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Effects of intercropping systems and *Rhizobium* inoculation on yields of maize (*Zea mays*) and two legumes (*Phaseolus vulgaris* and *Dolichos lablab*)

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Key words: *Rhizobium*, Legumes, Intercropping systems, Yield components, Grain yields

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Abstract

This study aimed to assess the effect of intercropping systems, *Rhizobium* inoculation and legumes on yield components and grain yields of maize and two legumes. To achieve this objective, field experiments were executed at Selian Agricultural Research Institute (SARI) for two cropping seasons. A randomised complete block design was used in a 3-factorial arrangement with two levels of *Rhizobium* (with and without rhizobia), 2 legumes (*P. vulgaris and D. lablab*) and 5 intercropping systems. The results showed that *Rhizobium* inoculation, cropping systems and legumes significantly ($P \leq 0.001$) increased maize and legumes yield components and grain yields in two seasons. The interaction between *Rhizobium* inoculation, legumes and cropping systems had significant effect ($P \leq 0.001$) on some of yield components and grains yield of maize and legumes in both seasons. These results suggest a significant yield increment by more than 35% when the two legumes were inoculated and intercropped with maize. Therefore based on these experimental findings, farmers should be advised to use *Rhizobium* as biofertilizers in maize-legumes intercrop as these improve soil fertility and crops yield.

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Introduction

Maize (*Zea mays*) is the most important cereal crop after wheat and rice crops and is cultivated in 160 countries on almost 150 million hectares and contributes to 36% (78.2 million tonnes) in the total grain production of the world (McCann, 2007; Dahmardeh *et al.,* 2009; Parihar *et al.,* 2011). In sub-Saharan Africa, it is a major staple food for an estimated 50% of the population and provides more than 50% of the basic calories (Jama *et al.,* 2000; Baltazari, 2014). However, food production, particularly maize, is not adequate to sustain farm families from one harvest season to the next (Kisetu and Mtakimwa, 2013). For example the potential maize production in Tanzania is four tonnes per hectare, but this quantity has not been attained mainly due to different agronomic practices and low soil fertility (Kisetu and Mtakimwa, 2013). The common practices used by farmers for managing soil fertility include the use of farm yard manure, plant residues and intercropping with grain legumes (Rufino *et al.,* 2007; Vanlauwe *et al.,* 2010).

Intercropping food crops is a common practice in Africa (Baltazari, 2014). The farmers' reasons for intercropping in Africa are often due to a desire for yield stability and ensuring household food security (Dahmardeh, 2009; Baltazari, 2014). Intercropping legumes and maize provides continuous ground cover which reduced runoff, soil loss, while increasing levels of soil organic matter and available N and P which contributes to yield gains in succeeding crops (Carlson, 2008), and affect the microbiological characteristics in rhizosphere of the crop species compared to sole cropping (Olufemi *et al.,* 2001; Mpairwe *et al.,* 2002; Dapaah *et al.,* 2003; Song *et al.,* 2007). Further studies by Mpairwe *et al.* (2002) and Li *et al.* (2003) indicated that the main reason of intercropping is to maximize use of plant growth resources such as sun light, space and nutrients for non-legume crops such as maize as well as to improve crop quality and amount per unit area (Dahmardeh *et al.,* 2010), thus improve food security (Asmat *et al.,* 2004). This is critical for smallholder farmers in sub-Saharan Africa such as those in Northern Tanzania, who have limited arable land (Ayisi and Mpangane, 2004; Baltazari, 2014).

Common bean and Dolichos lablab are among the recommended legume species for cropping systems in East Africa with potential use as an intercrop in food production systems for soil fertility improvement (Saha *et al.,* 2000) as well as increased crops yield. Although studies have indicated that rhizobia inoculants can improve the legumes crop yield (Dahmardeh *et al.,* 2010; Ibrahim *et al.,* 2011; Morad *et al.,* 2013), very little research have been carried out on the effectiveness of indigenous (natural) and inoculated (host-specific) rhizobia strains in maize-legumes intercrop. Therefore, this study intends to evaluate and compare different maize/legumes (Dolichos lablab and common bean) intercropping systems supplemented with rhizobia on growth parameters and grain yields of both crops in northern Tanzania.

Materials and methods

Description of the research experimental site

Two field experiments were conducted at Selian Agricultural Research Institute (SARI) farm in northern part of Tanzania (April 2015 to September 2015 and October 2015 to February 2016). SARI lies at Latitude 3°21'50.08" and Longitude 36°38'06.29"E at an elevation of 1390masl with mean annual rainfall of 870mm. The mean maximum temperature ranges from 22°C to 28°C whiles the mean minimum temperature ranges from 12°C to 15°C respectively.

Land preparation and planting of experiments

Land preparation involved clearing, ploughing, layout and finally planting. The experimental design followed a randomized complete block design (RCBD) in a factorial arrangement with 4 replications per treatment. The experimental treatments comprised of 2 levels of *Rhizobium* inoculation (with and without *Rhizobium*), 2 legumes (legume 1 being *P. Vulgaris* and legume 2 being *D. Lablab*) and 5 intercropping systems (sole maize or sole legumes, 1 row maize to 1 row legumes (1:1) i.e. 0 m or 0.45 m of legume from maize row, 1 row maize to 2 rows of legumes (1:2) i.e. 0.1 m or 0.2 m of legumes from maize rows). The field plots measured 4 m x 4 m with 5 rows of maize spaced at (0.9 m x 0.5 m) apart and 8 rows of legumes spaced at (0.5 m x 0.2 m). The plots were interspaced by 1 m to allow management of crops.

The first season crops were planted on 5th April, 2015 while the second season crops were planted on 14th, November, 2015. Prior to planting phosphate fertilizer as triple superphosphate was applied at the rates of 20 kg P/ha to supply soil P for crops uptake. The fertilizer was uniformly applied in to the holes and covered with little soil before planting maize or legume seeds to avoid seeds burning.

The BIOFIX legume inoculants were acquired from *MEA* Company Nairobi-Kenya, sold under license from the University of Nairobi. Maize variety (SEEDCO 503) was obtained from SEEDCO Seed Company in Arusha and Common bean seeds variety (Lyamungo 90) and Dolichos lablab variety (Rongai) were aquired from Selian Agricultural Research Institute-Arusha-Tanzania. Before planting, the specific legume seeds were thoroughly mixed with specific *Rhizobium* inoculants to supply (109cells/gseed), according to procedures stipulated by products manufacturer. To avoid contamination, the noninoculated seeds were planted first followed with the inoculated seeds. Three seeds were planted and later thinned to two plants after full plant establishment. Interplant spacing was maintained at 0.5 m throughout for maize and 0.2 m for legumes. The plant density was kept constant on a total plot area basis set at the optimum for sole crops and kept the same in intercrops. The plant population density of maize and legumes were maintained at 44,000 and 200,000 plants per hectare respectively. Weeding and agronomic management were done using hand hoe at different growth stage of the crop plant.

Data collection

The yield components and grain yield data were collected from maize plant. The plant height was measured using tape measure from ground level to the growing tip of the longest plant leaves and average data were recorded in cm per ten plants in each treatment plot at maturity. Biomass yield estimation involved ten maize plants above ground portions selected randomly at harvesting and sun dried for three days and then oven dried to constant weights at 70ºC.

After oven drying samples were weighed and data recorded as dry matter in kg/ha. Shelling percentage was calculated from the 10-plant sample as (seed weight/cob weight) x 100. Grain yield was determined by drying the seeds from each yield sample to a constant weight at 60ºC in an oven, weighing the sample with an electronic scale and then calculating grain yield in kg/ha at 14% Moisture content.

Data collected from legumes plant included number of leaves one week after planting, plant height, root and shoot length, leaf area, root and shoot dry weight, biomass yield, number of pods per plant, number of seeds per pod, 100 seeds weight and grain yield. The number of leaves was obtained from an average of four plants selected randomly in each treatment plot one week after planting. The average plant height in cm per ten plants was measured in each treatment plot at flowering stage whereby plant height was measured using tape measure from ground level to the growing tip of the longest plant leaves and average data was recorded. Root and shoot lengths involved carefully uproot of plant with the help of spade by digging soil core of 50 cm to both side and 100 cm in depth. Plants were placed into plastic buckets of water to remove adhering soil.

The shoots and roots were separately washed in water and distilled water several times. Thereafter, maximum root and shoot length was measured by using tape measure in cm. Leaf area estimation involved three plants samples where the maximum leaf length and leaf width were measured in cm and leaf area was computed using (Maximum leaf length L x maximum leaf width W). Then the LW was used in estimation LA using the formula reported by Peksen (2007). i.e. $LA = 0.919 + 0.682LW$. Shoot and root dry weight involved separating plant samples into shoot and root, then fresh weight were recorded. Samples were oven-dried at 70ºC for 48 hours and their constant dry weight was recorded using analytical weigh balance. Legumes biomass yield involved ten above ground legumes plant portions selected randomly at harvesting and sun dried for three days and then oven dried to constant weights at 70ºC. After oven drying samples were weighed and data recorded as dry matter in kg/ ha.

Number of pods per plant was assessed by sampling 10 plants from two side middle rows before the guard rows and the average worked out. Number of seeds per pod was taken from 10 representative plants at physiological maturity and pods were taken and then counted finally the mean value computed. 100 seed weight was assessed by randomly counting 100 threshed seeds and weigh them using electronic scale. Grain yield was determined by drying the seeds from each yield sample to a constant weight at 60°C in an oven, weighing the sample with an electronic scale and then calculating grain yield in kg/ha at 14% Moisture content.

Data analysis

A 3-way Analysis of Variance (ANOVA) was used to analyze data collected. The analysis was done using STATISTICA software program 2010. Fisher's least significant difference was used to compare treatment means at 5% level of probability

Results

Maize yield components and grain yield in two seasons

The maize yield components and grain yield increased significant (P≤0.001) due to *Rhizobium* inoculation. The maize plant height increased by 6.5%, biomass yield increased by 9.3%, shelling percentage increased by 0.9% while grain yields increased by 6.4% relative to plots with no *Rhizobium* inoculation for two seasons (Table 1). Common bean and Dolichos lablab increased the maize plant height by 6.8% and 6.6% relative to control for season 1 and 2 respectively. Biomass yield increased by 16.5%, shelling percentage increased by 1.4% while grain yield increased by 6.8% relative to control for two seasons (Table 1). Intercropping systems increased maize plant heights by 22% and 42% for season 1 and 2 respectively. Biomass yield increased by 48%, shelling percentage increased by 2.8% relative to control for two seasons. Grain yields increased by 25.6% and 25.8% for season 1 and 2, respectively (Table 1).

Interaction between *Rhizobium* and cropping systems had significant effect (P≤0.05) on maize plant height for two seasons (fig. 1).

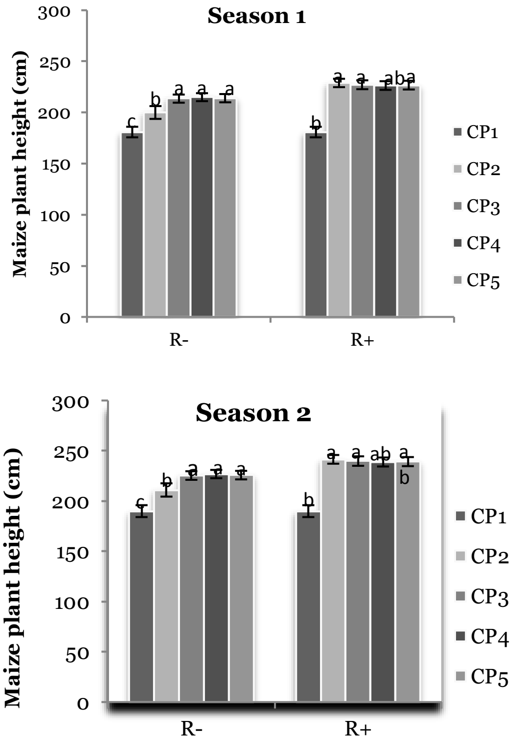


Fig. 1. Interactive effects of *Rhizobium* and cropping systems on maize plant height for season 1 and 2 (R-: Without *Rhizobium*, R+: With *Rhizobium*, CP1: Intercropping system 1, CP2: Intercropping system 2, CP3: Intercropping system 3, CP4: Intercropping system 4, CP5: Intercropping system 5).

Yield components and grain yields of two legumes (P. vulgaris and D. lablab.)

Rhizobium inoculation had significant effect (P≤0.001) on yield components and grain yields of two legumes (*P. vulgaris* L. *and D. lablab* L.) compared to uninoculated plots (Tables 2, 3 and 4) for two seasons. The increased in growth parameters and yields were by 11.7% and 11.9% number of leaves per plant, 10.3% and 12.7% plant height, 19.3% and 23.1% root length, 14.7% and 17.6% root dry weight for two seasons (Table 2). The shoot length increased by 16.2% and 14%, shoot dry weight increased by 6.6% and 6.4%, leaf area increased by 17.9% and 18.1% while biomass yields increased by 8% (Table 3) for two seasons.

Table 1. Effects of *Rhizobium* inoculation, legumes and intercropping systems on maize yield components and grain yield in two seasons.

Treatments	Season 1				Season 2			
	Maize Plant height (cm)	Maize biomass yields (kg/ha)	Maize shelling (%)	Maize grain yields (kg/ha)	Maize Plant height (cm)	Maize biomass yields (kg/ha)	Maize shelling (%)	Maize grain yields (kg/ha)
Rhizobium								
R-	204.70 ±2.92b	2372.08 ±83.82b	85.95 ±0.24b	934.20 ±13.60b	215.78 ±3.15b	2485.93 ±87.84b	82.54 ±0.23b	1119.82 ±16.31b
R+	218.03 ±3.53a	2591.65 ±91.23a	86.80 ±0.23a	993.55 ±18.71a	229.84 ±3.79a	2716.05 ±95.60a	83.31 ±0.23a	1190.97 ±22.43a
Legumes								
1	204.43 ±3.25b	2292.20 ±75.58b	85.77 ±0.25b	932.10 ±14.52b	215.66 ±3.43b	2402.23 ±79.21b	82.33 ±0.24b	1117.31 ±17.40b
2	218.30 ±3.19a	2671.53 ±91.70a	86.99 ±0.20a	995.65 ±17.83a	229.96 ±3.52a	2799.76 ±96.09a	83.52 ±0.19a	1193.48 ±21.37a
Intercropping systems								
1	180.88 ±3.52b	1820.38 ±16.83b	84.67 ±0.23b	812.25 ±3.43c	189.94 ±4.05b	1907.75 ±17.64b	81.33 ±0.26b	973.64 ±4.12c
2	214.44 ±5.19a	2584.31 ±129.53a	86.64 ±0.39a	997.06 ±19.96ab	226.23 ±5.48a	2708.36 ±135.75a	83.16 ±0.38a	1195.18 ±23.92ab
3	220.44 ±3.40a	2642.25 ±128.97a	86.59 ±0.34a	1017.13 ±19.45a	232.56 ±3.59a	2769.07 ±135.16a	83.11 ±0.32a	1219.23 ±23.37a
4	220.69 ±3.15a	2665.69 ±130.74a	87.06 ±0.35a	1022.00 ±18.66a	232.82 ±3.32a	2793.64 ±137.02a	83.57 ±0.33a	1225.07 ±22.37a
5	220.38 ±3.28a	2696.69 ±126.79a	86.94 ±0.31a	970.94 ±24.75b	232.49 ±3.46a	2826.13 ±132.87a	83.45 ±0.30a	1163.86 ±29.67b
3-Way ANOVA (F-statistic)								
Rhiz	26.78***	5.18*	11.0**	17.88***	24.62***	5.18*	9.6**	17.88***
Leg	29.03***	15.46***	23.2***	20.50***	25.43***	15.46***	23.1***	20.50***
Cr syst	35.88***	11.90***	11.9***	30.82***	34.41***	11.89***	10.8***	30.82***
Rhiz*Leg	0.08ns	0.002ns	0.0ns	0.55ns	0.07ns	0.002ns	0.1ns	0.55ns
Rhiz*Cr syst	3.19*	0.342ns	1.2ns	1.29ns	2.94*	0.34ns	1.4ns	1.29ns
Leg* Cr syst	0.17	0.049ns	0.3ns	0.57ns	0.23ns	1.05ns	0.1ns	0.57ns
Rhiz* Leg*Cr Syst	0.05ns	0ns	0.3ns	0.05ns	0.05ns	0.00ns	0.3ns	0.05ns

R-: Without Rhizobium, R+; With Rhizoubium, Legume 1: Common bean; Legume 2: D. Lablab; Intercropping System 1, 2, 3, 4 and 5 are sole maize, 10cm, 20 cm, 45cm and 0 cm of legumes from maize row respectively; Rhiz; Rhizobium, Leg; Legume, Cr Syst; Intercropping Systems. Values presented are means ± SE, n=4. *; **; *** = significant at P≤0.05, P≤0.01, P≤0.001 respectively, ns = not significant, SE = standard error. Means followed by dissimilar letter in a column are significantly different from each other at P=0.05 according to Fischer least significance difference (LSD).

The number of pods/plant increased by 46.5% and 43%, number of seeds/pod increased by 5.3% and 6.1%, 100 seeds weight increased by 8.9% and 10%, grain yields increased by 13.9% and 15.3% for season 1 and 2, respectively in the plots with *Rhizobium* inoculation (Table 4).

Legume 1 (Common bean) had less growth parameters measured and biomass yield than legume 2 (Dolichos lablab) for two seasons (Tables 2, 3 and 4). However, both legumes had significant (P≤0.001) effect on 100 seeds weight and grain yields with an increase of 9.5% and 11.8% 100 seeds weight, 71.3% and 81% grain yield for season 1 and 2, respectively (Table 4). Intercropping systems had significant effect (P≤0.001) on measured parameters and grain yields of two legumes except number of leaves per plant and plant height in two seasons. The number of leaves per plant increased by 8.7%, root length increased by 8.3% and 8.6 % while root dry weight increased by 13.2% and 10.3% for season 1 and 2 respectively (Table 2). The shoot length increased by 16.2% and 14%, shoot dry weight increased by 6.6% and 6.4%, leaf area increased by 17.9% and 18.1% while biomass yields increased by 8% for season 1 and 2, respectively (Table 3). All intercropping systems had significant effect (P≤0.001) on number of pods/plant and number of seeds/pod with an increase of 28.5% and 26.7% number of pods per plant, 11.3% and 13.8% number of seeds per pod. However, the cropping system 1 had highest number of pods/plant and number of seeds/pod than other cropping systems for season 1 and 2, respectively (table 4). Cropping system 1 was superior to intercropping systems 2, 3, 4 and 5 with an increase of 17.1% grain yield for two seasons (Table 4).

Table 2. Effect of *Rhizobium* inoculation and intercropping systems on yield components and grain yields of two legumes (*P. vulgaris* L. and *D. lablab* L.) in two seasons.

Treatments	Season 1				Season 2			
	No of leaves per plant	Plant height (cm)	Root length (cm)	Root dry weight (gm)	No of leaves per plant	Plant height (cm)	Root length (cm)	Root dry weight (gm)
Rhizobium								
R-	5.73 ±0.11b	93.95 ±6.39b	14.63 ±0.29b	25.35 ±0.71b	5.70 ±0.11b	93.70 ±6.36b	14.15 ±0.29b	25.17 ±0.76b
R+	6.40 ±0.12a	103.60 ±7.15a	17.45 ±0.31a	29.08 ±0.89a	6.38 ±0.10a	105.63 ±7.20a	17.42 ±0.29a	29.60 ±0.95a
Legumes								
1	5.60 ±0.10b	57.05 ±0.49b	14.33 ±0.26b	22.50 ±0.33b	5.53 ±0.09b	57.75 ±0.57b	14.25 ±0.29b	22.40 ±0.36b
2	6.53 ±0.11a	140.50 ±1.92a	17.75 ±0.26a	31.93 ±0.47a	6.45 ±0.08a	141.58 ±1.94a	17.32 ±0.32a	32.37 ±0.57a
Intercropping systems								
1	6.31 ±0.24a	100.94 ±11.59a	16.63 ±0.67a	28.94 ±1.39a	6.25 ±0.17a	100.31 ±11.33a	16.75 ±0.65a	28.75 ±1.57a
2	5.88 ±0.18b	100.56 ±11.42a	16.19 ±0.58ab	27.19 ±1.33b	5.75 ±0.17b	100.06 ±11.15a	15.81 ±0.70b	27.25 ±1.37bc
3	5.94 ±0.19ab	98.81 ±11.14ab	16.00 ±0.63b	26.75 ±1.36b	5.88 ±0.18b	100.13 ±11.22a	15.69 ±0.58b	26.75 ±1.51c
4	6.13 ±0.22ab	98.06 ±10.97ab	16.13 ±0.57b	27.63 ±1.23b	5.94 ±0.19b	100.44 ±11.29a	15.44 ±0.55b	28.12 ±1.34ab
5	6.06 ±0.19ab	95.50 ±9.77b	15.25 ±0.52c	25.56 ±1.45c	6.13 ±0.18b	97.38 ±10.27a	15.25 ±0.61b	26.06 ±1.59c
3-Way ANOVA (F-statistic)								
Rhiz	28.40***	40.39***	339.00***	172.10***	32.39***	68.07***	246.33***	127.18***
Leg	53.34***	3020.12***	498.29***	1101.78***	83.82***	3363.70***	217.16***	646.28***
Cr syst	1.46ns	1.66ns	8.47***	15.09***	3.12*	0.63ns	6.19***	5.95***
Rhiz*Leg	0.35ns	9.78**	0.03ns	18.61ns	3.00ns	12.09***	0.01ns	13.19ns
Rhiz*Cr syst	1.81ns	0.73ns	1.57ns	0.80ns	1.47ns	0.76ns	0.77ns	0.42ns
Leg* Cr syst	1.62ns	2.37ns	0.37ns	1.68ns	0.55ns	0.87ns	0.81ns	1.20ns
Rhiz* Leg*Cr Syst	0.64ns	0.80ns	1.49ns	0.49ns	0.24ns	0.75ns	0.70ns	0.71ns

R-: Without Rhizobium, R+; With *Rhizoubium*, Legume 1: Common bean; Legume 2: D. Lablab; intercropping System 1, 2, 3, 4 and 5 are sole maize, 10cm, 20 cm, 45cm and 0 cm of legumes from maize row respectively; Rhiz; Rhizobium, Leg; Legume, Cr Syst; Intercropping Systems. Values presented are means ± SE, n=4. *; **; *** = significant at P≤0.05, P≤0.01, P≤0.001 respectively, ns = not significant, SE = standard error. Means followed by dissimilar letter in a column are significantly different from each other at P=0.05 according to Fischer least significance difference (LSD).

Table 3. Effects of *Rhizobium* inoculation and intercropping systems on shoot length, shoot dry weight, leaf area and dry biomass yields of two legumes (*P. vulgaris* L. and *D. lablab* L.) in two seasons.

Treatments	Season 1				Season 2			
	Shoot length (cm)	Shoot dry weight (gm)	Leaf Area (cm)	Dry Biomass Yields (kg/ha)	Shoot length (cm)	Shoot dry weight (gm)	Leaf Area (cm)	Dry Biomass Yields (kg/ha)
Rhizobium								
R-	35.88 ±1.17b	147.93 ±3.23b	197.85 ±5.83b	3477.70 ±77.48b	37.40 ±1.10b	150.00 ±3.20b	206.75 ±6.16b	3503.50 ±77.72b
R+	41.68 ±1.06a	157.63 ±3.57a	233.23 ±6.89a	3758.70 ±89.11a	42.65 ±1.10a	159.62 ±3.55a	244.22 ±7.63a	3784.50 ±89.28a
Legumes								
1	32.73 ±0.43b	132.85 ±1.36b	184.30 ±2.48b	3121.70 ±30.15b	33.27 ±0.47b	134.97 ±1.34b	190.30 ±2.48b	3147.50 ±30.82b
2	44.83 ±0.93a	172.70 ±1.45a	246.78 ±6.44a	4114.70 ±37.50a	46.77 ±0.46a	174.65 ±1.45a	260.67 ±6.67a	4140.50 ±37.85a
Intercropping systems								
1	39.75 ±1.85a	160.44 ±4.98a	224.13 ±14.16a	3785.7 5±130.81a	40.94 ±1.93a	162.44 ±5.04a	235.37 ±15.07a	3823.70 ±130.81a
2	37.25 ±2.40b	152.19 ±6.06b	219.88 ±11.19a	3605.00 ±147.37b	40.12 ±1.79ab	154.25 ±6.06b	229.87 ±12.13ab	3630.0 ±147.36b
3	38.75 ±1.80ab	151.63 ±5.60b	214.75 ±10.82a	3589.25 ±140.26bc	39.87 ±1.93b	153.81 ±5.59b	224.50 ±11.64ab	3611.3 ±140.26bc
4	39.31 ±1.78ab	151.38 ±5.43b	211.81 ±9.63a	3602.00 ±131.53b	39.56 ±1.94b	153.37 ±5.39b	221.56 ±10.58ab	3630.00 ±131.53b
5	38.81 ±1.78ab	148.25 ±5.49b	207.13 ±9.34a	3509.00 ±136.62c	39.62 ±1.88b	150.18 ±5.33b	216.12 ±10.27b	3525.00 ±136.62c
3 Way ANOVA (F statistics)								
Rhiz	57.75***	54.17***	42.46***	101.97***	300.68***	55.00***	47.65***	101.97***
Leg	251.35***	914.19***	132.43***	1273.42***	1988.18***	934.53***	168.04***	1273.42***
Cr syst	1.22ns	9.54***	1.21ns	10.66***	2.70*	9.85***	1.50ns	12.38***
Rhiz*Leg	1.55ns	3.32ns	10.72ns	7.86**	0.00ns	3.64ns	12.87ns	7.86**
Rhiz*Cr syst	1.31ns	1.13ns	0.09ns	1.06ns	0.22ns	1.23ns	0.07ns	1.06ns
Leg* Cr syst	1.22ns	1.46ns	1.49ns	0.93ns	0.73ns	1.32ns	1.44ns	0.93ns
Rhiz* Leg*Cr Syst	1.53ns	3.02ns	0.41ns	3.19ns	0.66ns	3.09ns	0.39ns	3.19ns

R-: Without Rhizobium, R+; With Rhizoubium, Legume 1: Common bean; Legume 2: D. Lablab; intercropping System 1, 2, 3, 4 and 5 are sole maize, 10cm, 20 cm, 45cm and 0 cm of legumes from maize row respectively; Rhiz; Rhizobium, Leg; Legume, Cr Syst; Intercropping Systems. Values presented are means ± SE, n=4. *; **; *** = significant at P≤0.05, P≤0.01, P≤0.001 respectively, ns = not significant, SE = standard error. Means followed by dissimilar letter in a column are significantly different from each other at P=0.05 according to Fischer least significance difference (LSD).

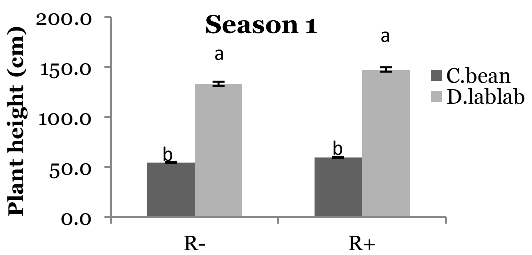
Table 4. Effects of *Rhizobium* inoculation and intercropping systems on number of pods per plant, number of seeds per plant, 100 seeds weight and grain yields of two legumes (*P. vulgaris L.* and *D. Lablab L.*) in two seasons.

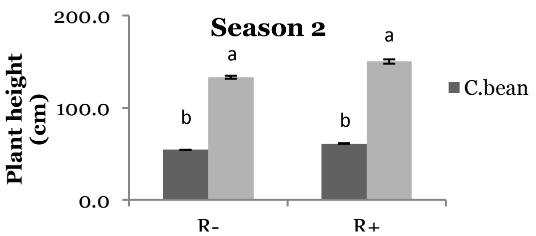
Treatments	Season 1				Season 2			
	Number of pods/plant	Number of seeds/pod	100 seeds weight (gm)	Grain yields Kg/ha	Number of pods/plant	Number of seeds/pod	100 seeds weight (gm)	Grain yields Kg/ha
Rhizobium								
R-	24.30 ±2.89b	3.21 ±0.07a	47.03 ±0.43b	1072.10 ±46.54b	26.12 ±2.88b	3.27 ±0.08b	46.62 ±0.55b	1061.06 ±48.91b
R+	35.60 ±4.53a	3.38 ±0.9a	51.22 ±0.38a	1221.63 ±57.09a	37.35 ±4.53a	3.47 ±0.09a	51.27 ±0.45a	1223.85 ±62.06a
Legumes								
1	7.18 ±0.23b	3.09 ±0.06b	51.36 ±0.37a	1448.53 ±31.62a	9.00 ±0.20b	3.15 ±0.06b	51.68 ±0.37a	1472.01 ±31.07a
2	52.73 ±1.96a	3.50 ±0.10a	46.89 ±0.39b	845.20 ±6.75b	54.47 ±1.97a	3.60 ±0.10a	46.21 ±0.51b	812.90 ±6.99b

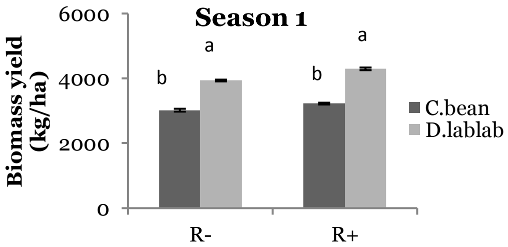
Treatments	Season 1				Season 2			
	Number of pods/plant	Number of seeds/pod	100 seeds weight (gm)	Grain yields Kg/ha	Number of pods/plant	Number of seeds/pod	100 seeds weight (gm)	Grain yields Kg/ha
Intercropping systems								
1	34.69 ±6.83a	3.55 ±0.15a	49.15 ±0.80a	1288.88 ±118.27a	36.44 ±6.86a	3.62 ±0.15a	49.50 ±1.02a	1283.90 ±121.61a
2	30.69 ±6.45b	3.31 ±0.15ab	49.28 ±0.79a	1107.50 ±71.48b	32.50 ±6.45b	3.37 ±0.15ab	49.21 ±0.97ab	1117.27 ±82.47b
3	28.94 ±6.08bc	3.31 ±0.15ab	49.10 ±0.85a	1118.38 ±73.83b	30.81 ±6.10bc	3.37 ±0.15ab	48.92 ±0.99ab	1108.02 ±79.84b
4	28.44 ±6.10bc	3.12 ±0.10b	49.06 ±0.88a	1100.94 ±69.53b	30.19 ±6.08bc	3.18 ±0.10b	48.84 ±0.96ab	1096.12 ±75.36b
5	27.00 ±5.80c	3.19 ±0.11b	49.04 ±0.87a	1118.63 ±77.78b	28.75 ±5.70c	3.31 ±0.12ab	48.26 ±1.07b	1106.97 ±86.42b
3 Way ANOVA (F statistics)								
Rhiz	229.55***	2.88ns	233.6***	112.27***	224.91***	3.84ns	152.14***	228.87***
Leg	3729.98***	17.00***	265.8***	1827.84***	3691.44***	19.44***	210.98***	3752.11***
Cr syst	12.59***	2.12ns	0.1ns	25.54***	12.44***	1.95ns	1.21ns	43.59***
Rhiz*Leg	192.58ns	0.10ns	0.0ns	27.44***	194.00ns	0.00ns	1.13ns	61.36***
Rhiz*Cr syst	0.15ns	4.65ns	0.8ns	0.69ns	0.266ns	4.59ns	0.10ns	2.16ns
Leg* Cr syst	3.58ns	1.41ns	0.0ns	25.38***	4.09ns	1.59ns	0.48ns	36.17***
Rhiz* Leg*Cr Syst	0.32ns	0.65ns	0.0ns	0.80ns	0.33ns	0.75ns	0.22ns	1.40ns

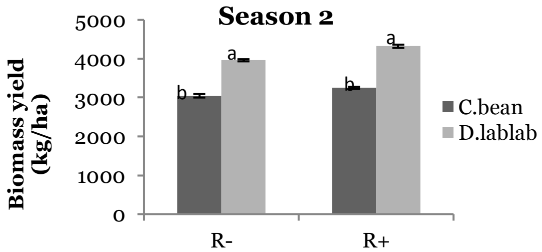
R-: Without Rhizobium, R+; With Rhizoubium, Legume 1: Common bean; Legume 2: D. Lablab; intercropping System 1, 2, 3, 4 and 5 are sole maize, 10cm, 20 cm, 45cm and 0 cm of legumes from maize row respectively; Rhiz; Rhizobium, Leg; Legume, Cr Syst; Intercropping Systems. Values presented are means ± SE, n=4. *; **; *** = significant at P≤0.05, P≤0.01, P≤0.001 respectively, ns = not significant, SE = standard error. Means followed by dissimilar letter in a column are significantly different from each other at P=0.05 according to Fischer least significance difference (LSD).

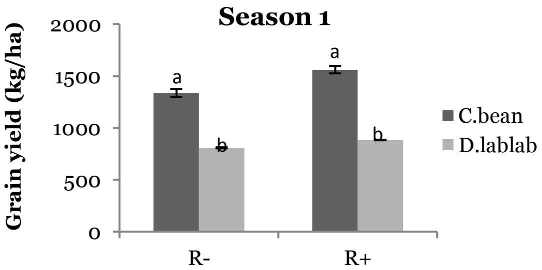
Interaction between *Rhizobium* and legumes had significant effect (P≤0.001) on plant height, biomass yield and grain yield for two seasons (Fig. 2). Interaction between legumes and cropping systems had significant effect (P≤0.001) on grain yield for two seasons. Legumes grain yields increased with the use of rhizobia in all cropping systems where cropping system 1 (sole crop) was superior to others (Fig. 3).











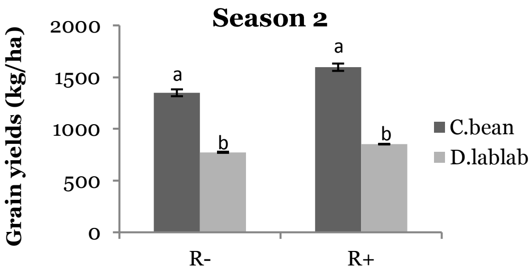


Fig. 2. Interactive effects of *Rhizobium* inoculation and legumes on plant height, biomass and grain yields for season 1 and 2 (R-: Without *Rhizobium*, R+: With *Rhizobium*, C. Bean: Common bean, D. lablab: Dolichos lablab).

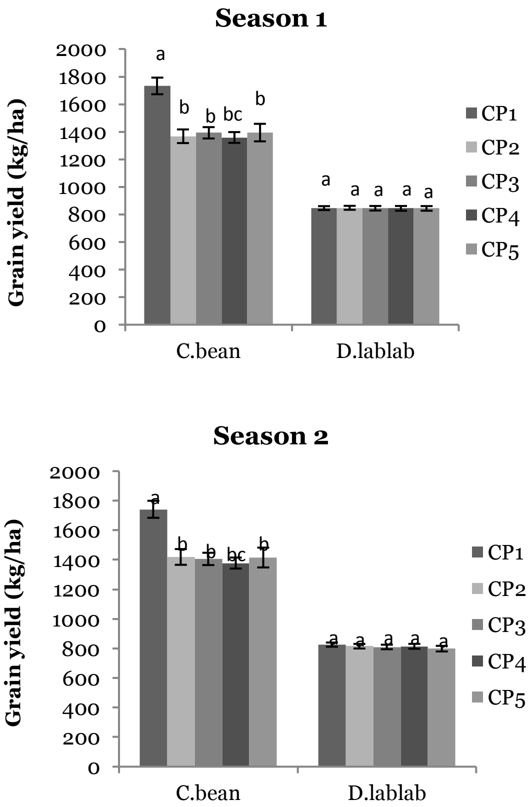


Fig. 3. Interactive effects of Legumes and cropping systems on grain yield for season 1 and 2 (CP1: Cropping system 1, CP2: Intercropping system 2, CP3: Intercropping system 3, CP4: Intercropping system 4, CP5: Intercropping system 5, C. Bean: Common bean, D. lablab: Dolichos lablab).

Discussion

The study findings report that legumes rhizobial inoculation significantly (P≤0.001) affected maize yield components and grain yields for two seasons. The observed increments in the plots with *Rhizobium* might be due to symbiotic relationship between *Rhizobum* and legumes root nodules which fix atmospheric nitrogen into a usable form used for the plant growth as reflected in the yield parameters. Studies by Ndakidemi and Semoka (2006) and Bambara and Ndakidemi (2010) reported that leguminous plants in association with *Rhizobium* are able to convert the atmospheric nitrogen into usable form which can be used by the maize plant in the intercrop. Plots intercropped with Dolichos lablab had highest maize yield components and grain yields than those intercropped with common bean. These could have been attributed by the release of biological nitrogen fixed by the legume for utilization by the maize crop because Dolichos lablab fixes more N than common bean (Lindemann and Glover, 2003).

Intercropping systems had significant effect (P≤0.001) on maize yield components and grain yield and showed the impact of competition for available growth resources such as water, nutrients, space, light and soil exploration for the two crops. Similar to our study, Alhaji (2008) reported that intercropping of different varieties of cowpea with maize was significant in affecting the yield components and grain yield of maize as determined by environmental factors and competition between the two crops (Lemlem, 2013), but these were high in the intercrop as compared with the sole maize.

The results from our study is in contrary to that of Moriri *et al.* (2010), because no nitrogen fertilizer was applied in sole cropping and the increased in grain yield in intercropping systems could have been attributed by presence of legume that conserve soil moisture and supply nitrogen to maize crop (From field observation). The yield similarity obtained in season 1 intercropping systems would suggest that maize yield might be affected in the next season as a subsequent crop in the same field because of residual nutrients release which would have been enhanced and set free for plant uptake during the previous season residue decomposition. The increase in yield components and final yield in season 2 of the present study have been confirmed in a study by Ledgard and

Giller (1995) that the benefits of an intercrop system between a legume and maize crop are more likely to occur to next crops yield as the main path-way transfer is due to root and nodule senescence and fallen leaves. Interaction between *Rhizobium* inoculations and intercropping systems had significant effect ($P \leq 0.001$) on maize plant height in two seasons. This implies that supplying *Rhizobium* to the legume in the cropping systems is an important if the maize growth parameters have to be realized.

The results further, indicate that *Rhizobium* inoculation had significant effect ($P \leq 0.001$) on yield components and grain yields of two legumes (*P. vulgaris* L. and *D. lablab* L.) in two seasons. Such significant increase in growth and yield due to *Rhizobial* inoculums have been reported in *Phaseolus vulgaris, Glycine max, Cajanus cajan*, *Cicer arietinum*, *Vigna unguiculata* and in *Arachis hypogea* (Mfilinge *et al.,* 2015). The increased yields were due to increased number of roots hairs and lateral roots induced by *rhizobial* inoculants thereby favouring N fixation and nutrient uptake by legumes (Biswas *et al.,* 2000). Similar to our study, the significant effect of *rhizobia* inoculation on legume yield and yield components have also been documented by (Tairo and Ndakidemi, 2013).

Where legumes were supplied with *rhizobium* had more yields attesting to be the suitable input for the intercrops. These results are similar to those of Mutungamiri *et al.* (2001) where yields of two inoculated legumes in the intercrops were generally higher than uninoculated. The *Rhizobium* inoculation influenced the leaf area in legumes which essentially create great canopy cover to the soil hence preserve more soil moisture for increased plant growth parameters. Intercropping systems were significant ($P \leq 0.001$) on yield components and grain yields. The increased in growth parameters were associated with closeness of intercropped *D. lablab and P. Vulgaris.* Ndung'u *et al.* (2005) reported that maize/common bean intercropping reduced common bean yield due to competition. Studies by Thobatsi (2009) and Saleem *et al.* (2011) also found similar results that intercropping maize with common bean, cowpea and soybean, respectively resulted in reduction of grain yields as compared to sole legumes.

Cropping system 1 (sole crop) had the highest yield components than other intercropping systems in two seasons due to minimum competition of both above and below growth resources plant in sole crop compared to intercrops (Hungria and Bohrer, 2000; Hefny and dolinski, 2001). Interaction between *Rhizobium* inoculation and legumes had significant effect ($P \leq 0.001$) on plant height, biomass yield and grain yield for two seasons. Also interaction between legumes and intercropping systems had significant effect ($P \leq 0.001$) on grain yield for two seasons. These interactions have been concluded by Fageria (2014) that, the increases in yield components and grain yield were due to the accumulation of N in plants.

Conclusion

Significant increase in yield components and final grain yields were recorded in maize/dolichos and maize/common bean intercrops with *Rhizobium* inoculation compared to sole system. The findings of this study indicate that *Rhizobium* and intercropping systems increased the overall grain yields of maize and intercropped legumes. The high grain yields obtained from the plots treated with *Rhizobium* suggests that the biofertilizers technology is an efficient supplier of N in the tested legumes. Therefore, these results strongly demonstrate the importance of using *Rhizobium* (biofertilizers) and cereal/legume intercropping systems as a substitute to expensive inorganic nitrogen fertilizers especially for poor resource farmers in the areas where land is scarce and productivity is low due to soil nutrients depletion.

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