize (M), Banana (B), Maize + Banana + Calliandra (MBC), Maize+ Banana+ Leucaena (MBL), Maize+ Banana+ Sesbania (MBS), Maize + Banana (MB) and Fertilized Maize (MF). Maize was planted at 0.75 m inter row by 0.3 m spacing. Fifteen (15) tagged maize and four (4) banana plants in each plot were sampled for measurement of height, number of green leaves, leaf area, stem diameter, intercellular Carbon (IV) oxide concentration, transpiration rate and net photosynthetic rate. The data was subjected to Analysis of Variance using Genstat statistical package version 15.2. Means were separated using Fischers' protected LSD test at 95% confidence level. The MBS treatment showed higher growth in terms of height, leaf area, number of leaves and stem diameter throughout the study period. Increased growth seen under fertilized maize was not significantly different from those under MBS. Gas exchange responses had no significant differences ($p \leq 0.05$) among most treatments. However, agroforestry tree species had shown higher intercellular Carbon (IV) oxide concentration, transpiration rates and net photosynthesis of maize and banana plants. *Sesbania sesban* reported maximum intercellular Carbon (IV) oxide concentration, transpiration rates and net photosynthesis as compared to those treatments without agroforestry trees. Therefore, incorporating nitrogen-fixing trees in farming could have a positive impact on growth, increased carbon (IV) oxide intake, transpiration rates and net photosynthetic rate. *Sesbania sesban* promoted growth and recorded higher gas exchange parameters of maize and banana. These findings may be used to advice smallholder farmers of Vihiga County on the best intercropping system and agroforestry tree species to adopt for maximum maize and banana yield.

Keywords: Sesbania sesban; Calliandra calothyrsus; Leucaena diversifolia; agroforestry; intercropping; Vihiga; Kenya; intercellular Carbon (IV) oxide concentration; net photosynthesis; transpiration rate.

1. INTRODUCTION

Climate plays a main role in influencing agricultural output by supplying the necessary inputs such as solar radiation, temperature and water required for plant growth. Conway [1], noted that climate change caused by deforestation has negative impact on food security and agricultural production. Deforestation is brought about by clearing of trees to bring more land to crop production. Therefore population pressure in high agricultural potential areas of Western Kenya such as Vihiga County has increased demand on food production, forcing smallholder farmers to practice poor methods of farming such as continuous cultivation, limited crop rotation and clearing large areas of natural forests [2]. Vihiga county is one of the most densely populated counties in the country with a population density of more than 1046 persons per km^2 [3]. This high population coupled with declining food production leads to poor farming practices, more so clearing trees to avail more land for crop production. This calls for a farming system that could incorporate trees with maize and banana crops on the same piece of land. Simultaneous tree-crop intercropping has earlier been reported to improve yields through enhancement of resource partitioning and facilitation [4]. The practice may also enhance the forest cover and in the process mitigate climate change as the plants will sequester more carbon from the atmosphere and also promote mineralization of soil organic matter. However, there is insufficient information on the effect of intercropping trees on the net photosynthetic rates, leaf transpiration rate and intercellular Carbon (IV) oxide concentration of maize and banana in Vihiga County which are determining factors for yield production. Therefore, adoption of sustainable land management technologies such as agroforestry which increases food production without depleting soil and water resources [5], restoring soil fertility [6] and increasing resilience of farming systems to mitigate climate change [7] is being promoted in Vihiga county in Kenya. Scherr and Sthapit [8] report on the mitigation of global climate change recommended the use of perennial trees in capturing carbon from the atmosphere as compared to the common bean legume which is seasonal. Maize and bananas are one of the essential nutrient suppliers in our daily diets; however, their production has been declining over the last decade mainly due to depleted soils, lack of appropriate farming practices and inputs as most small holder farmers who are the main producers of the crops lack finances to purchase high priced fertilizer inputs [9].

Studies by Hans Sjogren [10] on improved fallows with *Sesbania sesban* planted along the hedgerow reported improved soil fertility and maize yields in Western Kenya. However, this research could not establish the effect of *Sesbania sesban* on the growth and gas exchange responses. According to Palm et al. [11] some agroforestry tree species such as *Tithonia diversifolia*, *Senna spectabilis*, *Sesbania sesban* and *Calliandra calothyrus* planted along farm boundaries had proven beneficial to soil nutrients and improving maize production in Eastern and Western Kenya. Smallholder farmers in Vihiga County have not yet fully adopted *Leucaena diversifolia*, *Sesbania sesban* and *Calliandra calothyrus* in their farms due to inadequate information on their effects on the growth and gas exchange responses of maize and banana crops in an intercrop system. Most of the intercropping studies from previous studies have focused majorly on the increase of the nutrients in the soil. Intercropping trees with alfalfa has also shown increased soil N content and fertility resulting in an increase in intercropped crops' stem diameter [12,13]. Prasad et al. [14] proposed that changes in tree density of *Leucaena diversifolia* based agroforestry increased stem diameter and increased yield of cowpea compared to that of the sole cropped Cowpea (*Vigna unguiculata*) in Southern India. Nevertheless, it is not known whether similar results of increased stem diameter, leaf area, number of green leaves and plant height will be obtained when these agroforestry tree species are used with maize and banana intercrop in Vihiga County. Ashraf et al. [15] reported that tree heights of sweet basil were significantly increased under intercropping with aromatic tree plants. It had earlier been reported that competition for soil moisture reduces stem diameter, plant height and yield in maize in agroforestry systems compared to sole crops [16]. Emechebe [17] concluded that any difference in plant height between intercropping and monoculture would indicate a competition for growth factors during the vegetative development of the crop. The performance of alley lemongrass, with *Sesbania* prunings has resulted to significant increase in the plant height [18]. Despite these findings, there is limited information on how *Sesbania sesban*, *Calliandra callothyrsus* and *Leucaena diversifolia* agroforestry trees affect plant height of maize and bananas in Vihiga County. Iderawumi [19] observed that the number of leaves in maize and cowpeas intercrop increased compared to sole crops. In different findings by Amos et al. [20] highest vegetative growth was reported when intercropped with maize. *Sesbania sesban* fallow has been reported to increase the soil-water storage in the soil profile and drainage below the maximum crop root zone compared with conventionally tilled non-fertilized maize [21]. High yields after *Sesbania sesban* improved fallows, for example, have been recorded and mainly attributed to increased soil inorganic nitrogen generated during decomposition and mineralization of N-rich organic residues. Studies by Hans Sjogren [10] on improved fallows with *Sesbania sesban* planted along the hedgerow reported improved soil fertility and maize yields in Western Kenya. Intercropping maize with cowpea has been reported to increase light penetration in intercrops, reduces water evaporation and improves soil moisture conservation compared with sole-cropped maize [22].

There is need for studies to establish how *Sesbania sesban*, *Calliandra calothyrsus* and *Leucaena diversifolia* will impact on the growth and gas exchange responses of maize and banana intercrop in Vihiga County. There is need to adopt agroforestry tree species which improve nutrient accumulatin in the soils. However, intercropping systems involving selected agroforestry trees with maize and banana within Vihiga County have not been introduced. Intercellular Carbon (IV) oxide concentration and transpiration rate of maize have previously been reported to be affected by different agroforestry tree species: for instance, greater intercellular Carbon (IV) oxide concentration and transpiration rate have earlier been reported in *Paulownia fortune* than in *Grevellia robusta* and *Acacia* acuminata maize intercrops [23]. This is because the *Paulownia fortunei* is known to enhance soil stabilization, nutrient restoration and resource facilitation as compared to *Grevellia robusta* and *Acacia acuminate.* Sanjeev [24] found that transpiration rate was lower in garlic intercropped with quava, plum and poplar compared to the sole cropped garlic. Chaves et al. [25] reported that water is essential for photosynthesis and drought is an environmental factor that decreases photosynthesis. The decrease in photosynthesis is a consequence of limitation of CO_2 diffusion into the leaf resulting from decreased stomatal resistance to gaseous diffusion associated with stomatal closure to conserve water. This study sought to give an insight into the potential intercrop system and agroforestry tree species to smallholder farmers and other interested stakeholders to promote production of maize and bananas. There is need to select trees with desirable qualities that will be compatible with food crops under different agroforestry systems [26]. This study aims at establishing the effects of intercropping maize and banana with agroforestry tree species on maize and banana stem height, stem diameter, number of green leaves, leaf area, intercellular carbon (IV) Oxide concentration, transpiration rate and net photosynthetic rate.

2. MATERIALS AND METHODS

2.1 Site Description

The experiments were conducted for two consecutive seasons from August 2018 to September 2019 at Vihiga County (00^{o} 00'15.5''S; 034^{o} 35'53.1''E; 1522 meters above sea level) in Western Kenya. The soils had low N, P, K, Ca and Mg. The site receives an annual mean precipitation of 1750 mm with bimodal pattern of distribution, with long rains from March to July and short rains from August to November. The mean temperature of the study site was 28.7 degrees Celsius with a relative humidity of 40%. Preliminary soil chemical characteristics of the study site were determined at the beginning of the experiment. The soils were acidic with a low mean pH of 4.65 and high exchangeable aluminium (III) ions.

2.2 Experimental Design and Treatment

The experiment was laid out at Maseno University farm located in Vihiga County in a Randomized Complete Block Design (RCBD) with seven treatments i.e. unfertilized Maize (M), Banana (B), Maize + Banana + Calliandra (MBC), Maize+ Banana+ Leucaena (MBL), Maize+ Banana+ Sesbania (MBS), Maize + Banana (MB), Fertilized Maize (MF). The treatments were replicated three times. Williams banana varieties of the same age were obtained from KALRO-Thika and Hybrid maize seed H513 was purchased from an agrovet. Seeds of agroforestry trees were obtained from KEFRI-Muguga sown in seedbed and later transplanted in the nursery before being transplanted in the experimental plots at a spacing of 0.5m by 3m.

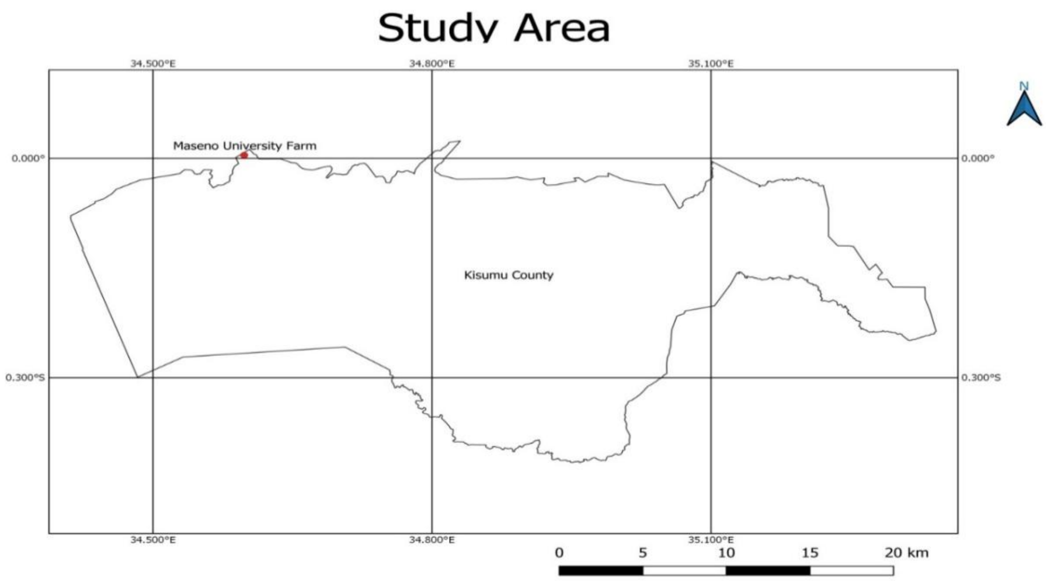

Fig. 1. Map showing the Vihiga study site at Maseno University farm. Source, Google maps

Plot sizes measured 9m by 12 m, banana holes were dug 2x2 feet, 20 kg of decomposed cow dung manure + 20 kg of top soil + 200g of NPK (N=14%, P=29%,K=6%, S=4%, Zn=0.1%, Cao=4%, B=0.1% and MgO= 1%) fertilizer was compounded in each banana hole before planting the banana. In agroforestry plots, the banana spacing was 3m by 3m, 3m by 2.5m in pure banana, , 6m by 2.5m in maize and banana, 0.75m by 30cm in maize and 2 rows banana x 4 within row in maize + banana+Agroforestry trees. Fully grown agroforestry trees were regularly pruned and the prunings applied in the same plots every fourteen days prior to data collection on 28 day intervals so as to give sufficient time for decomposition of twig and leaf biomass prunings.

2.3 Determination of Plant Growth Parameters

2.3.1 Determination of maize and banana plant height

The heights of four banana and fifteen maize plants were measured in centimeters (cm) using a meter rule from the stem base or soil surface to shoot apex after every two weeks. Plant heights were determined from 28 Days After Planting (DAP) until the maize plants attained physiological maturity.

Banana plants were measured at 143 Days After Transplanting (DAT) for 1st season and 360 DAT for 2nd season. All measurements were taken at an interval of 28 days following procedures by the International Board for Plant Genetic Resources [27]. The mean height was worked out and recorded.

2.3.2 Determination of number of green leaves per plant

The leaf numbers of four banana and fifteen maize plants were determined by counting fully expanded leaves 28 Days After planting (DAP) until the maize plants attained physiological maturity.

Banana plants were measured at 143 Days After Transplanting (DAT) for 1st season and 360 DAT for 2nd season. The measurements were taken at intervals of 28 days following procedure by the International Board for Plant Genetic Resources [27]. The leaf numbers per selected plant in each plot were counted and mean number worked out.

2.3.3 Determination of stem diameter

The stem diameter was determined from four banana and fifteen maize plants per treatment and per replication after thinning with a vernier caliper at 28 Days After Planting (DAP) maize. The measurements were taken at an interval of 28 days until physiological maturity.

Banana plants were measured at143 Days after transplanting (DAT) for 1st season and 360 DAT for 2nd season. The measurements were taken at intervals of 28 days following procedure by International Board for Plant Genetic Resources [27].

2.3.4 Determination of leaf area

Leaf width and length were measured using a 150 centimeter tape measure. Leaf length was measured along the leaf blade and leaf width at the broadest point of the third youngest leaf from the four banana and fifteen maize plants in each plot. Leaf area determination measurements began at 28 Days After Planting (DAP) until the maize plants attained physiological maturity. Leaflet area was then calculated as a product of length and width according to the formula of Maddoni and Otegui, [28] for maize as shown below.

$$LA = k (L \times W)$$

Where - LA = Leaflet area;
L = Length of the leaflet from base to the tip of a leaf;
W = Width of the leaflet from the widest point of a leaf; and
k= k-coefficient constant for maize which was 0.75

Banana plants were measured at 143 DAT for 1st season and 360 DAT for 2nd season following the procedure by the International Board for Plant Genetic Resources [27]. Leaflet area was then calculated as a product of length and width according to the formula of Musa et al. [29] as shown below;

$$LA = k (L \times W)$$

Where - LA = Leaflet area;
L = Length of the leaflet from base to the tip of a leaf;
W = Width of the leaflet from the widest point of a leaf; and
k= k-coefficient constant for banana was 0.5

2.4 Determination of Gas Exchange Measurements

The TPS-200 Photosynthesis System was used to measure intercellular Carbon (IV) oxide concentration, net photosynthetic rate and transpiration rate. The measurements were determined from an area of 2.5 cm^2 of the fully expanded sun exposed third youngest leaf from 15 maize and 4 banana tagged plants in each treatment and replication. This data was collected in the morning between 10.00 - 12.00 hours to avoid high afternoon temperatures [30]. During measurement the sensor head was gently held up and the clamp was opened to secure the leaf by ensuring the aperture was in the middle of the leaf for 45 seconds to allow stabilization of the readings before the clamp was opened to release the leaf. The procedure was repeated for all sampled plants in each treatment and in all replications after every two weeks. Measurements commenced 28 days after planting (DAP) for maize and readings taken consistently after every two weeks throughout the study period. Data on banana plants commenced 143 day after transplanting (DAT) during season 1 and 360 DAT during season 2 and recordings were done after 28 days during the study period.

2.5 Data Analysis

The data collected was subjected to Analysis of Variance (ANOVA) using the GenStat statistical package version 15.2. Means were separated using Fischers' protected LSD test at 95% confidence level.

3. RESULTS

3.1 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Maize Growth Parameters

3.1.1 Effect of intercropping maize and banana with agroforestry tree species on maize plant height

There was increase in maize plant height with increase in number of days after planting (DAP). The maize intercropped with *Sesbania sesban* and bananas (MBS) recorded significantly taller plants than Maize + Banana + Leucaena (MBL) and Maize + Banana + Calliandra (MBC) during the 1st season at 84 DAP (Table 1). However, MBS was not significantly taller than MF, M and MB treatments.

In the 2nd season, MBS recorded tallest maize plants which was not significantly different from the rest of the treatments at 84 DAP ($p \leq 0.05$) (Table 2). The maize under agroforestry trees species recorded taller maize plants in comparison to other treatments.

3.1.2 Effect of intercropping maize and banana with agroforestry tree species on maize leaf area

There was an increasing trend in leaf area of maize with increase in number of days after planting (DAP). There was no significant difference in maize leaf area among the treatments for both seasons ($p \leq 0.05$) (Tables 1 and 2). However, higher leaf area was recorded under *Sesbania sesban* treatments (MBS) and fertilized maize treatments both at 84 DAP during season 1.

During the 2nd season, the largest leaf area was recorded under MBS and MF. The least leaf area was registered under unfertilized maize during the two seasons. However, it was not significantly different from those treatments that registered largest leaf areas.

3.1.3 Effect of intercropping maize and banana with agroforestry tree species on maize leaf number

The number of leaves increased with increase in number of days after planting (DAP). The highest number of leaves was observed under MBS at 84 DAP in 1st season. However, MBS was not significantly higher than the other treatments ($p \leq 0.05$) (Table 1).

A similar trend was observed in the 2nd season; MBS, MBL, MF and M recorded higher numbers of leaves (Table 2). There was no significant effect of the treatments on the number of leaves of maize plants during the study.

3.1.4 Effect of intercropping maize and banana with agroforestry tree species on maize stem diameter

Maize stem diameter increased with increase in the number of days after planting (DAP). The largest stem diameters were recorded under MBL and MF treatments which were significantly different from MBC during 1st season (Table 1). However, MBL and MF were not significantly differently from MB, MBL, MBS and M. The maize under MBC treatment recorded the lowest maize stem diameters.

In the 2nd season, significantly larger stem diameters for maize were recorded under MBS and MF treatments (Table 2). However, they were not significantly different from the maize stem diameters under MBL and M ($p \le 0.05$). The lowest maize stem diameter was recorded under MBC treatments for both seasons.

Table 1. Effect of intercropping maize and banana with agroforestry tree species on maize growth during the first season

Parameter	Treatment	28 DAP	56 DAP	84 DAP
Height (cm)	M+B	30.6 b	42.9 ab	84.2 ab
	M+B+C	24.3 b	33.2 b	58.6 b
	M+B+L	29.2 b	37.3 ab	71.8 b
	M+B+S	42.8 a	56.6 a	133.4 a
	M+F	32.4 ab	46.1 ab	102.1 ab
	M Alone	31.7 ab	47.6 ab	99.0 ab
	LSD	**11.4**	**20.1**	**51.8**
Leaf Area (cm^2)	M+B	169.0 a	299.0 a	379.0 a
	M+B+C	197.0 a	340.0 a	394.0 a
	M+B+L	139.0 a	303.0 a	362.0 a
	M+B+S	159.0 a	282.0 a	422.0 a
	M+F	173.0 a	299.0 a	422.0 a
	M Alone	188.0 a	380.0 a	361.0 a
	LSD	**90.6**	**121.9**	**94.6**
Leaf Number	M+B	7.7 a	9.5 a	9.8 a
	M+B+C	7.8 a	9.2 a	10.0 a
	M+B+L	7.8 a	9.8 a	11.2 a
	M+B+S	6.8 a	8.3 a	12.0 a
	M+F	8.1 a	9.8 a	11.1 a
	M Alone	8.1 a	9.3 a	11.1 a
	LSD	**1.5**	**1.6**	**1.9**
Stem Diameter (cm)	M+B	1.0 ab	1.2 a	2.3 ab
	M+B+C	1.0 ab	1.1 a	2.1 b
	M+B+L	1.2 a	1.4 a	2.4 a
	M+B+S	0.8 b	1.0 a	2.2 ab
	M+F	1.1 ab	1.2 a	2.4 a
	M Alone	1.1 ab	1.2 a	2.2 ab
	LSD	**0.39**	**0.43**	**0.18**

Treatments with the same letter along the columns are not significantly different according to LSD at $p \le 0.05$; DAP = Days After Planting of maize

Table 2. Effect of intercropping maize and banana with agroforestry tree species on maize growth during the second season

Parameter	Treatment	28 DAP	56 DAP	84 DAP
Height (cm)	M+B	56.8 a	76.0 b	162.0 a
	M+B+C	73.4 a	140.0 ab	221.0 a
	M+B+L	92.9 a	130.0 ab	233.0 a
	M+B+S	85.5 a	162.0 a	240.0 a
	M+F	96.0 a	147.0 ab	232.0 a
	M Alone	66.9 a	116.0 ab	212.0 a
	LSD	**46.5**	**79.1**	**101.0**
Leaf Area (cm^2)	M+B	139.0 a	137.4 a	276.0 a
	M+B+C	119.0 a	151.8 a	268.0 a
	M+B+L	235.0 a	161.4 a	232.0 a
	M+B+S	225.0 a	124.3 a	284.0 a
	M+F	243.0 a	127.5 a	332.0 a
	M Alone	153.0 a	117.3 a	234.0 a
	LSD	**146.9**	**50.7**	**153.0**

Parameter	Treatment	28 DAP	56 DAP	84 DAP
Leaf Number	M+B	9.3 b	9.7 a	10.9 a
	M+B+C	10.3 ab	9.8 a	11.1 a
	M+B+L	10.3 ab	10.2 a	12.0 a
	M+B+S	11.3 a	11.3 a	12.1 a
	M+F	11.2 a	12.1 a	12.5 a
	M Alone	10.3 ab	10.1 a	11.6 a
	LSD	**1.3**	**3.3**	**3.1**
Stem Diameter (cm)	M+B	1.4 c	1.9 c	2.0 bc
	M+B+C	1.2 c	1.8 c	1.7 c
	M+B+L	1.4 c	2.0 bc	2.1 ab
	M+B+S	2.1 ab	2.3 ab	2.5 a
	M+F	2.2 a	2.4 ab	2.5a
	M Alone	1.5 bc	2.0 bc	2.3 ab
	LSD	**0.53**	**0.49**	**0.42**

Treatments with the same letter along the columns are not significantly different according to LSD at p≤0.05; DAP = Days After Planting of maize

3.2 Effect of Intercropping Maize and BananawithAgroforestry Tree Species on Banana Growth Parameters

3.2.1 Effect of intercropping maize and banana with agroforestry tree species on banana height

Banana height increased with increase in number of days after transplanting. During the 1st season the tallest banana plants were recorded under MBL treatment (Table 3). However, no significant differences were observed among the treatments at 199 DAT.

In the 2nd season MBS showed tallest banana plants at 416 DAT; however, it was not significantly different from the other treatments (Table 4). The least banana height was recorded under monocropped banana throughout the observation stages. Banana height under agroforestry tree species treatments recorded superior heights compared to the rest of the treatments.

3.2.2 Effect of intercropping maize and banana with agroforestry tree species on banana leaf area

Banana leaf area increased with increase in the number of days after transplanting (DAT). During the 1st season MBL treatment recorded the largest leaf areas of 4615 cm^2 which was however not significantly different from the rest of the treatments at 199 DAT (Table 3). Monocropped banana recorded the smallest leaf areas. Agroforestry tree species treatments recorded larger leaf areas than the monocropped banana and maize-banana treatments.

In the 2nd season MBS recorded the largest leaf areas at 416 DAT (Table 4). However, this was not significantly different from the rest of the treatments. Banana intercropped with agroforestry tree species had larger leaf areas than those without agroforestry tree intercrop.

3.2.3 Effect of intercropping maize and banana with agroforestry tree species on banana number of leaves

The number of green leaves increased with increase in number of days after transplanting (DAT). The highest number of green leaves was recorded under MBS and MBL at 199 DAT which was not significantly different from the rest of the treatments during 1st season (Table 3). Monocropped banana recorded the lowest number of green leaves. Bananas under agroforestry tree treatments recorded higher number of green leaves when compared to MB and B. Similarly, during the 2nd season, agroforestry tree treatments resulted into increased number of leaves, with MBS having the highest number of leaves at 416 DAT (Table 4). However, it was not significantly different from the rest of the treatments apart from B at 416 DAT.

3.2.4 Effect of intercropping agroforestry tree species on banana stem diameter

Banana stem diameter increased with an increase in the number of days after transplanting (DAT). In the 1st season the MBS treatment recorded the largest stem diameters which was not significantly different from the rest of the treatments at 199 DAT (Table 3). The banana monocrop reported the least stem diameters at the 199 DAT. During the 2nd season banana plants under MBS recorded large stem diameters at 416 DAT (Table 4). This was however not significantly different from the rest of the treatments except at 360 DAT under monocropped treatment which also reported the least stem diameters.

Table 3. Effect of intercropping maize and banana with agroforestry tree species on banana growth during the first season

Parameter	Treatment	143 DAT	171 DAT	199 DAT
Height (cm)	B	89.2 a	102.2 ab	117.6 a
	M+B	89.8 a	103.7 ab	113.3 a
	M+B+C	88.3 a	100.6 b	112 a
	M+B+L	88.5 a	109.7 ab	129.4 a
	M+B+S	93.1 a	120.3 a	128.2 a
	LSD	**23.27**	**19.03**	**35.71**
Leaf Area (cm^2)	B	1451 a	1842 a	2570 a
	M+B	1578 a	2181 a	3846 a
	M+B+C	1581 a	1751 a	2782 a
	M+B+L	1393 a	2035 a	4615 a
	M+B+S	1801 a	2206 a	3704 a
	LSD	**480.2**	**645.7**	**1429.1**
Number of Leaves	B	6.72 a	7.36 b	7.54 a
	M+B	5.65 b	7.23 b	7.86 a
	M+B+C	6.66 ab	7.88 b	7.91 a
	M+B+L	7.05 a	7.55 b	9.47 a
	M+B+S	8.68 a	8.86 a	9.23 a
	LSD	**2.895**	**1.555**	**5.62**
Stem Diameter (cm)	B	7.13 a	7.53 a	7.77 a
	M+B	7.43 a	7.87 a	8.03 a
	M+B+C	7.23 a	7.63 a	8.13 a
	M+B+L	7.33 a	7.77 a	8.07 a
	M+B+S	7.57 a	7.93 a	8.17 a
	LSD	**1.133**	**0.99**	**1.204**

Treatments with the same letter along the columns are not significantly different according to LSD at $p \leq 0.05$; DAT = Days After Transplanting of bananas

Table 4. Effect of intercropping maize and banana with agroforestry tree species on banana growth during the second season

Parameter	Treatment	360 DAT	388 DAT	416 DAT
Height (cm)	B	146.0 a	147.0 a	155.0 a
	M+B	149.0 a	161.0 a	178.0 a
	M+B+C	165.0 a	173.0 a	189.0 a
	M+B+L	176.0 a	182.0 a	193.0 a
	M+B+S	186.0 a	208.0 a	219.0 a
	LSD	**123.4**	**122.0**	**116.4**
Leaf Area (cm^2)	B	2500.0 a	2550.0 a	2923.0 a
	M+B	3061.0 a	3249.0 a	3667.0 a
	M+B+C	2584.0 a	3033.0 a	3702.0 a
	M+B+L	2602.0 a	2843.0 a	2765.0 a
	M+B+S	3241.0 a	3761.0 a	3481.0 a
	LSD	**2096.9**	**2671.1**	**2629.9**
Number of Leaves	B	6.8 ab	7.4 a	6.6 b

Parameter	Treatment	360 DAT	388 DAT	416 DAT
	M+B	5.8 b	7.2 a	7.6 ab
	M+B+C	6.8 ab	7.3 a	8.1 ab
	M+B+L	7.1 ab	7.9 a	6.8 ab
	M+B+S	9.6 a	9.0 a	10.3 a
	LSD	**2.9**	**3.5**	**3.6**
Stem Diameter (cm)	B	7.8 b	8.6 a	8.8 a
	M+B	8.0 ab	8.6 a	9.0 a
	M+B+C	8.2 ab	8.7 a	9.1 a
	M+B+L	8.2 ab	8.5 a	8.5 a
	M+B+S	9.3 a	9.9 a	10.0 a
	LSD	**1.3**	**2.3**	**2.2**

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

3.3 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Maize Gas Exchange Parameters

3.3.1 Effect of intercropping maize and banana with agroforestry tree species on the maize intercellular carbon (IV) oxide concentration (µmol CO_2 mol^{-1})

There was no consistent trend in intercellular carbon (IV) oxide concentration during the study period. Intercellular carbon (IV) oxide concentration among treatments showed significant differences only at the first observation stage of 28 days after planting during the first season (Table 5). No significant differences were recorded at 56 DAP and 84 DAP among the treatments. However, intercrop treatments with agroforestry tree species recorded the highest intercellular carbon (IV) oxide concentration with MBS recording higher intercellular carbon (IV) oxide concentration.

In the second season, significant differences were observed during the entire observation period (Table 6). MBS had significantly higher intercellular carbon (IV) oxide concentration at 84 DAP as compared to the other treatments. Maize treatments without agroforestry trees recorded lower intercellular carbon (IV) oxide concentration compared to the ones with agroforestry trees.

3.3.2 Effectofintercropping maize and banana with agroforestry tree species on maize transpiration rate (mmol H_2O m^{-2} s^{-1})

There were no significant differences among treatments on transpiration rates of maize crops during the 1st season in all observation stages (Table 5). Maize plants under agroforestry tree intercrop had higher transpiration rates, with MBS recording high rates compared to other treatments. Monocropped unfertilized maize showed low transpiration rates.

During the 2nd season, significant differences were observed at 84 DAP (Table 6). MBS treatment consistently recorded high transpiration rate throughout the observation stage among all treatments. In the same way as the 1st season, higher transpiration rates were recorded during 56 and 84 DAP under MBS. Maize plants planted in agroforestry trees showed high transpiration rates for the two seasons during all observation stages compared to other treatments. Monocropped maize plants had the lowest transpiration rates during the two seasons. The highest transpiration rate was recorded under MBS treatments for both seasons. However, transpiration rate values tremendously reduced in the second season, especially at the late stages of development. Transpiration rates under MBC treatments recorded the lowest rates among the agroforestry treatments during the entire period of study

3.3.3 Effect of intercropping maize and banana with agroforestry tree species on maize net photosynthetic rate (µmol CO_2 m^{-2} s^{-1})

The highest net photosynthesis was shown by MBS treatment at 84 DAP but it was not significantly different from other treatments at the same observation stage during the first stage (Table 5). The highest net photosynthesis rate was reported under maize in agroforestry tree treatments and the lowest under monocropped maize treatment. Among all the treatments, maize under *Sesbania sesban* tree species recorded higher net photosynthesis.

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

Parameters	Treatment	28 DAP	56 DAP	84 DAP
Intercellular CO_2 (µmol CO_2 m^{-2} s^{-1})	M+B	59.0 a	49.0 a	41.0 a
	M+B+C	31.0 b	31.0 a	47.0 a
	M+B+L	30.2 b	62.0 a	61.0 a
	M+B+S	32.4 ab	59.2 a	67.0 a
	M+F	28.8 b	41.0 a	49.0 a
	M Alone	33.2 ab	41.2 a	50.1 a
	LSD	**27.3**	**35.2**	**29.9**
Transpiration Rate (mmol H_2O m^{-2} s^{-1})	M+B	16.8 a	7.4 a	8.1 a
	M+B+C	13.1 a	7.1 a	7.3 a
	M+B+L	15.8 a	8.0 a	8.2 a
	M+B+S	16.9a	8.0 a	8.5 a
	M+F	11.9 a	7.2 a	6.5 a
	M Alone	12.7 a	6.5 a	7.8 a
	LSD	**6.7**	**2**	**3.1**
Net Photosynthesis (µmol CO_2 m^{-2} s^{-1})	M+B	16.4 a	3.2 b	39.0 a
	M+B+C	35.9 a	9.7 ab	36.0 a
	M+B+L	25.8 a	10.9 ab	39.0 a
	M+B+S	15.3 a	13.2 a	53.0 a
	M+F	14.3 a	5.1 b	36.0 a
	M Alone	15.1 a	9.2 ab	36.0 a
	LSD	**30.9**	**17.3**	**21.2**

Treatments with the same letter along the columns are not significantly different according to LSD at p≤0.05; DAP = Days After Planting of maize

Table 6. Effect of intercropping maize and banana with agroforestry tree species on maize gaseous exchange parameters during the second season

Parameters	Treatment	28 DAP	56 DAP	84 DAP
Intercellular CO_2 (µmol CO_2 m^{-2} s^{-1})	M+B	58.0 ab	23.6 b	14.6 b
	M+B+C	40.0 b	32.1 ab	28 b
	M+B+L	22.0 b	19.6 b	19.6 b
	M+B+S	73.0 a	55.2 a	57.2 a
	M+F	33.0 b	16.5 b	16.5 b
	M Alone	49.0 b	28.5 ab	14.2 b
	LSD	**61.6**	**45.5**	**43**
Transpiration Rate (mmol H_2O m^{-2} s^{-1})	M+B	4.1 b	4.0 a	0.3 f
	M+B+C	4.8 b	1.8 a	2.6 d
	M+B+L	7.6 b	2.2 a	3.6 c
	M+B+S	8.2 a	7.3 a	4.9 a
	M+F	4.9 b	5.3 a	4.3 b
	M Alone	3.6 b	1.6 a	1.4 e
	LSD	**5.2**	**8.9**	**0.3**
Net Photosynthesis **(**µmol CO_2 mol^{-1})	M+B	1.6 e	11.2 b	2.2 a
	M+B+C	3.8 c	9.7 ab	4.0 a
	M+B+L	5.2 b	10.9 ab	7.3 a
	M+B+S	5.9 a	13.2 a	5.7 a
	M+F	2.3 d	12.2 ab	5.3 a
	M Alone	0.6 f	11.1 b	3.7 a
	LSD	**5.9**	**8.7**	**8.9**

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

During the second season, significantly higher net photosynthesis was reported under MBS at 56 DAP which was not significantly different from that of MBL and MBC during the same observation stage (Table 6). Maize agroforestry tree treatments recorded highest net photosynthesis than those treatments without agroforestry trees during the study period. The lowest net photosynthetic rate was reported under unfertilized maize and in maize intercropped with bananas.

3.4 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Banana Gas Exchange Parameters

3.4.1 Effect of intercropping maize and banana with agroforestry tree species on banana intercellular Carbon (IV) oxide concentration (μmol CO_2 mol^{-1})

The banana intercellular Carbon (IV) oxide concentration was not significantly influenced by the treatments during the first and second season (Tables 7 and 8). Banana plants under agroforestry trees reported high intercellular Carbon (IV) oxide concentration followed by the maize banana intercrop and the least intercellular Carbon (IV) oxide concentration was reported under monocrop banana plants during the study period. Among agroforestry tree species treatments, bananas under *Sesbania sesban* treatments reported slightly higher intercellular Carbon (IV) oxide concentration at 171 DAT and 360 DAT for 1st and 2nd season respectively, though it was not significantly different from that reported under *Calliandra calothyrsus* and *Leucaena diversifolia* tree species treatments during the study period. The banana monocrop treatment showed the lowest intercellular Carbon (IV) oxide concentration throughout the study period.

3.4.2 Effect of intercropping maize and banana with agroforestry tree species on banana transpiration rates (mmol H_2O m^{-2} s^{-1})

Significant differences were observed on transpiration rates of bananas among the treatments during the first season with MBS showing the highest transpiration rates of 14.1 at 143 DAT (Table 7). However, it was not significantly different from MBL, MB and monocropped banana at 143 DAT and in all treatments at 171 DAT. Treatments with agroforestry trees recorded higher transpiration rates compared to those without agroforestry trees.

During the second season, significant differences were shown under MBS treatment throughout the observation stages (Table 8). The highest transpiration rate was registered in MBS with 13.4 at 360 DAT. High transpiration rates were reported under banana crops in agroforestry trees plots compared to monocropped bananas and banana intercropped with maize. Bananas planted under the *Leucaena diversifolia* and *Sesbania sesban* agroforestry tree species comparatively recorded slightly higher transpiration rates than the ones in *Calliandra carlothyrsus* tree species.

3.4.3 Effect of intercropping maize and banana with agroforestry tree species on banana net photosynthesis (μmol CO_2 mol^{-1})

There was no significant difference observed on the net photosynthetic rates of bananas among treatments during the first season (Table 7). MBL treatments registered highest net photosynthesis of 62.3 at 171 DAT which was not significantly different from the rest of the treatments. Banana plants under agroforestry tree treatments showed superior net photosynthetic rates than the monocropped and MB treatments.

Significantly, high differences were observed 388 DAT during the second season with net photosynthetic rate of 70 (Table 8). High net photosynthetic rates were reported under banana crops intercropped with agroforestry trees compared to monocropped bananas and banana maize intercrop. Maize intercropped with *Sesbania sesban* and *Leucaena diversifolia* consistently reported slightly higher net photosynthetic rates than the rest of the treatments during the study period. Sole bananas reported the least net photosynthetic rates.

Table 7. Effect of intercropping maize and banana with agroforestry tree species on gaseous exchange parameters of bananas during the first season

Parameters	Treatment	143 DAT	171 DAT	199 DAT
Intercellular CO_2 (μmol CO_2 m^{-2} s^{-1})	B	38.0 a	19.0 a	30.0 a
	M+B	25.0 a	30.0 a	73.0 a
	M+B+C	39.0 a	74.0 a	78.0 a
	M+B+L	49.0 a	42.0 a	70.0 a
	M+B+S	25.0 a	70.0 a	92.0 a
	LSD	**40.9**	**57.1**	**30.7**
Transpiration Rate (mmol H_2O m^{-2} s^{-1})	B	6.8 a	10.7 a	3.9 d
	M+B	9.8 ab	11.0 a	4.0 d
	M+B+C	12.7 a	10.6 a	4.7 c
	M+B+L	9.6 ab	12.5 a	5.3 b
	M+B+S	14.1 a	13.5 a	6.3 a
	LSD	**5.9**	**4.5**	**0.2**
Net Photosynthesis (μmol CO_2 mol^{-1})	B	10.5 a	14.9 a	15.4 a
	M+B	17.6 a	15.9 a	16.1a
	M+B+C	10.5 a	34.2 a	17.9 a
	M+B+L	22.1 a	62.3 a	24 a
	M+B+S	20.2 a	45.1 a	30.2 a
	LSD	**15.2**	**20.3**	**14.1**

Treatments with the same letter along the columns are not significantly different according to LSD at p≤0.05. DAT = Days After Transplanting of bananas

Table 8. Effect of intercropping maize and banana with agroforestry tree species on gaseous exchange parameters of bananas during the second season

Parameters	Treatment	360 DAT	388 DAT	416 DAT
Intercellular CO_2 (μmol CO_2 m^{-2} s^{-1})	B	23.0 a	41.0 a	19.0 a
	M+B	24.0 a	41.0 a	47.0 a
	M+B+C	45.0 a	42.0 a	41.0 a
	M+B+L	36.0 a	41.0 a	47.0 a
	M+B+S	55.0 a	49.0 a	51.0 a
	LSD	**33.4**	**11.2**	**32.1**
Transpiration Rate (mmol H_2O m^{-2} s^{-1})	B	9.9 c	5.1 b	3.9 d
	M+B	9.6 c	4.9 b	4.0 d
	M+B+C	11.8 b	4.9 b	4.7 c
	M+B+L	9.9 c	5.3 b	5.3 b
	M+B+S	13.4 a	7.4 a	6.3 a
	LSD	**0.5**	**0.8**	**0.2**
Net Photosynthesis (μmol CO_2 mol^{-1})	B	7.8 b	41.0 a	24.5 a
	M+B	9.6 b	45.0 a	45.1 a
	M+B+C	12.2 a	54.0 a	54.8 a
	M+B+L	7.8 b	70.0 a	46.3 a
	M+B+S	11.6 b	63.0 a	50.2 a
	LSD	**7.6**	**38.1**	**33**

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

4. DISCUSSION

4.1 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Maize Plant Growth Parameters

4.1.1 Effect of intercropping maize and banana with agroforestry tree species on maize plant height

Higher maize plant height was reported under maize in *Sesbania sesban* treatments as compared to other treatments during the two planting seasons. These results are in agreement with those of Ebeid et al. [18] who reported increased lemon grass height in the intercrop of Sesbania sesban tree species. The highest maize plant height under MBS treatments may be attributed to increased nutrients being availed by the nitrogen fixation and *Sesbania sesban* prunings which decomposed to provide the required nutrients. This could also be attributed to enhanced nutrient facilitation by the maize and the *Sesbania sesban* tree - plant interaction. *Sesbania sesban* trees were able to pump the nutrients from below the ground to avail them close to the surface for utilization by the maize crop. The lowest maize height under MBC treatments could be attributed to slow decomposition and release due to high levels of polyphenols which slows decomposition rate of the prunings. This reduced available nutrients in turn decreased the activities of the apical meristematic cells resulting to slow plant primary growth.

4.1.2 Effect of intercropping maize and banana with agroforestry tree species on maize plant leaf area

There were no significant differences observed in the leaf area of the maize plants in all treatments. However, highest leaf area was recorded under *Sesbania sesban* and fertilized maize treatments. The findings are in agreement with those of (Becham et al. 2018). The high leaf areas of maize intercropped with *Sesbania sesban* can be attributed to nutrient facilitation resulting from nitrogen fixation and leaf and twig decomposition of the *Sesbania sesban* prunings. The high leaf areas may also be due to more moisture within soils as the ground surface where evapotranspiration is reduced as the leafy *Sesbania sesban* and other intercrop plants provided mulching effect. *Sesbania sesban* is also known to increase soil-water storage in the soil profile [21]. Increased soil water therefore resulted into increased leaf area surface to promote the rate of cuticular transpiration and photosynthetic efficiency.

4.1.3 Effect of intercropping maize and banana with agroforestry tree species on number of green leaves of maize

Number of maize leaves did not show significant differences among treatments. More number of leaves were recorded in the MBL treatments which was second to fertilized maize. To the contrary, the MBS treatments recorded the least number of leaves in 1st season and in maize banana during 2nd season. These findings are in agreement with earlier findings of [19]. The highest number of leaves in fertilized maize was due to readily available nutrients that were released to the maize plants. The low number of leaves recorded in maize banana treatment during 2nd season could be attributed to depletion of nutrients as there was minimal nutrient recycling and nitrogen fixation as they lacked the nitrogen fixing trees.

4.1.4 Effect of intercropping maize and banana with agroforestry tree species on maize stem diameter

Significant differences were registered in stem diameter among treatments at 84 DAP. The largest stem diameter was recorded under *Sesbania sesban*, *Leucaena leucocephala* and in fertilized maize treatments respectively. The findings are in line with those of (Becham et al. 2018 and [16]. The large stem diameter reported under MBS and MBL may be attributed to the high inorganic nitrogen generated during decomposition and mineralization of N-rich organic residues. Additionally, the increase may also be due to the reduction in competition for soil moisture and resource partitioning that promoted photosynthetic efficiency which channeled photo-assimilates to the growth regions that resulted into stem growth. The high stem diameter registered in fertilized maize was due to fast release of available nutrients from the fertilizer. However, fertilizer application may not be easily accessible to most economically challenged smallholder farmers.

4.2 Effect of Intercropping Maize and Banana with Agroforestry Tree Species onBanana Plant Growth Parameters

4.2.1 Effect of intercropping maize and banana with agroforestry tree species on banana plant height

There were no significant differences in banana plant height among the treatments. The tallest banana plants were registered under *Leucaena leucocephala* in the 1st seasons and in the sesbania treatments in the 2nd seasons. The findings concur with those of Ashraf et al. [15] and Ebeid et al. [18]. Increased banana height in MBS and MBL may be attributed to the high amount of nitrogen that was fixed through their nitrogen fixing capacity and the high nutrient quality of their leaf and twig prunings that decomposed releasing the required nutrients for growth. The two agroforestry trees may also have promoted resources partitioning, facilitation processes and increased complementarity use of growth resources such as nitrogen, phosphorus, calcium and magnesium.

4.2.2 Effect of intercropping maize and banana with agroforestry tree species on banana plant leaf area

Banana leaf area did not show significant differences among all the treatments during the study period. MBS treatments showed largest leaf areas for both seasons and the least leaf area was reported in the sole banana crops. These findings are in agreement to the earlier findings of Ashraf et al. [15]. The large leaf areas in MBS treatments may be due to the high amount of nitrogen that was fixed through their efficient nitrogen fixing capacity and the high nutrient quality of their leaf and twig prunings that decomposed, thereby recycling the required nutrients for growth. The mulching and surface covering of the crops in the intercrop could have also facilitated reduction in soil surface evapotranspiration. This resulted in increased soil water which might have necessitated increased leaf size to enhance water loss through expanded leaf sizes. This adaptation could further result in increased surface area for light harvesting for primary productivity.

4.2.3 Effect of intercropping maize and banana with agroforestry tree species on banana number of green leaves

Significant differences were observed at 171 DAT and slightly at 360 and 416 DAT under MBS treatments. These results are in tandem with earlier findings of Iderawumi [19] who reported increased number of green leaves in maize and cowpeas intercrop. Similar results were also reported by Amos et al. [20] in maize-legume intercrop. The increased number of green leaves under the MBS treatments may be attributed to the increased nitrogen that was fixed by *Sesbania sesban* trees and the decomposition of leaf biomass from the prunings. There were slight changes in the number of green leaves in bananas and this may be attributed to the succulent nature of the banana pseudo stem which has high ability to store more water making it less susceptible to dangers to water shortages. This ensures reduced rate of leaf withering, thus most leaves are retained on the plant. The rate of new leaf development is also relatively low.

4.2.4 Effect of intercropping maize and banana with agroforestry tree species on banana stem diameter

Banana stem diameter did not show significant differences during the study period. Higher banana stem diameter was recorded in the intercrop of agroforestry trees with *Sesbania sesban* having relatively larger stem diameters than the rest of the treatments. The results are in line with earlier findings of Muthuri et al. [16] who reported larger wheat and maize diameters under P. deltoids intercrop. The larger stem diameters in *Sesbania sesban* treatments may be attributed to the added biomass resulting from regular prunings and nitrogen fixed by the nitrogen fixing plants and improved resource partitioning and availed high inorganic nitrogen.

4.3 Effect of Intercropping Maize and Banana with Agroforestry Tree Species On Maize Gas Exchange Parameters

4.3.1 Effect of intercropping maize and banana with agroforestry tree species on maize intercellular Carbon (IV) oxide concentration

Higher intercellular Carbon (IV) oxide concentrations were reported at 84 DAP in both seasons. During both seasons, the highest intercellular Carbon (IV) oxide concentration was reported under MBS treatment. The findings are in agreement with those of Ghanbari et al. [22] and Mithamo [31]. The higher intercellular Carbon (IV) oxide concentration in MBS may be attributed to Sesbania sesban plants providing sufficient mulch that conserved soil water. This in turn resulted into stomatal opening of maize plants eliciting more carbon (IV) oxide intake consequently increasing intercellular Carbon (IV) oxide concentration within the leaves.

In the second season, similar results to those of the 1st season were recorded with MBS showing higher intercellular Carbon (IV) oxide concentration rate at 83 DAP. In MBS, *Sesbania sesban* trees may have developed deep roots to pump and utilize water from below ground. Sesbania sesban may have also increased soil-water storage in the maize and banana rhizosphere. This could probably have made the maize plants to access more water that was readily availed to various plant cells. This promoted stomatal opening as a way of losing the excess water which in turn resulted into more carbon (IV) oxide intake by the leaves. The increased uptake increased its concentration around the rubisco enzyme. This could have resulted into high rates of photosynthesis producing osmotically active sugars that further enabled guard cells to bulge and stomata remaining open for water and CO_2 diffusion.

4.3.2 Effect of intercropping maize and banana with agroforestry tree species on maize transpiration rate

There was no significant difference in transpiration rate among treatments in the 1st season but significant differences were registered in the 2nd season at 28 and 84 DAP. Maize in agroforestry trees showed higher transpiration rates compared to those in other treatments without agroforestry trees. MBS had higher transpiration rates followed by MBL and MBC. These results are in agreement with earlier findings by Ghanbari et al. [22] who reported improved conservation of soil moisture in maize intercropped with cowpea compared to sole cropped maize. The high transpiration rates witnessed among agroforestry tree treatments may be due to the surface cover of trees that reduced water loss from the soil via soil evapotranspiration. This could also be due to agroforestry trees utilizing and pumping water from below the water table and availing it to the maize rhizosphere. Increased water in the soil rhizosphere resulted into increased stomatal opening to facilitate rapid cuticular transpiration through leaf surfaces. The highest transpiration rates recorded in the *Sesbania sesban* treatments can be attributed to the deep rooted *Sesbania sesban* trees which reduced competition for the soil available water by utilizing water from the water table deep below the ground and availing it to the maize rhizosphere.

4.3.3 Effect of intercropping maize and banana with agroforestry tree species on maize net photosynthetic rate

Significant net photosynthetic rate was registered at 56 DAP in 1st season and at 28 and 56 DAP in the 2nd season. High photosynthetic rates were registered under agroforestry tree treatments with *Sesbania sesban* recording the highest net photosynthetic rates than the rest of the treatments. The results of this study are in agreement with those of Sanjeev [24] (2016) who reported increased net photosynthesis in the garlic intercropped with quava, plum and poplar compared to sole cropped garlic. The high photosynthetic rates observed under *Sesbania sesban* may be due to the increased intercellular Carbon (IV) oxide concentration that was brought about by availability of soil water that facilitated stomatal opening allowing transpiration and promoting carbon (IV) oxide uptake and intercellular Carbon (IV) oxide concentration.

4.4 Effect of Intercropping Maize and Banana with Agroforestry Tree Species on Maize Gas Exchange Parameters

4.4.1 Effect of intercropping maize and banana with agroforestry tree species on banana intercellular Carbon (IV) oxide concentration

There were no significant differences in intercellular Carbon (IV) oxide concentration during the entire period of study. However, high amounts of intercellular Carbon (IV) oxide concentration were registered under agroforestry treatments with MBS treatments recording the highest intercellular Carbon (IV) oxide concentration compared to bananas without agroforestry trees. These findings are in agreement with those of Ghanbari et al [22], Mithamo [31] and Santos et al. [32]. The higher intercellular Carbon (IV) oxide concentration in MBS treatments may be attributed to banana and Sesbania sesban plants providing ground mulch to soils. Thereby making them to be saturated with water. This in turn resulted into stomatal opening of banana plants resulting into more carbon (IV) oxide intake and hence its intercellular Carbon (IV) oxide concentration. The promoted stomatal opening as a way of dispensing off the excess water in return resulted to more carbon (IV) oxide intake. Increased uptake increased its concentration around the rubisco enzyme. This let to high rates of photosynthesis producing osmotically active sugars that further enabled the guard cells to bulge and stomata remaining open for water and CO_2 diffusion.

4.4.2 Effect of intercropping maize and banana with agroforestry tree species on banana transpiration rate

Banana transpiration rates recorded significant differences during the whole study period at 171 DAT. High transpiration rates were observed under agroforestry tree treatments with *Sesbania sesban* having highest rates compared to the rest of the treatments. The results are in agreement with findings of Ghanbari et al. [22] who reported improved conservation of the soil moisture in maize intercropped with cowpea compared to sole cropped maize. The high transpiration rates under agroforestry tree treatments may be attributed to the surface cover of the trees that may have reduced water loss from the soil via soil evapotranspiration. This could also have been due agroforestry trees utilizing and pumping water from below the water table and availing it to the banana rhizosphere. Increased water in the soil rhizosphere resulted into increased stomatal rhythm that could have facilitated rapid cuticular transpiration through leaf surfaces. The highest transpiration rates recorded in banana under *Sesbania sesban* treatments could also be attributed to the deep rooted *Sesbania sesban* trees which reduced competition for the soil available water by utilizing water from the water table deep below the ground.

4.4.3 Effect of intercropping maize and banana with agroforestry tree species on banana net photosynthetic rate

The net photosynthetic rate showed significant differences only at 360 DAT with MBC treatment being significantly high than the rest of the treatments. The agroforestry trees with banana and maize treatments displayed high banana photosynthetic rates compared to those treatments without the trees. The results of this study are in agreement with those of Sanjeev [24] who reported increased net photosynthesis in the garlic intercropped with quava, plum and poplar compared to sole cropped garlic. The more water in the soil promoted carbon (IV) oxide diffusion in to the leaf as a result of enhanced stomatal opening to facilitate loss of excess water. The findings are also in agreement with those by Chaves et al. [25]. The high photosynthetic rates observed may be attributed to the increased intercellular Carbon (IV) oxide concentration that was brought about by availability of soil water that facilitated stomatal opening allowing transpiration and promoting carbon (IV) oxide uptake and intercellular Carbon (IV) oxide concentration.

5. CONCLUSION

Sesbania sesban recorded maximum growth rates in comparison with other agroforestry trees. The good results reported on growth and gas exchange responses was due to high inorganic nutrients generated during decomposition and mineralization of prunings and maize straws availing nutrients necessary for growth. Consequently, agroforestry tree species recorded significantly taller plants, higher leaf areas, number of leaves and stem diameters. Agroforestry tree species increased the intercellular Carbon (IV) oxide concentration, transpiration rates and net photosynthesis of maize and banana plants. *Sesbania sesban* promoted maximum intercellular Carbon (IV) oxide concentration, transpiration rates and net photosynthesis. Increased gas exchange responses were due to increased soil-water storage within the soil profile and rhizosphere. Therefore, incorporating nitrogen-fixing trees in farming could impact positively on plant growth, increased intercellular Carbon (IV) oxide concentration, transpiration rates and net photosynthesis. Increased carbon (IV) oxide intake enhanced the concentration of CO_2 around rubisco enzyme, resulting into increased photosynthesis that led to production of more photo-assimilates necessary for plant growth.

6. RECOMMENDATIONS

From this study, *Sesbania sesban* may be recommended in both maize and banana as it promotes sustainability in plant growth, gas exchange parameters such as intercellular Carbon (IV) oxide concentration, transpiration rates and net photosynthesis of maize and banana plants. *Sesbania sesban* is therefore recommended for intercropping in the agro-ecological zones of Kenya to promote growth, productivity, climate mitigation and soil fertility improvements.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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