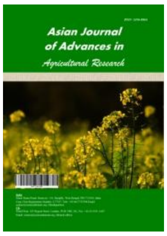

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Effect of Time of Introduction of Legumes into Cassava on the Productivity of Cassava in Cassava-Legume based Intercropping Systems

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Authors' contributions

This work was carried out in collaboration among all authors. Author AM design the study, performed the statistical analysis and wrote the first draft. Author ABK plays an important role in designing the study and interpreted the result. Author TBRY plays a very important role in data collection and searched the literature. Author ARC helped in designing the study and proof reading the manuscript. Author KMY helps in designing the study and writing of the first draft. All authors read and approved the final manuscript.

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ABSTRACT

Background and Objective: The time of sowing component crops is an important management variable that can improve productivity and increase land equivalent ratio in intercropping systems. The study aimed to evaluate the effect of the time of introduction of legumes into cassava on cassava productivity.

Study Design: The experiment was a factorial randomized complete block design with three replications.

Place and Duration of Study: Field trials were conducted in 2015/2016 and 2016/2017 cropping seasons in three agro-climatic zones.

Methodology: The treatments consisted of seven cropping associations, two cassava architectures, two spatial arrangements of cassava, and two introduction times of the legume. The cassava was grown on flat land and the legumes were inserted in between the rows of the cassava. The introduction of the legumes were done in two stages, namely: simultaneous

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introduction in which the cassava and the legumes were planted at the same time and late introduction in which, the cassava was introduced four weeks after the cassava was planted.
Results: The result shows that values for both yield and growth parameters of cassava were higher when the legumes were introduced four weeks after the establishment of the cassava. Also, the land equivalent ratios for both times of introductions were greater than one and were higher when the legumes were introduced four weeks after the establishment of the cassava.
Conclusion: For higher productivity of cassava in a cassava-legume-based intercropping system, the introduction of the legumes into the cassava should be delayed for at least four weeks after the cassava is established.

Keywords: Time of introduction; productivity; intercropping system; late introduction; simultaneous introduction; land equivalent ratio.

1. INTRODUCTION

The rationale behind intercropping root crops like cassava with grain legumes is based on the premise that root crops can utilize the nitrogen fixed by the legume. In this relationship, the legume may either increase the supply of available nitrogen or competes with the non-legume for the fixed nitrogen [1]. In general, it has been proven that non-leguminous plants do not normally benefit from the associated legumes that are planted together unless the non-leguminous plants continue to take up nitrogen after the leguminous plants have begun to senesce and die. However, if the legume is planted earlier, it may compete with the non-legume for soil mineral nitrogen but there could be an opportunity later for rapid and effective transfer of nitrogen to the non-legume companion crop. On the other hand, if the legume is established late, the non-legume would have already taken up soil mineral nitrogen as such, there will be little or no chance for nitrogen transfer and in most cases some nitrogen may be lost before it can be transferred to another crop [2].

Thus, the relative time of introducing the intercrop into the cropping system has both biological and practical implications. For example, Andrews [3] observed that planting component crops at different times may minimize competition for growth limiting factors as peak demand for these factors may vary among crops. Addo-Quaye et al*.* [4] also, reported that the relative time of introducing the component crop could affect the yields of component crops, which he attributed to the interspecific competition between the component crops for resources.

Cassava (*Manihot esculenta Crantz*) is the third-largest source of carbohydrate in the tropics, after rice and Maize [5] and is a staple food for more than 800 million people living in developing countries where it is used for different purposes including direct human consumption and industrial processing of starch-based products [6,7]. It is a long duration crop that develops slowly during its early growth stages and it takes a long time to mature. Therefore, intercropping cassava with early maturing crops may improve productivity and resource use efficiency in cassava-based cropping systems.

In the tropics, cassava is frequently intercropped with maize [8]. However, cassava-legume intercropping may be more beneficial because of the ability of the legumes to fix nitrogen and the contribution to nutritional security [9]. However, despite the benefits of cassava-legume based intercropping systems, there is a lack of adequate information relating to the optimum time of introducing legumes into cassava that would enhance the productivity of cassava and minimize inter-specific competition.

The objective of this research therefore, was to examine the effect of the relative time of introducing the various legumes into cassava on the productivity of cassava in three agro-climatic zones where cassava is intercropped with legumes in Sierra Leone.

2. MATERIALS AND METHODS

2.1 Study Areas

The study was conducted between 2015-2017 under rainfed condition in three Agro-climatic zones namely Sumbuya (N 08.04088^0 , W 011.478955^0) in Bo district representing the transitional rain forest with an annual rainfall of 1,956.28 mm, temperature of 26.85^{o}C, and relative humidity of 81.85%. Makeni (N 08.8720^0, W 012.0376^0) in Bombali district representing the savannah woodland with an annual rain fall of 1,915.41 mm, temperature of 27.31^{o}C, and relative humidity of 77.44% and Segbwema (N 07.9930^0, W 010.95224^0) in Kailahun district representing the rain forest with an annual rainfall of 2,194.15 mm, temperature of 26.15^{o}C and relative humidity of 86.02% (Fig. 1).

2.2 Land Preparation

Land preparation was done manually using cutlass and hoe and the plots were laid out using a measuring tape, garden line and pegs.

2.3 Planting Material

Two cassava varieties were used, slicass 6 which is the erect type and slicass 1 which is the branching type. The three legumes used were cowpea (IITA 573-1-1), soybean (slibean 2) and groundnut (slinut 1). These materials were obtained from Njala Agricultural Research Center.

2.4 Planting and Spacing

The cassava varieties were planted on a flat land in June for both the simultaneous and late introduction trials. Stem cuttings of about 25 cm long with five nodes of each cassava variety were used. Cassava was planted at the spacing of 1 m x 1 m and 2 m x 0.5 m respectively; whilst cowpea and groundnut were planted at the spacing of 50 cm x 20 cm with two seeds per hole for cowpea and one seed per hole for groundnut. On the other hand, soybean was planted at the spacing of 50 cm x 10 cm with two seeds per hole. The legumes were introduced in between the rows of the cassava. The legumes were introduced in two phases namely: simultaneous introduction in which both the cassava and legume were planted at the same time and late introduction in which, the legumes were introduced four weeks after the cassava was planted.

2.5 Experimental Design and Treatments

The experiment was a factorial randomized complete block design with three replications. Each plot measured 6 m x 7 m with a space of 1 m between each plot. The treatments consisted of seven cropping associations (sole cassava, sole groundnut, sole cowpea, sole soybean, cassava + cowpea, cassava + groundnut and cassava + soybean), two cassava architectures (branched and erect) and two spatial arrangements (1 m x 1 m and 2 m x 0.5 m).

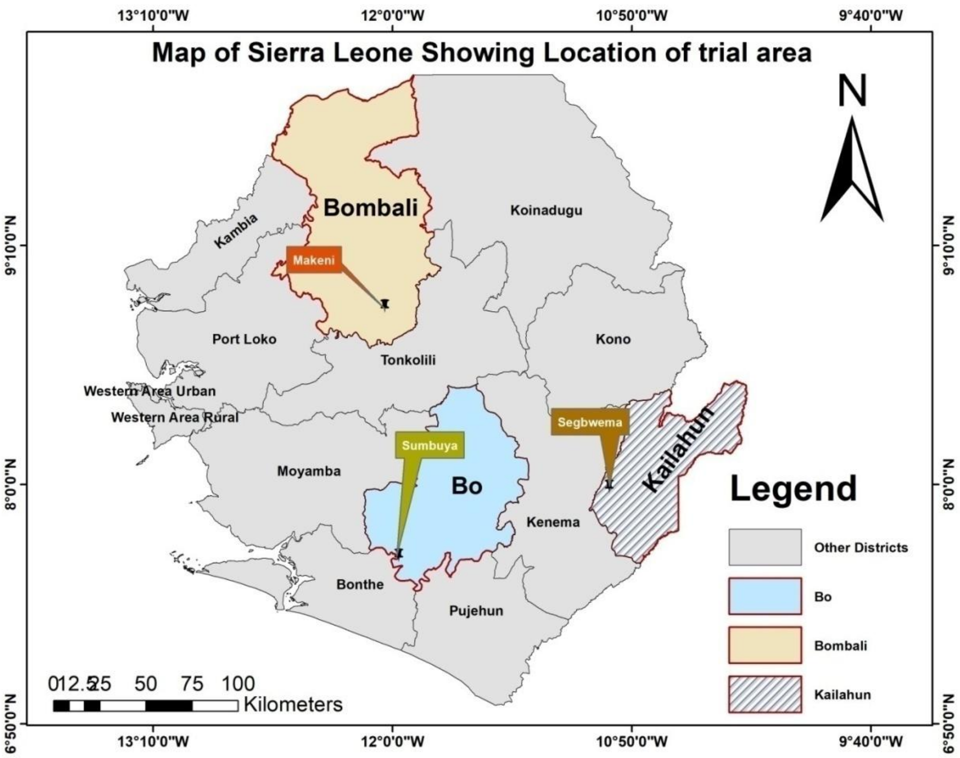

Fig. 1. Map of Sierra Leone showing trial sites of the different agro-climatic zones in Sierra Leone

2.6 Data Collection

The important growth parameters measured included plant height, canopy width, and stem girth. These parameters were measured at 3, 6, 9, and 12 months after planting. Measurement was taken on ten randomly selected tagged plants. Plant height was obtained by measuring the vertical height of the plant from the ground level to the apex using a calibrated stick of about 3m long. Stem girth was measured using a vernier caliper 10 cm above the ground. Canopy width or diameter was determined by measuring the diameter covered by the plant's canopy perpendicularly and parallel to the ridge with the aid of a meter rule.

The yield parameters determined were the number of marketable roots, root yield, forage yield and total biomass yield. Forage yield was determined by weighing the tender stems and leaves using a sensitive scale. This was later expressed in Kg/ha.

Root yield was determined by harvesting all the cassava plants within the net plot followed by detachment of all the storage roots from the stump and weighing using a salter scale. Root yield was also expressed in t/ha. The storage roots per treatment were sorted based on whether they were marketable or not. A storage root was considered marketable when it weigh between 100-400 g.

The land equivalent ratio was calculated for both introduction times using the equation proposed by Willey and Rao [10].

$$LER = \{La + Lb\}$$
$$La = (Yab/Yaa)$$
$$Lb = (Yba/Ybb)$$

Where La and Lb are the land equivalent ratios for the individual crops, Yab and Yba are the individual crop yields in intercropping and Yaa and Ybb are the individual crop yields in sole cropping.

2.7 Data Analysis

All data collected were subjected to analysis of variance (ANOVA) using the SAS statistical package (SAS Institute, [11]) and means were compared using the Student Newman-Keuls Test (SNK) at a 0.05 level of significance.

3. RESULTS

3.1 Yield Parameters

3.1.1 Number of marketable root

Analysis using ANOVA reveals significant differences in the number of marketable root across time of introduction of legume into the cassava with respect to cropping system ($F = 27.77$, $P < .001$), spatial arrangement ($F = 11.09$, $P < .001$) and plant architecture ($F = 25.62$, $P < .001$) (Table 1). In the case for cropping system, the number of marketable root was significantly higher concerning the late (19.45) introduction compared to the simultaneous (15.98) introduction. The number of marketable root was 18% higher for the late introduction compared to the simultaneous introduction. In addition, the number of marketable root was higher for the cassava-soybean bean system for both the late and simultaneous introduction compared the sole cassava, cassava-groundnut and cassava-cowpea systems. There were however no significant differences in the number of marketable root between cassava-cowpea and cassava-groundnut systems for both the late and simultaneous introductions (Table 1).

Similarly, for both spatial arrangement and plant architecture, the late introduction was also observed to have recorded a higher number of marketable roots compared to the simultaneous introduction (Table 1). For spatial arrangement, the number of marketable root recorded for the late introduction was 20% higher for the simultaneous introduction. Pertaining to plant architecture, the erect cassava variety was observed to have recorded a significantly higher number of marketable roots for both simultaneous and late introduction compared to the branched variety. In addition, more marketable root was produced when the legume was introduced late (20.25) into the cassava compared to the simultaneous (16.23) introduction (Table 1). Furthermore, the three-way interactions among cropping system x spatial arrangement x plant architecture with respect to the number of marketable root across time of introduction of the legumes was not significant ($F = 1.18$, $P = .30$).

3.1.2 Root yield

Root yield varies significantly across the time of introduction of the legumes with respect to the spatial arrangement ($F = 7.91$, $P = .005$) and plant architecture (F = 15.05, $P < .001$); but was not significantly different about cropping system (F = 1.65, $P = .104$) even though yields were slightly higher for the late introduction compared to the simultaneous introduction (Table 1).

Concerning cropping system, the cassava-soybean cropping system recorded the highest root yield across time of introduction but was not significantly different from the sole cassava. For the simultaneous introduction, there was no significant difference in root yield among the sole cassava, cassava-soybean and cassava-groundnut systems. The cassava-cowpea system was observed to have recorded the least root yield (Table 1). In addition, for the late introduction, significant differences in root yield were not registered between cassava-soybean and sole cassava and between cassava-groundnut and cassava-cowpea.

For both spatial arrangement and plant architecture, significantly higher root yield was produced when the legumes were introduced late into the cropping system. The mean root yield for the late introduction with respect to spatial arrangement and plant architecture were 10% and 9% higher respectively compared to the simultaneous introduction (Table 1).

3.1.3 Forage yield

Forage yield was significantly different concerning time of introduction of the legume into the cassava across cropping system (F = 36.8, $P < .001$) and plant architecture (F = 4.75, $P = .03$). However it was not significantly different with respect to spatial arrangement (F = 1.05, $P = .353$) (Table 1). In the case for cropping system, a higher forage yield was produced when the legume was introduced late (9.02) into the cropping system compared to the simultaneous introduction (7.89). Forage yield was not significantly different across cropping system when the legumes were introduced late into the cropping system. However, significant differences were recorded in forage yield when both cassava and legumes were planted simultaneously (Table 1). The cassava-soybean cropping system was observed to have produced the highest forage yield followed by the sole cassava, cassava-groundnut and cassava-cowpea.

Similarly, with respect to plant architecture, the late introduction (9.01) was observed to have recorded the highest forage yield compared to the simultaneous introduction (7.88). The forage yield produced by introducing the legume late was 13% higher than the simultaneous introduction. In addition, the branch cassava architecture was observed to have recorded higher forage yield across the two times of introduction compared to the erect cassava architecture (Table 1). In addition, the three-way interactions among cropping system x spatial arrangement x plant architecture with respect to forage yield across legume introduction time was not significant (F = 2.77, $P = .066$).

3.1.4 Total biomass yield

There were no significant differences in the total biomass yield across time of introduction of the legume with respect to spatial arrangement (F = 0.12, $P = .909$) architecture of the cassava (F = 1.29, $P = .258$) and cropping systems (F = 0.02, P = .885) (Table 1). In the case of spatial arrangement, a slightly higher biomass yield was reported for the late introduction (50.87) than the simultaneous introduction (47.65) of the legume. However, there were no significant differences in total biomass yield between the 1 m x 1 m and the 2 m x 0.5 m special arrangement of cassava (Table 1).

Similarly, there was no significant difference in total biomass yield with regards to plant architecture across the time of introduction of the legumes; however, the late introduction was observed to have registered the highest biomass yield (50.67) compared to the simultaneous introduction (47.73). In addition, intercropping legumes with cassava using the erect cassava variety recorded the highest total biomass yield across the two times of introductions. Furthermore, the three-way interactions among cropping systems x spatial arrangement x plant architecture with respect to total biomass yield across legume introduction time was not significant (F = 1.12, $P = .346$).

3.2 Growth Parameters

3.2.1 Plant height

Plant height with respect to the cropping system varies significantly (F = 6.81, $P < .001$) between the time of introduction of the legume into the cassava with the late introduction recording a significantly higher value compared to the simultaneous introduction (Table 2). Plant height for the simultaneous introduction ranges from 73.45-217.18 whilst that for the late introduction ranges from 78.11-224.03. On average, plant height for the late introduction was 5% higher than the simultaneous introduction. In general, plant height was observed to increase with the age of the cassava plant (Table 2). Within the cropping system, the sole cassava was observed to have recorded higher values at 3 MAP and 6 MAP respectively for both simultaneous and late introductions compared to the cassava-soybean, cassava-groundnut, and cassava-cowpea systems. This trend was however reversed at 9 MAP and 12 MAP where in the cassava-soybean system was observed to have recorded significantly higher value compared to the sole cassava, cassava-groundnut, and cassava-cowpea systems across both times of introduction (Table 2).

Concerning spatial arrangement of cassava, significant differences (F = 3.43, *P* = .019) in plant height between the times of introduction of the legumes were recorded only at 9 MAP. Cassava plant height was on average generally higher for the late introduction of the legume and with the 1 m x 1 m spatial arrangement compared to the 2 m x 0.5 m arrangement across the various times of observation (Table 2).

For plant architecture, significant differences in plant height between the times of introducing the legumes into the cassava was observed only at 3 MAP (F = 26.76, *P* < .001) and 9 MAP (F = 98.03, *P* < .001) with the late introduction again consistently recording higher values compared to the simultaneous introduction (Table 2). In addition, plant height was significantly higher when the legumes were intercropped using the erect cassava variety compared to the branching type across both times of introduction. Plant height was 12% higher on average when the erect cassava variety was used for intercropping compared to the branching type. Also, the three-way interactions among cropping system x spatial arrangement x plant architecture with respect to plant height between times of introduction of the legumes were not Significant (F = 1.30, *P* = .277).

3.2.2 Canopy width

Canopy width was not significantly different at 6 MAP (F = 2.24, *P* = .111), 9 MAP (F = 1.04, *P* = .378), and 12 MAP (F = 1.61, *P* = .115) between both times of introduction with respect to cropping system; even though higher canopy width was recorded for the late introduction compared to the simultaneous introduction (Table 3). Significant differences in canopy width were however recorded at 3 MAP (F = 3.96, *P* = .048). Generally, canopy width was observed to increase with the age of the cassava plant.

Within cropping system, significant differences were recorded in canopy width with the cassava-soybean system recording on average higher canopy width compared to the other cropping systems across both times of introduction. The cassava-cowpea cropping system was observed to have recorded the least canopy width.

In the case for spatial arrangement, significant differences in canopy width between the times of introducing the legume within the cropping system was not significant (F = 2.24, *P* = .109). However, within spatial arrangement, significant differences were recorded in canopy width at 9 MAP (F = 3.96, *P* = .048) and 12 MAP (F = 4.81, *P* = .029) for the simultaneous introduction and at 6 MAP and 12 MAP for the late introduction (Table 3). Canopy width was observed to be higher when legumes were intercropped with cassava using the 1 m x 1 m spatial arrangement compared to the 2 m x 0.5 m spatial arrangement.

Concerning plant architecture, significant differences in canopy width between the times of introducing the legumes were only significant at 3 MAP. Significant differences were however not recorded with plant architecture at 6 MAP, 9 MAP, and 12 MAP for both the late and simultaneous introductions. The branched cassava architecture was observed to have recorded the highest canopy width compared to the erect.

3.2.3 Stem girth

Stem girth was significantly different across time of introduction of the legume with respect to cropping system at 6 MAP (F = 7.05, *P* = 0.0012) and 9 MAP (F = 8.91, *P* = .002) respectively. It was however not significant at 3 MAP (F = 1.23, *P* = .269) and 12 MAP (F = 1.52, *P* = .212) respectively even though higher values were recorded for the late introduction than the simultaneous introduction (Table 4). Stem girth was generally observed to increase with the age of the cassava plant.

Table 1. Effect of time of introduction of the legumes into the cassava on the yield and yield related components of cassava

Parameters	Simultaneous Planting				Four weeks after planting cassava (Late)			
	Yield components				Yield components			
	Number of marketable root	Root yield (t/ha)	Forage yield (t/ha)	Total biomass (t/ha)	Number of marketable root	Root yield (t/ha)	Forage yield (t/ha)	Total biomass (t/ha)
Cropping system								
Cassava-groundnut	13.47 b	26.77 a	6.76 b	50.98 a	16.63 b	24.19 b	8.26 a	47.00 b
Cassava-cowpea	13.21b	21.50 b	7.82 b	41.16 c	16.10 b	22.68 b	9.25 a	42.34 b
Cassava-soybean	20.20 a	26.77a	9.23 a	53.42 a	22.94a	29.20 a	9.85 a	58.64 a
Sole- cassava	17.06 a	24.42 a	7.83 b	46.72 b	22.44a	29.12 a	8.71 a	52.51a
Mean	**15.98 b**	**24.70 a**	**7.89 b**	**48.07 a**	**19.45 a**	**26.29 a**	**9.02 a**	**50.12 a**
Spatial arrangement								
1 m x 1 m	15.84 a	24.80 a	7.92 a	48.11 a	21.01a	25.62 a	9.42 a	52.09 a
2 m x 0.5 m	16.83 a	24.50 a	7.84 a	47.26 a	20.03a	28.88 a	8.38 a	49.65 a
Mean	**16.34 b**	**24.65 b**	**7.88 a**	**47.65 a**	**20.52 a**	**27.25 a**	**8.90 a**	**50.87 a**
Plant architecture								
Erect	20.36 a	25.56 a	7.69 a	48.02 a	24.12	32.93 a	7.75 b	58.48 a
Branch	12.09 b	23.60 a	8.07 a	47.43 a	16.38	21.23 b	10.26 a	42.85 b
Mean	**16.23 b**	**24.58 b**	**7.88 a**	**47.73a**	**20.25 a**	**27.01 a**	**9.01 a**	**50.67 a**

Means in column with the same letter are not significantly different at P>0.05 (SNK)

Table 2. Effect of time of introduction of legumes into the cassava on the height of cassava

Parameters	Simultaneous Planting Plant height (cm)				Four weeks after planting cassava (Late) Plant height (cm)			
	3 MAP	**6 MAP**	**9 MAP**	**12 MAP**	**3 MAP**	**6 MAP**	**9 MAP**	**12 MAP**
Cropping system								
Cassava-groundnut	76.80 b	108.67 b	140.17 c	210.48 c	79.72 b	105.16 b	157.90 c	215.07 c
Cassava-cowpea	61.42 c	93.63 c	139.03 c	185.55 d	72.54 b	110.51 ab	148.24 d	196.02 d
Cassava-soybean	74.33 b	110.44 b	174.81 a	256.92 a	75.53 b	115.69 b	187.20 a	258.63 a
Sole- cassava	81.28 a	115.00 a	158.57 b	215.75 b	84.63 a	114.55 a	161.47 b	226.41 b
Mean	**73.45 b**	**106.94 b**	**153.15 b**	**217.18 b**	**78.11 a**	**111.48 a**	**163.70 a**	**224.03a**
Spatial arrangement								
1 m x 1 m	77.85 a	113.14 a	158.21 a	224.52 a	82.20 a	115.28 a	164.01 a	227.28 a
2 m x 0.5 m	74.24 a	105.83 b	152.07 a	214.88 b	77.51 b	109.58 b	163.-8 a	217.72 b
Mean	**76.05 a**	**109.49 a**	**155.14 b**	**219.70 a**	**78.86 a**	**112.43 a**	**163.54 a**	**222.50a**
Plant architecture								
Erect	85.69 a	117.11 a	175.01 a	241.85 a	88.32 a	124.06 a	184.18 a	241.20 a
Branch	66.28 b	102.11 b	134.93 b	198.31 b	71.71 b	101.14 b	142.44 b	203.51 b
Mean	**75.99 b**	**109.61a**	**154.97b**	**220.08 a**	**80.01 a**	**112.60a**	**163.31a**	**222.36 a**

Means in column with the same letter are not significantly different at P>0.05 (SNK)

Table 3. Effect of time of introduction of legumes into the cassava on canopy width of cassava

Parameters	Simultaneous Planting Canopy width (cm)				Four weeks after planting cassava (Late) Canopy width (cm)			
	MAP	6MAP	9MAP	12 MAP	3MAP	6 MAP	9 MAP	12 MAP
Cropping system								
Cassava-groundnut	61.49 a	87.44 c	146.10 b	197.23 b	69.22 b	91.81 c	145.31 a	215.61 b
Cassava-cowpea	55.44 b	83.89 c	127.30 c	190.13 c	61.91 c	90.82 c	127.94 b	174.60 d
Cassava-soybean	64.11 a	97.30 a	141.89 a	213.68 a	74.16 a	100.20 a	147.31 a	221.30 a
Sole- cassava	63.49 a	91.91 b	141.26 a	190.17 c	69.65 a	95.19 b	144.80 a	187.56 c
Mean	**61.14 b**	**90.14 a**	**139.14 a**	**197.80 a**	**68.74 a**	**94.51 a**	**141.49 a**	**199.76 a**
Spatial arrangement								
1 m x 1 m	62.68 a	92.13 a	143.85 a	204.34 a	70.79 a	99.36 a	142.49 a	205.36 a
2 m x 0.5 m	61.13 a	89.06 a	135.34 b	184.45 b	66.40 a	88.25 b	142.35 a	183.46 b
Mean	**61.91 a**	**90.60 a**	**139.59 a**	**194.40 a**	**68.60 a**	**93.81 a**	**142.42 a**	**194.41 a**
Plant architecture								
Erect	61.63 a	84.15 b	117.80 b	155.25 b	67.78 a	88.08 b	128.12 b	168.71 b
Branch	62.32a	97.54 a	162.93 a	236.67 a	70.78 a	101.24 a	152.14 a	223.42 a
Mean	**61.98 b**	**90.85 a**	**140.37 a**	**195.96 a**	**68.90 a**	**94.66 a**	**142.63 a**	**196.07 a**

Means in column with the same letter are not significantly different at P>0.05 (SNK)

Within the cropping system, significant differences were recorded in stem girth with the cassava-soybean system recording the highest stem girth across the times of introduction compared to the other cropping systems. There were however no significant differences in stem girth between sole cassava and the cassava-soybean and that between cassava-groundnut and cassava-cowpea systems.

Pertaining to spatial arrangement, significant differences (F = 3.05, *P* =.007) in stem girth were recorded with respect to the time of introduction of the legume. On average, the late introduction was observed to produce significantly higher stem girth compared to the simultaneous introduction. The stem girth recorded with respect to the late introduction was 5% higher for the late introduction compared to the simultaneous introduction (Table 4). In general, there were no significant differences in spatial arrangement with respect to stem girth; however, the 1 m x 1 m spatial arrangement was observed to have recorded a slightly higher stem girth compared to the 2 m x 0.5 m spatial arrangement (Table 4).

For plant architecture, significant differences were recorded with respect to stem girth at 9 MAP (F = 3.28, *P* = .004) and 12 MAP (F = 4.47, P = .004) respectively across the time of introduction of the legumes into the cropping system. Stem girth was observed to be relatively higher with the late introduction compared to the simultaneous (Table 4). For the simultaneous introduction, significant differences were reported in stem girth at 3 MAP, 6 MAP, and 9 MAP respectively whilst for the late introduction, significant differences in stem girth were reported at 3 MAP and 6 MAP respectively (Table 4). In general, it was observed that the erect cassava variety was reported to have recorded higher stem girth compared to the branching variety. Also, the three-way interactions among cropping system x spatial arrangement x plant architecture with respect to stem girth across time of introduction of the legume into the cropping system were not significant (F = 1.14, *P* = .339).

3.3 Land Equivalent Ratio

There were significant differences in land equivalent ratio with respect to the time of introduction of the legume into the cassava across cropping systems. However, there were no significant differences in land equivalent ratio concerning the time of introduction of the legumes into the cassava across spatial arrangement and cassava plant architecture even though higher values were recorded with respect to the late introduction for both parameters (Table 5). With respect to the cropping system, higher values were recorded for the late introduction (2.05) compared to the simultaneous introduction (1.84). The land equivalent ratio for the late introduction was 10.24% higher compared to the simultaneous introduction (Table 5). The land equivalent ratio for both the simultaneous and late introductions with respect to cropping systems, spatial arrangement and plant architecture were all above one (1).

4. DISCUSSION

The time of introduction of the legumes into the cassava had a significant effect on the number of marketable roots, root yield, forage yield and the total biomass yield across cropping systems, spatial arrangement and cassava plant architecture. The values for these mentioned yield parameters were higher when the legumes were introduced late into the cassava. This finding concord with the observations of Ofori and Stern [12] who reported that crops that are established earlier in intercropping systems often have an initial competitive advantage over those that are planted later. The higher cassava root yield recorded when legumes were introduced late into the cassava could be attributed to the time given for the cassava plants to explore large soil volume by the production of many roots. These roots probably exhaustively competed enough for water, dissolved mineral nutrients and space before the establishment of the legumes. In addition**,** cassava might have taken advantage of inter-specific competition for growth resources between the two crops, as cassava was established four weeks before the legumes were introduced. Nyi et al. [13] also found that cassava yield could be increased considerably if cassava is established earlier than the component crop in an intercrop thus, creating strong inter-specific competition for growth resources in favour of cassava at the time when the component crop is still a weak competitor. This result concords with the findings of Mbah et al. [14] who reported a higher yield component of cassava when legumes were introduced four weeks after the establishment of cassava. Similarly, Nyi et al. [13] found that cassava root yield was significantly lower when cassava was planted three weeks after groundnut compared to when both crops were planted together. Thus, it is

Table 4. Effect of time of introduction of legumes into the cassava on stem girth of cassava

Parameters	Simultaneous Planting Stem girth (cm)				Four weeks after planting cassava (Late) Stem girth (cm)			
	3MAP	**6MAP**	**9MAP**	**12 MAP**	**3MAP**	**6MAP**	**9 MAP**	**12 MAP**
Cropping system								
Cassava-groundnut	1.07 b	1.61b	2.15 b	3.70 b	1.08 b	1.76 b	2.49 b	3.75 b
Cassava-cowpea	1.04 b	1.51 b	2.11 b	3.63 b	1.07 b	1.70 b	2.43 b	3.74 b
Cassava-soybean	1.33 a	1.73 a	2.42 a	4.06 a	1.35a	1.89 a	2.63 a	4.38 a
Sole- cassava	1.35 a	1.80 a	2.36 a	3.95 a	1.26 a	1.89 a	2.57 a	4.07 a
Mean	**1.20 a**	**1.67 b**	**2.26 b**	**3.84 a**	**1.19 a**	**1.81 a**	**2.53 a**	**3.90 a**
Spatial arrangement								
1 m x 1 m	1.27 a	1.74 a	2.32 a	4.05 a	1.25 a	1.90 a	2.55 a	4.07 a
2 m x0.5 m	1.21 a	1.67 a	2.27 a	3.75 b	1.14 a	1.75 a	2.54 a	4.00 a
Mean	**1.24 a**	**1.71 b**	**2.30 b**	**3.89 b**	**1.20 a**	**1.83 a**	**2.55 a**	**4.04 a**
Plant architecture								
Erect	1.42 a	1.85 a	2.42 a	3.97 a	1.37 a	1.98 a	2.65 a	4.15 a
Branch	1.06 b	1.56 b	2.17b	3.80 a	1.03b	1.68b	2.43 a	3.90 a
Mean	**1.24 a**	**1.70a**	**2.29 b**	**3.89 b**	**1.20 a**	**1.82 a**	**2.53 a**	**4.03 a**

Means in column with the same letter are not significantly different at p>0.05 (SNK)

Table 5. Effect of time of introduction of legumes into the cassava on land equivalent ratio of cassava-legume intercrop

	Simultaneous Planting	**Four weeks after planting cassava**
	Land Equivalent Ratio (LER)	**Land Equivalent Ratio (LER)**
Cropping system		
Cassava-groundnut	1.47 b	1.61 b
Cassava-cowpea	1.80 b	1.92 b
Cassava-soybean	2.24 a	2.61 a
Mean	**1.84 b**	**2.05 a**
Spatial arrangement		
1 m x1 m	1.88 a	1.85 a
2 m x 0.5 m	1.84 a	1.98 a
Mean	**1.86 a**	**1.92 a**
Plant architecture		
Erect	2.04 a	2.30 a
Branch	1.66 b	1.50 b
Mean	**1.85 a**	**1.90 a**

Means in column with the same letter are not significantly different at P>0.05 (SNK)

clear that where cassava is the main crop in an intercropping system, the component crops should be introduced after cassava is well established to maximize cassava root yield.

On the other hand, the recorded root yield reduction of cassava resulting from the simultaneous establishment is because of increase in interspecies competition for limited growth resources thus resulting in the reduction in both growth and yield components of cassava. This observation is consistent with the findings of Ogola et al. [15]. The decrease in root yield resulting from the simultaneous introduction was greater in the cassava-cowpea system compared to the other intercropping cropping systems, which is consistent with the findings of Legodi [16] who also reported a greater decrease in root yield of cassava-cowpea system with larger crop canopy compared to chickpea with much smaller canopy. Based on the results it could be concluded that, the more you delayed the planting of legume the higher the chances for cassava to grow well.

In general, irrespective of the time of introduction, the yield parameters of cassava were highly influenced by the cropping system. The number of marketable root, root yield, forage yield and total biomass yield was on average higher with the cassava-soybean intercropping system compared to the sole cassava and the other cropping systems. This result is in contrast with the findings of Prabhakar and Nair [17] and Ogola et al. [15]. These authors reported higher yield with the sole cassava relative to cassava intercropped with grain legumes. According to Maluleke et al. [18], yield advantages in intercropping can arise when component crops have different growth patterns and make major demands on resources at different times. Thus, in an intercropping system, a component crop can positively modify the growing environment for the benefit of the other crop, which can lead to an overall yield advantage relative to the sole crop [19].

Similarly, the relative time of introduction of the legume into the cassava significantly affects the growth parameters (plant height, stem girth and canopy width) of cassava. Higher values of these parameters were recorded when the legumes were introduced four weeks after the establishment of the cassava than when the cassava and the legumes were planted simultaneously. One possible reason for this could be that the earlier planted cassava had greater competitive advantage for growth resources than the other component crop in the intercropping system. Another reason could be that the cassava plant probably had lower competition for growth resources such as light, water and nutrients when the legumes were planted four weeks after cassava. This observation concords with the findings of Legodi and Ogola [20] who suggested that the late sown legumes probably did not pose any meaningful competition to the cassava.

Similarly, Laurence et al. [21] also reported higher growth parameters for maize when different green manure legumes were planted later in an already well established maize crop than planted simultaneously with maize.

On the other hand, the low values of the growth parameters recorded with respect to the simultaneous introduction could be attributed to inter-specific competition for resources as reported by Francis et al. [22] and Assefa and Ledin [23] for maize-legume intercropping system. From the result, it could be suggested that planting cassava and legumes at the same time increased interspecies competition for growth limiting factors thus resulting into reduction in the value of the growth parameters.

In general, irrespective of the time of introduction of the legume into the cassava, the growth parameters were affected by cropping system. The value of the growth parameters of cassava was depressed by intercropping at 3 MAP and 6 MAP. The depression in value of these growth parameters could be related to the luxuriant growth of the legumes, which was more evident in the case of the cassava-cowpea intercropping system. This result agrees with the findings of Anilkumar and Sasidhar [24] who reported a reduction in plant height of cassava due to intercropping. In addition, Adetunji and Amanze [25] reported similar findings in which the height of sunflower intercropped with two varieties of cassava were significantly reduced by intercropping relative to the sole cassava.

The depression in the value of these growth parameters at this stage in the intercropping system could probably be due to initial competition for growth resources between the component crops, which reduced the rate of assimilated photosynthates. Sheela and Kunja [26] have also reported similar findings. The situation was however different in the sole cassava system where plant population density was low as such, there was less interference with each other than at higher density. The relatively higher value reported for the growth parameters concerning the cassava-soybean bean system at 9 MAP and 12 MAP respectively, compared to the sole system could be that the system may have benefitted more from the nitrogen that was fixed at these stages as well as the organic matter that could have been added by the soybean residue after harvest. This observation corroborates with the findings of Makinde et al. [27] who reported that cassava-soybean system could benefit from soil fertility and the long-term productivity of cassava. In addition, under the cassava-soybean intercropping system, more photosynthate may have been channeled to the stem and leaves thus resulting into the significant increase in the values of these growth parameters.

The result also shows that irrespective of the time of introduction of the legume into the cassava, higher values of the reported growth parameters across the times of observation were on average higher for the 1 m x 1 m spatial arrangement of cassava compared to the 2 m x 0.5 m spatial arrangement. A probable reason for this could be the smaller intra plant distance between the 2 m x 0.5 m spatial arrangement resulted in more interplant competition for assimilates and also, the mutual shading which may have resulted into the reduction of photosynthesis and the subsequent decrease in the value of the assessed growth parameters.

The land equivalent ratio was greater than one for all the treatments indicating that it was advantageous to grow cassava with these legumes in association compared to growing cassava in pure stand. There was also evidence from the results that introducing the legumes four weeks into the cassava system was more productive compared to the simultaneous introduction. The higher productivity could be due to the complementary and efficient use of the growth resources by the component crops. Work done by several scientists has reported land equivalent ratios higher than one for cassava legume intercropping systems. For example, Mason et al. [28] have reported land equivalent ratio of 1.48 to 1.56 for cassava-legume intercropping. Also, Mba and Ezumah [29] reported higher productivity for cassava-legumes intercropping systems.

5. CONCLUSION

The study shows that the productivity of cassava was higher when the legumes were introduced late into the cassava.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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