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# ECONOMIC BENEFITS OF MAIZE AND LEGUMES (COMMON BEAN AND DOLICHOS LABLAB) INTERCROP AS INFLUENCED BY RHIZOBIAL INOCULATION

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**ABSTRACT**

This study was conducted to assess the economic benefits of maize-legumes intercrops as influenced by *Rhizobium* inoculation. To achieve this aim, field experiments were conducted at Selian Agricultural Research Institute (SARI) farm in northern Tanzania for two cropping seasons. A randomized complete block design was used in a 3-factorial arrangement with two levels of *Rhizobium* (with and without rhizobia), 2 legumes (*Phaseolus vulgaris* and *Lablab purpureus*) and 5 cropping 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). Economic analysis was done based on simple fiscal analysis. Land equivalent ratios (LERs) for maize-legumes intercrops were greater than 1 in both cropping seasons indicating resource use efficiency in intercrops compared with sole crop. The LERs in this study provided insight that, in order to produce the same yields of both legumes and maize in the separate, more than 100% of land will be required. The results further showed that *Rhizobium* inoculation significantly ($P \leq 0.001$) increased marginal net return (MNR) and marginal rate return (MRR) for both maize and legumes in the two cropping seasons. The intercrop maize was most profitable than sole maize with an increase of more than 25% compared with sole maize. In conclusion *Rhizobium* inoculation in the maize legumes intercrops resulted in superior and robust improvements in crop yields and therefore economic benefits, relative to the uninoculated plots. These led to high net return per dollar of investment and marginal returns in the intercropped plot followed by sole legumes.

**Keywords:** cropping systems, grain yield, land equivalent ratio, marginal net return, marginal rate return.

## INTRODUCTION

Intercropping system is an income augmenting measure from cereal-legumes field (Tsubo *et al.,* 2005). Farmers commonly intercrop to secure food production by averting risk, and to maximize utilisation of land and labour (Monicah *et al.,* 2010). Although intercrops reduce the yield of individual crop, the reduction is compensated by the collective yield and further increased the net profit to the farmer (Amanullah *et al.,* 2007). The higher gross return and dietary requirements have been achieved under intercropping than sole cropping. Amanullah *et al.* (2007) and Liu *et al.* (2006) reported that intercropping leads to better use of physical resources (solar radiation, mineral nutrients and water), provide high labour productivity than sole cropping and reduces risk as compared with sole cropping. In legume and non-legume association, the nutrient use efficiency is greater because of the ability of the legume to fix atmospheric N and made available later to associated non-legume, thus resulting in higher yield of non-legume than it is in sole crop yield (Ndakidemi, 2006; Amanullah *et al.,* 2007).

The long duration legumes such as pigeon pea and dolichos lablab offered a scope for accommodating intercrops in between rows, reduced the risk of dependence on a single crop, provided early and additional income and hence useful for small and subsistence farmers (Saleem *et al.,* 2015). The yield increase is not only due to improved nitrogen nutrition of the non-legume component, but also to other unknown causes (Takim, 2012). Competition among mixtures is thought to be a major aspect affecting yield as compared with sole cropping of cereals (Ndakidemi, 2006), and a number of indices such as land equivalent ratio and monetary advantages have been used to describe competition between component crops of intercropping systems (Takim, 2012). Land Equivalent Ratio (LER) is the tool used to study and evaluate intercropping systems. By using the LER concept, one is able to compare the production of the intercrop and express it relative to the yield from a sole crop system (Beets, 1982). LER indicates the yield advantage obtained by growing two or more crops as an intercrop compared with growing the same crops individually (Dariush, *et al.,* 2006). A study by Dhima *et al.* (2007) reported that the LER value of 1, indicates no difference in yield between the intercrop and the collection of monocultures while when LER is greater than 1, the intercropping favours the yield and economic output of the species. In contrast, when LER is lower than 1, the intercropping negatively affects the yield and (economic outputs) of plants grown in mixtures (Dhima *et al.,* 2007). Fiaban *et al.* (2008) reported that the LER verifies the effectiveness of intercropping for using the resources of the environment compared with sole cropping.

*Rhizobium* inoculation to legumes has been reported to stimulate root nodulation and increase biological nitrogen fixation eventually improving growth

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and yields of the legume crops (Dahmardeh *et al.,* 2010; Morad *et al.,* 2013) and the benefits are shared to the neighbouring crop through the improved soil N content (Nursima, 2009). Tairo and Ndakidemi (2013) and Mmbaga *et al.* (2015) reported that the use of beneficial soil bacteria in legume plants significantly increase the marginal rate of return and the grain yield of the intercropped crops. The economic analysis of various maize-legumes intercrops revealed that the performance of legume as intercrop was the most profitable one (Segun-Olasanmi and Bamire, 2010). The maximum economic benefits or the highest net return were obtained when cereal crops and legumes were planted at the same time under intercrops system (Vijay *et al.,* 2014).

Despite the lack of sufficient information about LERs and monetary benefit and their influence on component crops in intercropping, risk-averse smallholder farmers unabatedly continue growing crops in a mixture, which finally lowers the productivity of the system (Lawson, 2013). These necessitate the study to evaluate monetary advantages in the maize-legume intercropping systems and it is in light of this background that the present study called for in-depth look at LER and economic benefits of *rhizobium* inoculation in the maize-legume intercrop systems.

## 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 3º21'50.08" and Longitude 36º38'06.29"E at an elevation of 1390masl with mean annual rainfall of 870mm. The mean maximum temperature ranges from 22ºC to 28ºC whiles the mean minimum temperature ranges from 12ºC to 15ºC respectively.

### Experimental design and planting

Land preparation involved clearing, ploughing, layout and finally planting. The experimental design followed a randomized complete block design (RCBD) in a 3-factorial arrangement with 4 replications per treatment. The experimental treatments consisted of 2 levels of *Rhizobium* inoculation (with and without *Rhizobium*), 2 legumes (legume 1 being *Phaseolus vulgaris* and legume 2 being *Lablab purpureus*) and 5 cropping 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 × 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 × 0.2 m). The plots were interspaced by 1 m to allow management of crops. The first season crops were planted on 5$^{th}$ April, 2015 while the second season crops were planted on 14$^{th}$, 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 obtained 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 obtained from Selian Agricultural Research Institute-Arusha-Tanzania. Before sowing, the legume seeds were thoroughly mixed with *Rhizobium* inoculants to supply (109cells/gseed), following procedures stipulated by products manufacturer. To avoid contamination, the non-inoculated seeds were planted first followed with the inoculated seeds. Three seeds were planted and 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 other agronomic practices were done manually using hand hoe at different growth stages of the crop plant.

### Yield data collection

Grain yields were determined by harvesting a net plot area of 16m$^2$ of each treatment. Then the cobs/pods were threshed and the seed yield was determined by drying the seeds from each yield sample to a constant weight at 60$^0$C in an oven, weighing the sample with an electronic scale and then calculating grain yield in Kg/ha at 14% Moisture content.

### Assessment of the advantages of maize/legume intercropping system

An assessment of land return was made from the yield of pure stands and from each separate crop within the mixture. The calculated figure is called the Land Equivalent Ratio (LER), where intercrop yields are divided by the pure stand yields for each crop in the intercropping system and the two figures added together (Sullivan, 2003).

$$\text{LER} = \frac{\text{intercrop maize}}{\text{sole maize}} + \frac{\text{intercrop legume}}{\text{sole legume}}$$

The land equivalent ratio (LER) was used as the first criterion for mixed stand advantage for both legumes (common bean and dolichos lablab) and cereal (maize) (Fiaban *et al*., 2008).

### Economic analysis

Assessment of the profitability of tested technologies in the production of maize-legumes was based on simple fiscal analysis. To achieve this, marginal net return (MNR) was calculated for every treatment using the formula:

$$\text{Profit (MNR)} = Y \times P - \text{TVC}$$

Where Y is total yield of maize or legumes grain (Kg/ha), P denote the selling price at farm gate (USD/kg) and TVC is the total variable costs being the cost of all the inputs involved in the experiment. It involves all costs related to production including; labour, fertilizers, seeds etc.

The selling price at farm gate was estimated to be Tsh. 1, 900/= equivalent to US$0.86/kg, for common bean variety Lyamungo 90, Tshs. 2,800/= equivalent to US$1.27/kg, for dolichos lablab variety Rongai and Tshs. 550/= equivalent to US$0.25/kg for maize. An exchange rate of 2,200 Tanzania shillings to 1 USD (June 2016) was used. Thus the marginal rate of return (MRR) was computed using the formula:

$$MRR = MNR / TVC$$

**Table-1.** Input cost and labour charges for farming operation.

| **Input / Labour** | **Unit &/ Amount** | **Unit cost** (T.shs.) | **Total cost** (T.shs.) | **Total cost** (US$) |
|---|---|---|---|---|
| Common bean seeds variety Lyamungo 90 | 15 kg | 2,500 | 37,500 | 17.1 |
| Dolichos lablab seeds variety Rongai | 15 kg | 3,000 | 45,000 | 20.4 |
| Maize seeds variety SEEDCO 503 | 12 kg | 5,500 | 66,000 | 30 |
| Inoculants: BIOFIX legume inoculants | 4 packets | 2,500 | 10,000 | 4.56 |
| Fertilizer (TSP) | 1 bag | 65,000 | 65,000 | 29.55 |
| Land hiring | 1 hectare | 90,000 | 90,000 | 40.91 |
| Land preparation | Tractor | 65,000 | 65,000 | 29.55 |
| Planting per hectare (sole+intercrop) | 8 | 10,000 | 80,000 | 36.36 |
| Weeding 3 rounds (sole+intercrop) | 14 | 10,000 | 140,000 | 63.64 |
| Crop harvesting per hectare (sole+intercrop) | 5 | 10,000 | 100,000 | 45.45 |
| Threshing and processing /100kg (sole+intercrop) | 8 | 10,000 | 80,000 | 36.36 |
| Fertilizer application: | | | | |
| Rhizobial inoculation | 2 | 10,000 | 20,000 | 9.09 |
| 20kg P (sole+intercrop) | 3 | 10,000 | 30,000 | 13.64 |
| Total | | | 828,500 | 376.61 |

**Data analysis**

A 3-way ANOVA was used to analyze the data collected. The analysis was done using STATISTICA software program 2010. Fisher's least significant difference was used to compare treatment means (Steel and Torrie, 1980), at 5% level of probability.

**RESULTS**

Results indicate that the highest maize yield was obtained from 0.45 m of legume from maize row intercropping combinations while the lowest one was from sole maize. The highest legume yield was from sole planting and the lowest one was from 0.45 m of legume from maize row intercropping combinations (Table-2). Intercropping of maize with legumes at a mix-proportion of 2 rows of legumes to 2 rows of maize (1:1) or 1 row of legumes to 2 rows of maize (1:2) planting patterns gave higher yield for both cropping seasons (Table-2). The partial $LER_{maize}$ was lower in sole maize compared with intercrops while partial $LER_{legume}$ was higher in sole legume compared with intercrops (Table-2). It is expected that, partial LER of legumes decreased as the proportion of maize increased in mix-proportions. The partial $LER_{maize}$ is higher than 1 in intercrops compared with sole crop while the partial $LER_{legume}$ is lower than 1 but close to 1 in intercrops compared with sole crop (Table-2). Maximum and minimum LERs of 2.119 and 2.063 for season 1 and 2.115 and 2.058 for season 2 were attained when 0.2 m of legume from maize row and 0 m of legume from maize row intercropping combinations were used, respectively (Table-2).

*Rhizobium* inoculation, legumes and intercropping systems resulted into increased marginal net of return (MNR) and marginal rate of return (MRR) in maize crop for both season except for sole maize crop in cropping season 1 as indicated in Table-3. The results show that *Rhizobium* inoculation result to an increase of 27.8% and 17.3% MNR, 28.6% and 17% MRR of maize relative to un-inoculated treatments for cropping season 1 and 2, respectively. Dolichos lablab-maize intercrop increased the maize MNR by 29.5% and 18.4%, MRR by 28.6% and 20.4% compared with common bean in cropping season 1 and 2, respectively. Intercropping systems increased the maize MNR by 110.1% and 70.5%, MRR by 191.2% and 73.3% compared with sole maize in cropping season 1 and 2, respectively.

*Rhizobium* inoculation increased marginal net of return (MNR) and marginal rate of return (MRR) of legumes for both cropping seasons (Table-4). The MNR increased by 14.4% and 15.8% while MRR increased by 10.9% and 12.4% relative to un-inoculated treatments for cropping season 1 and 2, respectively. Common bean had

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the highest MNR of 19% and 25%, MRR of 20% and 25.7% than Dolichos lablab in cropping season 1 and 2, respectively. Sole legumes had the MNR of 16.9% and 17.2%, MRR of 16.7% and 17.5% higher than all intercropping systems for season 1 and 2 respectively.

The results indicated significant (P≤0.001) interactive effect between *Rhizobium* inoculation and legumes; legumes and cropping systems on legumes marginal net return and marginal rate return for both cropping seasons (Figures 1-4).

Generally, the total labour cost was very little affected by the cropping systems but labour requirements for the different operations differed. Sole cropping required about 30% less labour for planting and 20% more labour for weeding (data not shown). In both cropping seasons, the cropping systems with the common bean was highly profitable than those with dolichos lablab because of high yields and high price in the market.

**Table-2.** Grains yield (Kg/ha) and land equivalent ratios of maize and legume in sole crops and intercrop systems for two cropping seasons.

| | **Cropping season 1** | | | | | **Cropping season 2** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **Yields** (Kg/ha) | | **Partial LERs** | | **Total LERs** | **Yields** (Kg/ha) | | **Partial LERs** | | **Total LERs** |
| | **Maize** | **Legume** | **Maize** | **Legume** | | **Maize** | **Legume** | **Maize** | **Legume** | |
| Sole maize | 812.25 | | 1.0 | | 1.0 | 973.64 | | 1.0 | | 1.0 |
| Sole legume | | 1288.88 | | 1.0 | 1.0 | | 1283.90 | | 1.0 | 1.0 |
| 0.1 m of legume from maize row | 997.06 | 1107.5 | 1.228 | 0.859 | 2.086 | 1195.18 | 1117.27 | 1.228 | 0.870 | 2.098 |
| 0.2 m of legume from maize row | 1017.13 | 1118.38 | 1.252 | 0.868 | 2.119 | 1219.23 | 1108.02 | 1.252 | 0.863 | 2.115 |
| 0.45 m of legume from maize row | 1022.00 | 1100.94 | 1.258 | 0.854 | 2.112 | 1225.07 | 1096.12 | 1.258 | 0.854 | 2.112 |
| 0 m of legume from maize row | 970.94 | 1118.63 | 1.212 | 0.868 | 2.063 | 1163.86 | 1106.97 | 1.195 | 0.862 | 2.058 |

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**Table-3.** Effects of *Rhizobium* inoculation, legumes and cropping systems on profitability and marginal rate of return (MRR) of maize for two cropping seasons.

| Treatments | | | Season 1 | | Season 2 | |
|---|---|---|---|---|---|---|
| | **MNR** (US$/ha) | **TVC** (US$/ha) | **MRR** (US$/ha) | **MNR** (US$/ha) | **TVC** (US$/ha) | **MRR** (US$/ha) |
| Rhizobium | | | | | | |
| $R^-$ | 38.55±4.31b | 195.00±1.17a | 0.20±0.02b | 84.95±4.98b | 195.00±1.17a | 0.44±0.02b |
| $R^+$ | 53.39±6.63a | 195.00±1.17a | 0.28±0.03a | 102.74±6.55a | 195.00±1.17a | 0.53±0.04a |
| Legumes | | | | | | |
| 1 | 38.03±4.55b | 195.00±1.17a | 0.20±0.02b | 84.33±5.26b | 195.00±1.17a | 0.43±0.03b |
| 2 | 53.91±5.41a | 195.00±1.17a | 0.28±0.03a | 103.37±6.29a | 195.00±1.17a | 0.54±0.03a |
| Cropping systems | | | | | | |
| 1 | 1.81±0.86c | 201.26±0.0a | 0.01±0.02c | 42.16±1.03c | 201.26±0.0 a | 0.21±0.01c |
| 2 | 57.91±4.99ab | 191.36±0.0b | 0.30±0.03ab | 107.43±5.98ab | 191.36±0.0b | 0.56±0.03ab |
| 3 | 62.92±4.86a | 191.36±0.0b | 0.33±0.03a | 113.45±5.83a | 191.36±0.0b | 0.59±0.03a |
| 4 | 64.14±4.66a | 191.36±0.0b | 0.34±0.02a | 114.91±5.59a | 191.36±0.0b | 0.60±0.03a |
| 5 | 51.37±6.19b | 191.36±0.0b | 0.27±0.03b | 99.61±7.42b | 191.36±0.0b | 0.52±0.04b |
| 3-Way ANOVA (F-statistic) | | | | | | |
| Rhiz | 17.88*** | 0.0ns | 17.89*** | 17.88*** | 0.0ns | 17.89*** |
| Leg | 20.50*** | 0.0ns | 20.26*** | 20.50*** | 0.0ns | 20.26*** |
| Cr syst | 57.54*** | 0.0*** | 56.61*** | 52.52*** | 0.0*** | 56.61*** |
| Rhiz*Leg | 0.55ns | 0.0ns | 0.55ns | 0.55ns | 0.0ns | 0.56ns |
| Rhiz*Cr syst | 1.29ns | 0.0ns | 1.29ns | 1.29ns | 0.0ns | 1.29ns |
| Leg* Cr syst | 0.57ns | 0.0ns | 0.61ns | 0.57ns | 0.0ns | 0.61ns |
| Rhiz* Leg*Cr Syst | 0.05ns | 0.0ns | 0.05ns | 0.05ns | 0.0ns | 0.05ns |

$R^-$; Without *Rhizobium*, $R^+$; With *Rhizobium*, Legume 1: *Phaseolus vulgaris*; Legume 2: *Lablab purpureus*; Cropping System 1, 2, 3, 4 and 5 are sole maize, 0.1 m, 0.2 m, 0.45 m and 0 m spacing of legumes from maize row, respectively; Rhiz; *Rhizobium*, Leg; Legume, Cr Syst; Cropping Systems. Values presented are means ± SE, n=4. *** = significant at $p \leq 0.001$ respectively, ns = not significant, SE = standard error. Means followed by dissimilar letter(s) in a column are significantly different from each other at p=0.05 according to Fischer least significance difference (LSD)

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**Table-4.** Effects of *Rhizobium* inoculation and cropping systems on profitability and marginal rate of return (MRR) of legumes (*Phaseolus vulgaris* and *Lablab purpureus*) for two cropping seasons.

| Treatments | | | Season 1 | | Season 2 | |
|---|---|---|---|---|---|---|
| | **MNR** (US$/ha) | **TVC** (US$/ha) | **MRR** (US$/ha) | **MNR** (US$/ha) | **TVC** (US$/ha) | **MRR** (US$/ha) |
| Rhizobium | | | | | | |
| $R^-$ | 773.31±19.59b | 314.21±0.26b | 2.46±0.06b | 756.90±20.44b | 314.21±0.26b | 2.41±0.07b |
| $R^+$ | 903.75±23.63a | 327.86±0.26a | 2.76±0.07a | 899.34±27.96a | 327.86±0.26a | 2.75±0.09a |
| Legumes | | | | | | |
| 1 | 926.35±26.59a | 319.39±1.09a | 2.90±0.08a | 946.55±26.04a | 319.39±1.09a | 2.96±0.08a |
| 2 | 750.72±7.60b | 322.69±1.09a | 2.32±0.02b | 709.70±7.91b | 322.69±1.09a | 2.20±0.02b |
| Cropping systems | | | | | | |
| 1 | 960.78±59.74a | 321.04±1.81 a | 2.99±0.19a | 952.48±63.10a | 321.04±1.81 a | 2.97±0.20a |
| 2 | 805.26±24.84b | 321.04±1.81a | 2.51±0.07b | 806.94±33.25b | 321.04±1.81a | 2.51±0.10b |
| 3 | 813.94±24.71b | 321.04±1.81a | 2.53±0.07b | 797.97±29.90b | 321.04±1.81a | 2.48±0.09b |
| 4 | 798.77±21.96b | 321.04±1.81a | 2.49±0.06b | 788.58±26.11b | 321.04±1.81a | 2.45±0.08b |
| 5 | 813.93±31.71b | 321.04±1.81a | 2.53±0.09b | 794.68±39.08b | 321.04±1.81a | 2.47±0.12b |
| 3-Way ANOVA (F-statistic) | | | | | | |
| Rhiz | 108.52*** | 2.03*** | 56.19*** | 207.64*** | 2.03*** | 121.42*** |
| Leg | 196.74*** | 9.18ns | 208.98*** | 601.76*** | 9.18ns | 126.67*** |
| Cr syst | 24.04*** | 5.36ns | 23.74*** | 41.85*** | 5.36ns | 41.34*** |
| Rhiz*Leg | 14.74*** | 0.0ns | 12.41*** | 34.12*** | 0.0ns | 28.13*** |
| Rhiz*Cr syst | 0.65ns | 0.0ns | 0.69ns | 2.21ns | 0.0ns | 2.16ns |
| Leg* Cr syst | 23.81*** | 0.0ns | 23.45*** | 31.78*** | 0.0ns | 31.37*** |
| Rhiz* Leg*Cr Syst | 0.80ns | 0.0ns | 0.76ns | 1.19ns | 0.0ns | 1.04ns |

$R^-$; Without *Rhizobium*, $R^+$; With *Rhizobium*, Legume 1: *Phaseolus. vulgaris*; Legume 2: *Lablab purpureus*; Cropping System 1, 2, 3, 4 and 5 are sole maize, 0.1 m, 0.2 m, 0.45 m and 0 m spacing of legumes from maize row, respectively; Rhiz; *Rhizobium*, Leg; Legume, Cr Syst; Cropping Systems. Values presented are means ± SE, n=4. *** = significant at p≤0.001 respectively, ns = not significant, SE = standard error. Means followed by dissimilar letter(s) in a column are significantly different from each other at p=0.05 according to Fischer least significance difference (LSD)

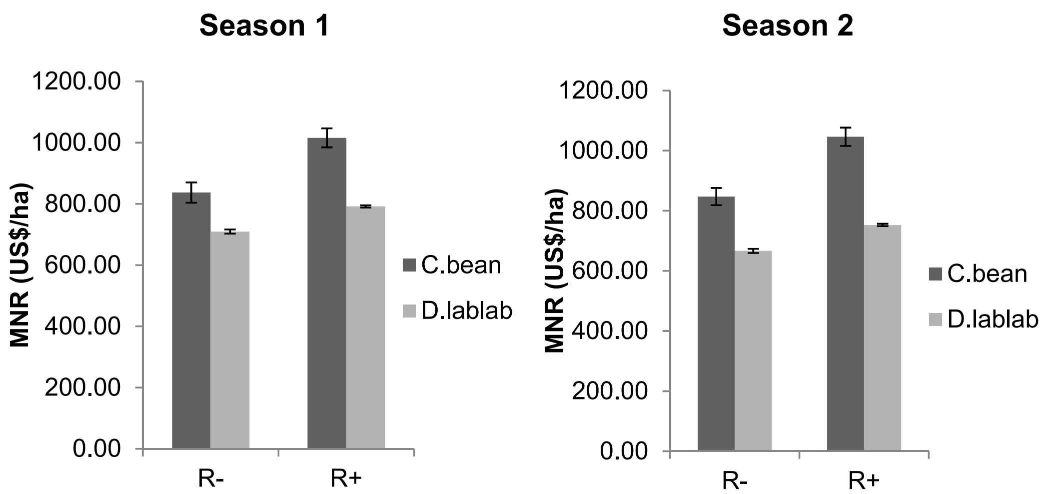


**Figure-1.** Interactive effects between *Rhizobium* inoculation and legumes on Marginal Net Return (MNR) for two cropping seasons ($R^-$: Without *Rhizobium*, $R^+$: With *Rhizobium*, C. Bean: Common bean, D. lablab: Dolichos lablab).

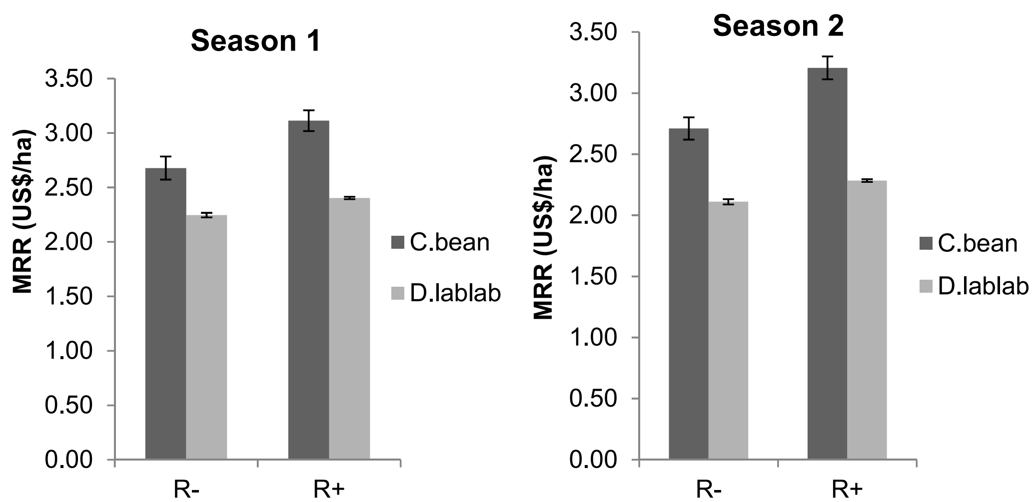


**Figure-2.** Interactive effects between *Rhizobium* inoculation and legumes on Marginal Rate Return (MRR) for two cropping seasons ($R^-$: Without *Rhizobium*, $R^+$: With *Rhizobium*, C. Bean: Common bean, D. lablab: Dolichos lablab).

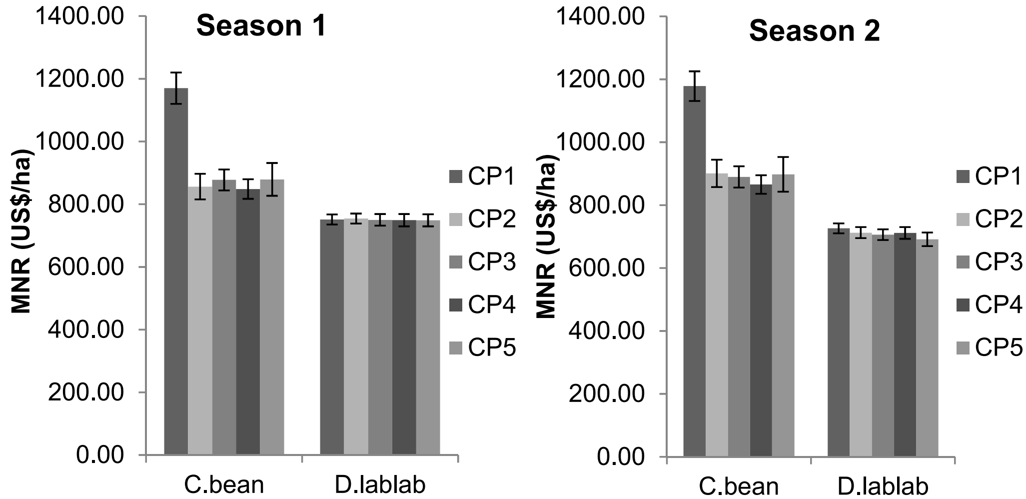


**Figure-3.** Interactive effects between legumes and cropping systems on Marginal Net Return (MNR) for two cropping seasons (CP1: Cropping system 1, CP2: Intercropping system 2, CP3: Intercropping system 3, CP4: Intercropping system 4, CP5: Intercropping system 5, C. Bean: Common bean, D. lablab: Dolichos lablab).

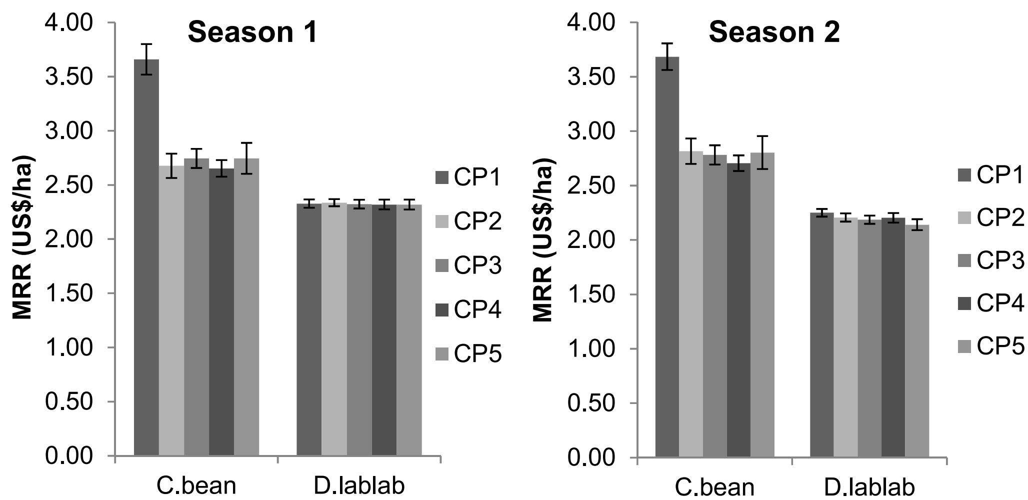


**Figure-4.** Interactive effects between legumes and cropping systems on Marginal Rate Return (MRR) for two cropping seasons (CP1: Cropping system 1, CP2: Intercropping system 2, CP3: Intercropping system 3, CP4: Intercropping system 4, CP5: Intercropping system 5, C. Bean: Common bean, D. lablab: Dolichos lablab).

## DISCUSSIONS

The results from this study showed that maize intercropped with legumes yielded higher than sole cropping maize. The reason for increased yield in intercropped maize may be attributed to nitrogen fixing ability of legumes (Chen *et al.,* 2004), as opposed to sole maize where no N fertilizer was applied. The partial LERs for maize intercrops were greater than one while the legumes had less than one. This indicate that maize compete more than legumes in the intercrops for growth resources than when is grown in the sole systems (Sharma and Behera, 2009). However the higher maize partial LERs would also have been attributed by legumes biological nitrogen fixation and soil moisture conservation in the intercrops that were availed to maize crop compared with sole maize crop (Ashish *et al.,* 2015). The land equivalent ratio indices were the greatest in maize component of the intercropping systems. The total LER values were higher than one showing the advantage of intercropping over sole cropping in regard to the use of environmental resources for plant growth (Chen *et al.,* 2004). Prasad and Brook (2005) and Takim (2012) reported LERs of intercrops of greater than unity (1.30 to 1.45), indicating higher efficiency of intercropping compared with intercrops. In both cropping seasons, the agronomic advantage of maize and legumes measured in

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terms of LER for grain yield of all intercropping treatments was greater than unity, indicating higher land use efficiency of intercrops compared with the sole crops. Overall, the LERs of all treatments for grain production were slightly higher in the season 1 than in the season 2 with values for grain ranging from 2.063 to 2.119 in season 1 and 2.058 to 2.115 in season 2. These indicated that any combination of legumes with maize increased land use efficiency by more than 100%. Chen *et al.* (2004) and Hauggaard-Nielsen *et al.* (2001) reported the similar results on pea-barley, maize-faba bean and bean-wheat intercrops. The land equivalent ratio indices were the greatest in maize legumes at all the mix-proportion, indicating that for the same amount of grain yield more land area would be required for sole cropping system compared with intercropping. Searle *et al.* (1981) reported that yield levels of intercropped cereals were similar to the sole crop, indicating little competition from legumes, and therefore the potential for additional productivity from the legume component in intercropping systems.

The economic analysis of this study indicated that *Rhizobium* inoculated plots significantly ($P \leq 0.001$) increased the marginal net return (net profit) and marginal rate of return over un-inoculated treatments. A study by Santalla *et al.* (2001) indicated more net income in the maize-legumes intercrop compared with sole cropping of maize. Higher grain yield and net income under planting pattern with changing mix-proportions may be explained in higher total productivity under intercropping with relatively less input investment (Banik *et al.,* 2006). When maize crop was intercropped with dolichos lablab gave the highest marginal net return and marginal rate return than common bean. This was because dolichos lablab had broad leaves which conserved more soil moisture (from field observation), high ability to fix more nitrogen and being late maturity than common bean. Lawson (2013) reported that as legumes maturity are delayed, the maize developed competitive potential which out-competed the legumes for space and light leading to more returns of intercropped maize. This study suggests that intercropping maize with *Rhizobium* inoculated legumes generated greater economic returns than pure-stand maize in both cropping seasons. Legumes were the most promising pure-stand and were economically superior to the one in the intercrops. An overall, net benefit of intercropped *Rhizobium* inoculated legumes with supplement of maize was economically more profitable for both pure-stand maize and maize intercrops. The intercropped maize gave the highest net benefits while the sole maize gave the lowest net benefits. These were opposite in the intercropped legumes where the net benefits were from intercrops and the lowest benefits were from sole legumes. Highest net return and marginal rate of return were obtained from maize-legumes intercrops. The intercrop system was economically feasible relative to sole crop maize and sole legumes as reported from different intercrop studies including Segun-Olasanmi and Bamire (2010); Ndakidemi and Dakora (2007) (maize-cowpea), Addo-Quaye *et al. (*2011) (maize-soybean), and Abera *et al*. (2016) (maize-common bean). However, the monetary advantage from the intercrop system decreased as labor cost to legume grain price ratio increased. Interaction between *Rhizobium* and legumes occurred when rhizobial strains form effective symbioses as they interact with their own specific host legumes (Denison and Kiers, 2004). This contributes to maximum nitrogen fixation which led to more marginal rate and net returns as observed in the present study. Although legumes had lower yield in the mixture but are more expensive in markets, sole planting of them would not reach the profitable level gained with maize and legumes. The LER significantly affect the efficiency of intercropping as confirmed by the economic and land use efficiency values.

The results indicated significant interactive effect between *Rhizobium* and legumes; legumes and cropping systems on MNR and MRR for both cropping seasons (Figures 1-4). This means that using rhizobial inoculants in intercropping legumes with maize consistently resulted in higher net benefits, marginal rate of returns and returns per $US investment than sole cropping.

## CONCLUSIONS

We conclude that intercropping of maize with *Rhizobium* inoculated common bean or dolichos lablab in different planting patterns may affect grain yield, competition between the crops (maize and legumes), and economics returns as compared with sole cropping of the same crops. Regardless of planting patterns, maize-legumes intercropping had the highest yield advantages with optimum exploitation of the land and environmental resources. These led to higher profitability, suggesting potential increase in household incomes.

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## REFERENCES

Abera H., K. Mesfin and S. Adera. 2016. Maize (*Zea mays* L.) -Common Bean (*Phaseolus vulgaris* L.) intercropping response to population density of component crop in Wolaita Zone Southern Ethiopia. J. Nat. Sci. Res. 6: 15.

Addo-Quaye A. A., A. A. Darkwa and G. K. Ocloo. 2011. Yield and productivity of component crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement. J. Agric. Biol. Sci. 6: 50-57.

Amanullah M. M., E. Somasundaram, K. Vaiyapuri and K. Sathyamoorthi. 2007. Intercropping in cassava. Agric. Rev. 28: 179-187.

Ashish D., D. Ista, K. Vineet, S. Y. Rajveer, Y. Mohit, G. Dileep, S. Adesh. and S. S. Tomar. 2015. Potential Role of Maize-Legume Intercropping Systems to Improve Soil Fertility Status under Smallholder Farming Systems for

Sustainable Agriculture in India. Interl. J. Life Sci. Biotech. Pharma Res. 4: 3.

Banik P., A. Midya, B. K. Sarkar and S. S. Ghose. 2006. Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. Eur. J. Agron. 24: 325-332.

Beets W. C. 1982. Multiple cropping and tropical farming systems. Westview Press, Boulder. pp. 156.

Chen C., M. Westcott, K. Neill, D. Wichman and M. Knox. 2004. Row configuration and nitrogen application for barley-pea intercropping in Montana. Agron. J. 96: 1730-1738.

Dahmardeh M., A. Ghanbari, B. Syahsar and M, Ramrodi. 2010. The role of intercropping maize (*Zea mays L.*) and Cowpea (*Vigna unguiculata L.*) on yield and soil chemical properties. Afr. J. Agric. Res. 5: 631-636.

Dariush M., M. Ahad and O. Meysam. 2006. Assessing the land equivalent ratio (LER) of two corn (*Zea mays L.*) varieties intercropping at various nitrogen levels in Karaj, Iran, J. Centr. Eur. Agric. 7: 359-364

Denison R.F. and Kiers E.T. 2004, Lifestyle alternatives for rhizobia. Mutualism, parasitism, and forgoing symbiosis. FEMS Microbiol. Letters 237: 187-193.

Dhima K. U., A. A. Lithourgidis, I. B. Vasilakoqlou and C. A. Dordas. 2007. Competition indices of common vetch and cereals intercropping in two seeding ratio. Field Crops Res. 100: 249-258.

Fiaban Y., A. Mehmet and E. Mustafa 2008. Identification of Advantages of Maize-Legume Intercropping over Solitary Cropping through Competition Indices in the East Mediterranean Region. Turk. J. Agric. For. 32: 111-119

Hauggard-Nielson H., P. Ambus and E. S. Jensen. 2001. Evaluating pea and barley cultivars for complementary in intercropping at different levels of soil N availability. Field Crops Res. 72: 185-196.

Lawson Y. D., A. Issahaku, S. K. Acheampong, B. Adams and V. Tuffour. 2013. Time of planting and weed suppression abilities of some legumes intercropped with maize in the Guinea savanna zone of Ghana. Agric. Biol. J. North Amer. 4: 358-363.

Liu J. H., Z. H. Zeng, L. X. Jiao, Y. G. Hu, Y. Wang and H. Li. 2006. Intercropping of different silage maize cultivars and alfalfa. Acta. Agron. Sci. 32: 125- 130.

Mmbaga G. W., K. M. Mtei, and P. A. Ndakidemi. 2015. Yield and Fiscal Benefits of *Rhizobium* Inoculation Supplemented with Phosphorus (P) and Potassium (K) in Climbing Beans (*Phaseolus vulgaris* L.) Grown in Northern Tanzania. Agric. Sci. 6: 783-797.

Monicah M., P. Pieter, M. Daniel, K. James, M. Jayne, M. Roel and V. Bernard. 2010. A staggered maize–legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya. Field. Crops. Res. 115: 132-139.

Morad M., S. Sara, E. Alireza, C. M. Reza and D. Mohammad. 2013. Effects of seed inoculation by *Rhizobium* strains on yield and yield components in common bean cultivars (*Phaseolus vulgaris* L.). Intl. J. Biosci. 3: 134-141.

Ndakidemi P. A. and F. D. Dakora. 2007. Yield components of nodulated cowpea (*Vigna unguiculata*) and maize (*Zea mays*) plants grown with exogenous P in different cropping systems. Austr. J. Exper. Agric. 47: 583-589.

Ndakidemi P.A. 2006. Manipulating legume/cereal mixtures to optimize the above and below ground interactions in the traditional African cropping systems. Afri. J. Biotechn. 5: 2526-2533.

Nursima K. A. 2009. Profitability of intercropping corn with mungbean and peanut. USM R & D. J. 17: 65-70.

Prasad R. B. and R. M. Brook. 2005. Effect of varying maize densities on intercropped maize and soybean in nepal. Experl. Agric. 41: 365-382.

Saleem R., Z. I. Ahmad, M. A. Anees, A. Razzaq and A. Saleem. 2015. Productivity and land use efficiency of maize-mungbean intercropping under different fertility treatments. Sarhad. J. Agric. 31: 37-44.

Santalla M., A.P. Rodino, P.A. Casquero and A.M. de Ron. 2001. Interactions of bush bean intercropped with field and sweet corn. Eur. J. Agron. 15: 185-196.

Searle P. G., Y. Comudon, D. Sheddon and R. A. Nance. 1981. Effect of maize and legume intercropping system and fertilizer nitrogen on crop yields and residual nitrogen. Field Crops Res. 4: 133-45.

Segun-Olasanmi A.O. and A.S. Bamire. 2010. Analysis of costs and returns to maize-cowpea intercrop production in Oyo state, Nigeria. Poster presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010.

Sharma A. R. and U. K. Behera. 2009. Recycling of legume residues for nitrogen economy and higher productivity in maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system. Nutr. Cycl. Cropping Syst. 83: 197-210.

Steel R. G. D. and J. H. Torrie. 1980. Principles and procedures of statistics: A biometrical approach, Second Edition. McGraw Hill, New York.

Sullivan P. 2003. *Intercropping principles and production practices*. Appropriate Technology Transfer for Rural Areas Publication. Retrieved from http://www.attra.ncat.org.

Tairo E. V. and P. A. Ndakidemi. 2013. Yields and economic benefits of soybean (*Glycine max* L.) as affected by *Bradyrhizobium japonicum* inoculation and phosphorus supplementation. Amer. J. Res. Comm. 1: 159-172.

Takim F. O. 2012. Advantages of Maize-Cowpea Intercropping over Sole Cropping through Competition Indices. J. Agric and Biodivers. Res.. 1: 53-59

Tsubo M., S. Walker and H. O. Ogindo. 2005. A simulation model of cereal-legume intercropping systems for semi-arid regions I. Model development. Field. Crops. Res. 93: 10-22.

Vijay K. C., D. Anil, S. K. Paramasivam and S. C. Bhagirath 2014. Productivity, Weed Dynamics, Nutrient Mining, and Monetary Advantage of Maize-Legume Intercropping in the Eastern Himalayan Region of India. Plant Prod. Sci. 17: 342-352.