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Effect of different planting proportions and nitrogen fertilizer in intercropping forage sorghum and lima bean

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In order to study the effect of intercropping on forage yield of sorghum and yield components of lima bean at different planting proportions and nitrogen fertilizer levels, an experiment was conducted at the research farm of University of Tehran in the year of 2010. This experiment was arranged in a split plot design with four replications. The main factor consisted of four nitrogen application treatments, and second factor consisted of seven different planting proportions including pure stands of each crop with replacement and additive series. Quantitative attributes such as dry weights of sorghum, yield and yield component of lima bean were measured in two sampling during growth season. The highest fresh and dry weight of sorghum fodder belonged to additive proportions of sorghum. Nitrogen application treatments had significant effect on sorghum total dry matter of fodder (160 urea kgha^{-1}) and total yield of lima bean (80 urea kha^{-1}) seed. Evaluation of Land Equivalent Ratio (LER) indicated that the highest LER obtained in the combination of 100% sorghum and 20% lima bean which indicates the advantage of intercropping (LER = 1.25).

Key words: Intercropping, additive series, replacement series, land equivalent ratio.

INTRODUCTION

Researchers put emphasis on the relation between biodiversity and sustainability in as much as a marginal increase in diversity will enhance the complexity and productivity of ecosystem (Burel and Baudry, 1995; McLaughlin and Mineau, 1995). Effective utilization of resources and improving crop productivity makes intercropping to play an important role in agriculture (Yang et al., 1999). Inter and intra-specific competition determines the degree of resource complementarily; however, the availability of environmental resources and the relative frequency of the species and the density of components inevitably influence competition. Yield advantage occurs when inter- specific competition is less than intra-specific competition in other mean the components of intercrop compete only partly for the same growth resources (Vandermeer, 1992; Willey, 1985). Intercropping cereal and legumes is a practice in which the N fixed by the latter enhances the qualitative and quantitative traits of the former to finally reaching food security and sustainability (Swaminathan, 1998). The efficiency of such cropping systems is expressed as land equivalent ratio (LER) in which the application of different levels of nitrogen fertilizers affects its increasing, decreasing and unchanging trend (Ghanbari and Lee, 2003). Just as providing enough nitrogen optimizes the yield potential, disregarding proper management like

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applying excessive amount of N fertilizer proves disagreeable outcome, so determining proper nitrogen fertilizer rate in order to produce more forage and to reduce environmental hazard must be taken into consideration (Jaynes et al., 2001). Production of forage sorghum with applying little amount of N fertilizer is manageable, but this crop displays a great deal of reaction in response to applied nitrogen (Ram and Sing, 2001).

Considering soil fertility, weather conditions and the species, the rate of consumption for N fertilizer by farmers varies from 45 to 224 $kgha^{-1}$ (Zhao et al., 2005). Forage sorghum displayed a positive reaction to increasing nitrogen to about 200 $kgha^{-1}$ but further application had no effect on yield increase (Gupta and Sing, 1988). Although, sorghum utilizes nitrogen more efficiently than corn and is more resistant to drought and higher temperatures (Young and Long, 2000) but inadequacy of N fertilizer reduces congregation of dry matter and leads to growth reduction (Zhao et al., 2005). The legume typically suffers competition from the cereal which results in lower yield in intercropping compared with sole-cropping; moreover addition of N fertilizer may impede the growth due to greater competition from increased cereal growth (Searle et al., 1981; Chui and Shibles, 1984; Ofori and Stern, 1986; Rao et al., 1987). Replacement series are intercrop patterns in which the total density is kept constant although the proportion of each species varies proper to its recommended sole-cropping and in additive series the species are grown in a way that the overall density exceeds 100% which induces the most productive intercrops (Fukai and Trenbath, 1993). Lima bean can be grown in a wide range of ecological conditions from warm temperate zones as well as arid and semi arid tropical regions. Intercropping lima bean with maize or sorghum and its sole-cropping is common in Africa (Brink and Belay, 2006).

Utilizing forage sorghum is being practiced recently in many parts in Iran although corn has almost always been the option for most dairies but marked downward trend in water resources forces agronomists for a proper substitute, therefore in order to improve nutritive value and high efficiency to utilize resources, intercropping with legumes is introduced in a complementary system in that such systems are being recognized to increase productivity and resource use efficiency in a high input agriculture (Burel and Baudry, 1995).

The objective of the present study were to evaluate forage intercropping advantage and intercrop competition under different levels of N soil availability to examine how nitrogen response of each yield component affects the productivity of the system as a whole.

MATERIALS AND METHODS

The experiment was conducted in the Agricultural Research Centre, University of Tehran, Aboureyhan, in the south-west of Tehran (latitude 35°, 28'; longitude 51°, 44' and elevation 1280 m), Iran. The experiment was established in a silt loam soil with PH 7.1. Seed bed preparation included ploughing, disk harrowing and cultivation. Sowing was performed manually by planting tree times more seeds than the expected plant densities. The design was in randomized complete block design in split plot arrangement with four replications. Each plot consisted of six rows, and each row was 5 m long. The first and last row in each plot were considered as marginal effects. The main plots consisted of four levels of nitrogen fertilizer as (N_0:0, N_1:80, N_2:160 and N_3:240 urea $kgha^{-1}$) and sub plots including seven different planting proportions as pure stands of sorghum (SSSS) and lima bean (BBBB), replacement series as 75% sorghum + 25% bean (SSSB), 50% sorghum + 50% bean (SBSB), 25% sorghum + 75% bean (SBBB) and additive series as 100% sorghum + 10% bean (SB10%) and 100% sorghum + 20% bean (SB20%). Plots were fertilized with the same amount of fertilizer as 60 $kgha^{-1}$ p_2o_5 and 60 $kgha^{-1}$ k_2o but N fertilizer was added once before planting and then two thirds of it at the fourth leaf stage of forage sorghum. The row spacing for sorghum was 0.75 m and the beans 0.5 m in both sole-cropping and intercropping plots. Sorghum and bean were sown to a depth of 5 and 4 cm respectively by hand in 20 may 2009. About three weeks after first irrigation, rows were thinned to the required experimental density.

Hoeing was performed mainly in two stages when the height of the plants reached 10 and 20 cm and then because of shading the competition capability of weeds reduced significantly. Forage sorghum was harvested in two cuts. First cut was performed in 4 August 2009 after the height of the plant was almost 1.5 m. In order to keep subsistence and the continuation of the growth, sorghum was harvested from 10 cm above the soil surface (Slatter and Stuart, 1995). Fresh weight of the samples were measured at site straight away then the samples were put in the oven at 70°C for 48 h and weighed to record dry matter yield. The second cut of sorghum was done as the same trend for the first cut with simultaneous harvest for bean. In order to determine yield component of lima bean after randomly selecting 10 plants from each plot and transferring to the laboratory the number of pods, seeds per pod and 100 seed weigh was measured. The analysis of variance of the data was carried out, using SAS software. Treatment mean differences were separated by the Duncan multiple range test (DMRT) at probability level of 0.05. The efficiency of intercropping system can be evaluated by the land equivalent ratio (LER) defined as the total area required under sole-cropping to produce the equivalent yields obtained under intercropping.

$$LER = Ls + Lb = (Ys / Ss) + (Yb / Sb)$$

Where Ss and Sb are sole crop yields of the component crop sorghum and bean, and Ys and Yb are the yields of component sorghum and bean in the intercrop.

A total LER value greater than 1.0 indicates advantages from intercropping in terms of the use of environmental resources for plant growth. Value Ls and Lb greater than 0.5 indicate advantage for an individual species in intercropping system over the sole cropping (Table 1).

RESULTS AND DISCUSSION

Forage fresh and dry matter of sorghum

Results of variance analysis for fresh and dry weight of intercropping forage sorghum are represented in Table 2. The result of variance analysis for fresh weight of sorghum revealed that the effect of planting pattern

Table 1. Meteorological parameters during the growing seasons.

Months	Temperature (°C)			Rainfall (mm)	Relative humidity % mean
	Minimum	Maximum	Mean		
April	6.6	20.1	13.3	3.3	49
May	13.2	26.5	19.8	2	46
June	16.5	34.2	26.3	.5	33
July	22.3	38.3	30.3	0	28
August	21.5	39.8	30.6	.2	35
September	16.7	34	25.4	6.4	40

Table 2. ANOVA based on randomized complete block design (RCBD) for fresh and dry matter yield and yield in each plant of sorghum.

	1st harvest				2nd harvest			
	Fresh weight	Fresh weight	Dry weight	Dry weight per plant	Fresh weight	Fresh weight	Dry weight	Dry weight per plant
Block	413603082	10737.15	1131753	82.74	592967882	15745.48	43633332.71	358.86
Factor (A)	58821832$^{n.s}$	653.81$^{n.s}$	11389140.35**	610.04**	6287326$^{n.s}$	862.15$^{n.s}$	14255739.81**	1184.05**
Error (a)	84560258	9381.59	333122.3	31.02	92699363	7365.85	73497.62	14.62
Factor (B)	3414785026**	38176.87**	158426533.92**	980.70**	3400415104**	114083.54**	150986246.0**	651.17**
A*B	40667665$^{n.s}$	27.97$^{n.s}$	75515.72$^{n.s}$	15.93$^{n.s}$	50537326$^{n.s}$	414.65$^{n.s}$	43459.71$^{n.s}$	80.50$^{n.s}$
Error (b)	76822005	364.65	261515.5	26.3	67495660	657.43	379882	39.37
Total	24471577474	831790.62	846517356.58	9078.34	24441944896	732198.95	834888739.42	11586.47

was significant ($p < 0.01$). Mean comparison using Duncan multiple range test showed that the highest amount of yield for fresh weight obtained in additive series (100% S : 20% B) in which with the reduction of sorghum in replacement patterns the yield of fresh weight decreased and resulted to the lowest amount of yield in (25% S : 75% B). Nitrogen levels did not have any significant effect on fresh weight of sorghum. Analysis of variance for yield of per plant considering fresh weight indicates a significant effect, in that with the increase in proportion of lima bean the yield of forage sorghum increases as well. The effect of nitrogen fertilizer on dry weight was significant ($p < 0.01$). Mean comparison of nitrogen levels using DMRT revealed that increasing nitrogen to the level of 160 kg per ha resulted to the increase in yield for forage dry weight of sorghum although there was no significant difference between the two treatments of 160 and 240 kg nitrogen per ha (Figure 1). There are various reports considering the positive effects of nitrogen fertilizer on yield increase. The majority of the surveys reported yield increase proper to increasing nitrogen even though the best possible treatment or nitrogen level is highly dependent on the characteristics of soil, climate and the experimental place. Coaldrake (1985) and Bebawi (1989) reported that with increasing nitrogen levels in forage sorghum and millet the number of tillers and the leaf area of plants increases and this ultimately leads to a rise in dry matter. Zhao et al. (2005) reported that different amount of nitrogen fertilizer with affecting the height and the leaf area resulted in significant difference between treatment. On low-N soils, the non-legume is often suppressed, but on high-N soils the vigorous growth of the non-legume usually causes it to dominate over the legume by shading (Trenbath, 1976).

Orthogonal contrasts were used in order to evaluate a response surface (Table 4). The result revealed there is a quadratic relationship that

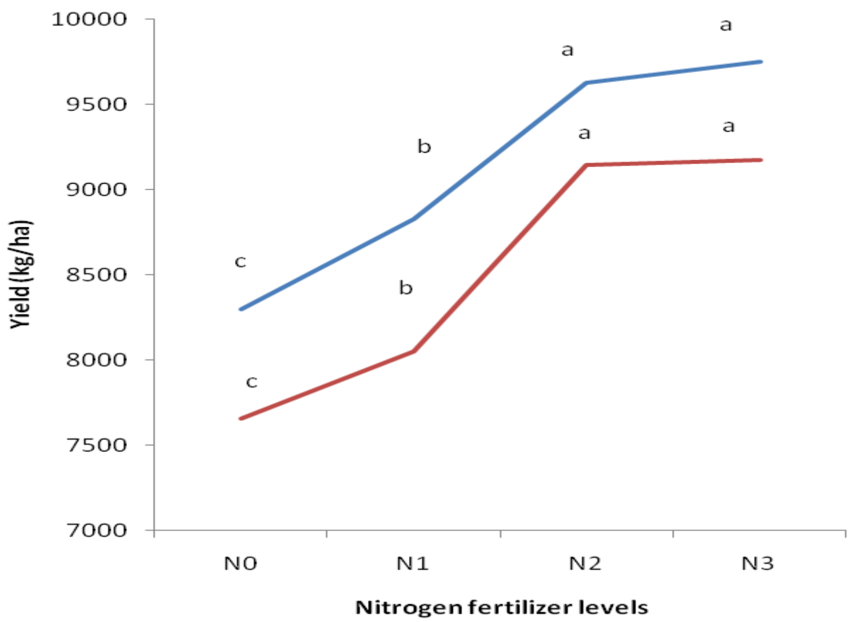

Figure 1. Dry matter yield comparison of forage sorghum under different levels of nitrogen fertilizer.

comprised of the linear and quadratic trends. The highly significant F value for this linear trend implies that any increase in fertilizer N will increase the yield in that the slope is positive. The linear response in nitrogen uptake to fertilizer nitrogen indicates that luxury levels of nitrogen had not been reached by the plants (Comudum, 1981). In addition, the significance of quadratic effect implies that beside an increasing trend there is a quadratic trend between yield and fertilizer and increasing yield for each amount of N fertilizer is not stable and it starts to slow down from the 160 kg.ha^{-1} level. There was no significant cubic contrast however. The effect of row proportion on dry weight revealed that there was significant dry matter yield and yield in each plant (Table 3). Lowering the proportion of sorghum in intercropping resulted to the reduction of yield therefore the combination of 25% S: 75% B with 3905.32 kg.ha^{-1} ranked the lowest (Figure 2). It should be taken into consideration that this lower amount of yield is due to reduction of sorghums proportion in intercropping and even though the number of plants in this pattern is 1.4 of the sole cropping but the amount of yield will not follow this proportion. Total biomass yield of intercropped maize per unit area tended to increase with increasing maize population (Luiz and Willey, 2008). Greater resource use by intercrops was considered as the biological basis for obtaining yield advantages (Willey, 1979; Keating and Carberry, 1993).

The morphological and physiological differences among intercrop components result in their ability to occupy different niches. Thus, environmental resources could be more efficiently utilized and converted to biomass by mixed stands of crops than by pure stands.

Soybean grain yield

The result of analysis of variance revealed that nitrogen fertilizer and planting patterns had significant effect on the yield of lima bean (Table 5). Mean comparison showed that increasing nitrogen to the level of 80 kg.ha^{-1} increased the yield of seed per hectare but more input of nitrogen not only did not affect the yield but also there was significant decrease of yield in comparison with control treatment (Figure 3). Such results from a legume which obtains its nitrogen from biological fixation with bacteria is expectable and it seems that the increase of seed yield at level of 80 kg.ha^{-1} is the result of nitrogen performance to act as a starter and reduction of seed yield at the level of 240 kg.ha^{-1} nitrogen is most likely due to its effect to prevent the function of bacteria to fix nitrogen, besides the competition for growth resources caused lima bean to be overcomed by sorghum. On high regimen of nitrogen, the process of fixation by legumes reduces and in these conditions the non-legume species has more dominance and completion for limiting source (Hiebsch and Mc Collum, 1987). The utilization of different nitrogen levels in intercropping bean with corn resulted to the yield reduction of legume with increasing nitrogen fertilizer (Weil and Mcfadden, 1991). Mean comparison for different levels of planting patterns indicated that increasing forage sorghum in row proportion lead to significant reduction in seed yield of lima bean in which the sole cropping of lima bean with 1866.66 kg.ha^{-1} ranked the highest and in contrast the additive series had the lowest amount of yield (Table 6).
Intercropping corn and soybean under different planting

Table 3. Duncan's mean comparison test results for fresh and dry matter yield and yield in each plant of sorghum.

	1st harvest				2nd harvest			
	Fresh weight	Fresh weight per plant	Dry weight	Dry weight per plant	Fresh weight	Fresh weight per plant	Dry weight	Dry weight per plant
SSSS	68313[bc]	343.125[f]	10763.82[b]	53.81[e]	65250[bc]	294.37[e]	9980.11[c]	50.94[c]
SSSB	66266[c]	470[c]	9378.63[c]	62.88[c]	60031[c]	419.35[b]	8514.22[d]	57.39[b]
SBSB	53156[d]	545[b]	6994.12[d]	68.74[b]	49438[d]	492.52[a]	6504.42[e]	64.29[a]
SBBB	40531[e]	578.75[a]	3905.32[e]	75.72[a]	35563[e]	501.87[a]	3437.5[f]	68.12[a]
SB 10%	73625[b]	383.125[e]	11771.22[a]	58.88[d]	70750[ab]	366.25[d]	11034.62[b]	54.29[bc]
SB 20%	80813[a]	411.875[d]	11948.13[a]	59.73[dc]	74625[a]	382.14[c]	11521.13[a]	57.28[b]

Means of each group in columns of each treatment with similar letters are not significantly different.

Table 4. Orthogonal contrast to evaluate response surface.

Contrast	df	Mean square	F value
Linear	1	421733917.9	1557.02**
Quadratic	1	11607529.8	42.85**
Cubic	1	69698.5	0.26[n.s]

* p< 0.05; **p < 0.01; ns: non significant.

pattern and nitrogen fertilizer revealed that seed yield of soybean was the highest compared with intercropped patterns in which the competition for resources highly affected yield and yield components (Panhwar et al., 2004). The results by Ntare et al. (1993) showed that the legume is suppressed when intercropped with a c_4 crop. Grain yield per unit area of intercropped beans decreased as maize population increased (Mutungamiri et al., 2001).

Number of pods per plant

Number of pods per plant was the yield component most responsible for the yield in that it was significant for different planting patterns ($p < 0.01$) and N levels ($p < 0.05$) (Figure 4). Mean comparison for nitrogen levels indicated that increasing nitrogen to 80 $kg.ha^{-1}$ increased the number of pods of lima bean although there was no significant effect between the application of N_2 and N_3 levels, besides by reducing the proportion of lima bean in intercropping patterns the number of pods per plant decreased as well. The highest number of pods obtained in sole cropping as though additive series were ranked as the lowest (Table 6). When nitrogen increased from 0 to 30 $kg.ha^{-1}$, the number of pods per plant increased from plant population of M1 to M2. The number of pods per plant is the most sensitive component of yield and the most important attribute to determine yield of bean (Rezends and Ramalho 1994; Scarisbrick et al., 1977). In intercropping soybean and sorghum, the fewer number of pods per plant and the fewer number of seeds per pod was responsible for decreased yield of soybean (Elmor et al., 1984).

Number of seeds per pod

Analysis of variance for number of seed per pod revealed that the effect of row proportion was significant ($p < 0.01$) in that the highest number of seed per pod obtained in sole-cropping of lima bean (Table 5). The significance of this trait is that it has a very high correlation with beans yield (Jindal and Guptal, 1984). On the other hand, it is reported that the number of seed per pod is less in intercropped plants in comparison with sole-cropping although this difference is not statistically significant (Oforti and Stern, 1987; Tsubo et al., 2001).

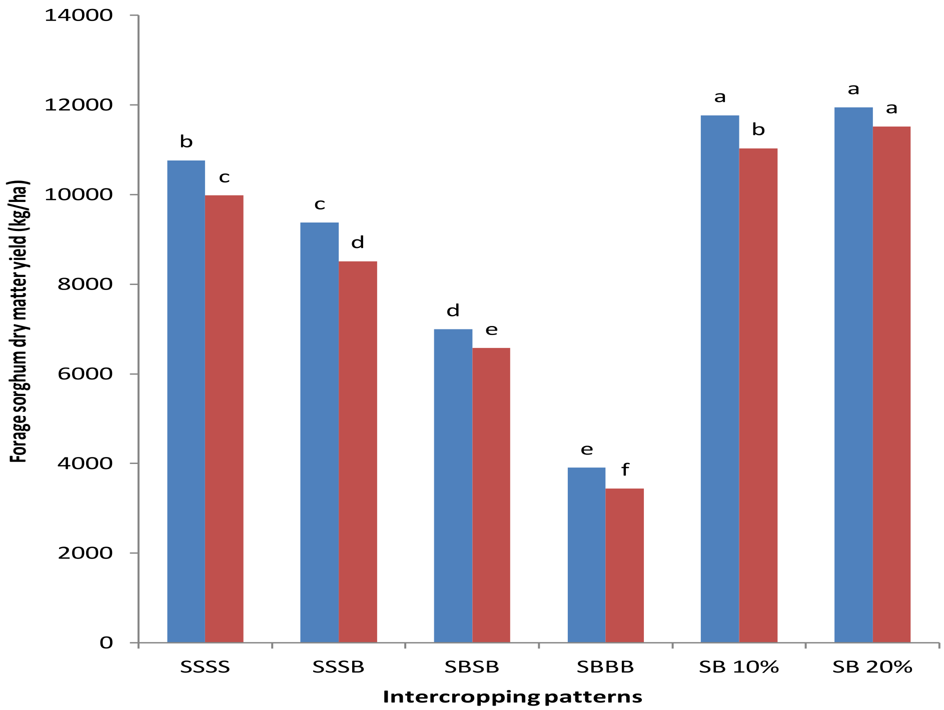

Figure 2. Dry matter of forage sorghum of 1st and 2nd harvest.

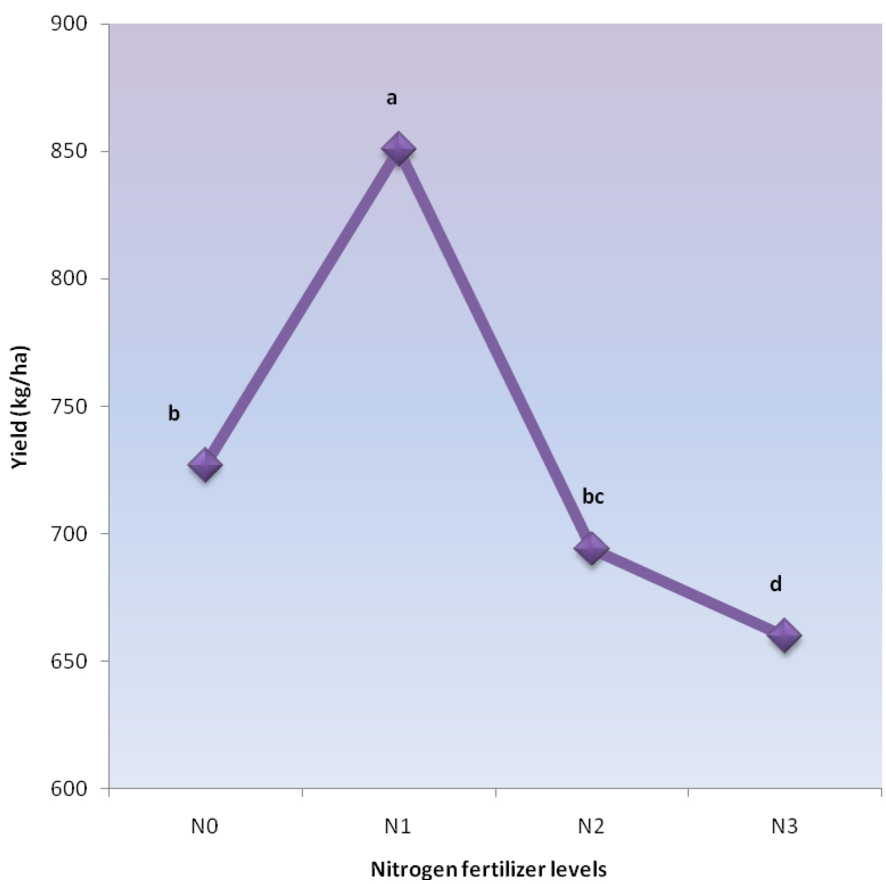

Figure 3. Yield comparison of lima bean under different nitrogen fertilizer.

Table 5. ANOVA based on randomized complete block design (RCBD) for yield and yield component of lima bean.

	df	Yield per hectare	Yield per plant	Number of pods per plant	Number of seed per pod	Weight of 100 seed
Block	3	94280.11	11.054	12.41	0.9702	212.5
Factor (A)	3	166015.69**	20.91**	23.06*	0.0325$^{n.s}$	48.61$^{n.s}$
Error (a)	9	6830.99	1.06	10.19	0.3438	271.75
Factor (B)	5	7616160.52**	124.37**	288.84**	10.46**	1766.66**
A*B	15	9672.58^{ns}	0.676^{ns}	4.80^{ns}	0.3688^{ns}	41.11^{ns}
Error (b)	60	6640.79	0.74	6.49	0.531	110.27
Total	95	39466808	784.94	2104.04	95.84	19295.84

* p< 0.05; **p < 0.01; ns: non significant.

Table 6. Duncan's mean comparison test results for yield and yield component of lima bean.

	Yield per hectare	Number of pods per plant	Number of seed per pod	Weight
BBBB	1866.86^{a}	15.668^{a}	5.662^{a}	308.75^{a}
SBBB	1207.07^{b}	14.756^{a}	5.593^{a}	302.50^{ab}
SBSB	709.02^{c}	12.637^{b}	5^{b}	295.51^{b}
SSSB	349.68^{d}	12.218^{b}	4.543^{b}	286.87^{c}
SB 10%	133.87^{e}	6.643^{c}	3.868^{c}	285.11^{c}
SB 20%	130.34^{e}	5.387^{c}	3.831^{c}	283.125^{c}

Means of each group in columns of each treatment with similar letters are not significantly different; * p< 0.05; **p < 0.01; ns: non significant.

Lima bean 1000 seed weight

Analysis of variance showed that there was significant difference among different row proportions and it indicated that increasing sorghum lead to the reduction of weight of 100 seeds in that the additive series had the lowest amount for this trait. Significant difference between sorghum and soybean in various planting patterns considering weight of seed is reported (Lesoing and Francis, 1999). The significant positive relation between beans seed yield with increasing its proportion in intercropping on one side and decreasing its yield with increasing sorghums proportion on the other side is due to sorghums shading on the shorter species which resulted in decreased yield (Parves et al., 1989).

Land equivalent ratio (LER)

The yield advantages of intercropping treatments relative to sole-cropping are indicated by total LER values (Table 7). With no nitrogen applied, the sorghum LER in intercropping was about the unity. The decrease below unity might have been the result of some competition from the beans even though at this level of nitrogen the intercropped sorghum produced as much yield as sole-cropping and that any competition from the beans could have been slight. Total LER tended to increase with increasing nitrogen to the level of N2 (Figures 5 to 7). LER values were greater than one in almost all intercropping systems with different planting ratios which indicated yield advantage of intercropping over sole cropping of sorghum. The highest LER obtained by sowing the crops in additive designs in ratio of 100%S + 20%L; it is apparent that by maintaining the proportion of sorghum at 100% in intercropping, sorghums yield are less affected by bean competition than when sorghum proportion is lowered in replacement designs. Bean LER increased with increasing bean population (Luiz and Willey, 2008). This might be attributed to the fact that bean plants possibly benefited from the nitrogen applied though this trend started to decrease for highest level of applied nitrogen. Reducing bean density to 25% gave a higher sorghum LER and a corresponding decrease in beans LER in as much as the lowest bean LER obtained in ratio of 75% S + 25% B.

The result indicated that intercropping of forage sorghum and lima bean gave higher land use efficiency than sole cropping of sorghum.

Conclusions

The study conducted revealed that in additive series, yield of forage sorghum increased to a significant level and ranked the highest among other row proportions.

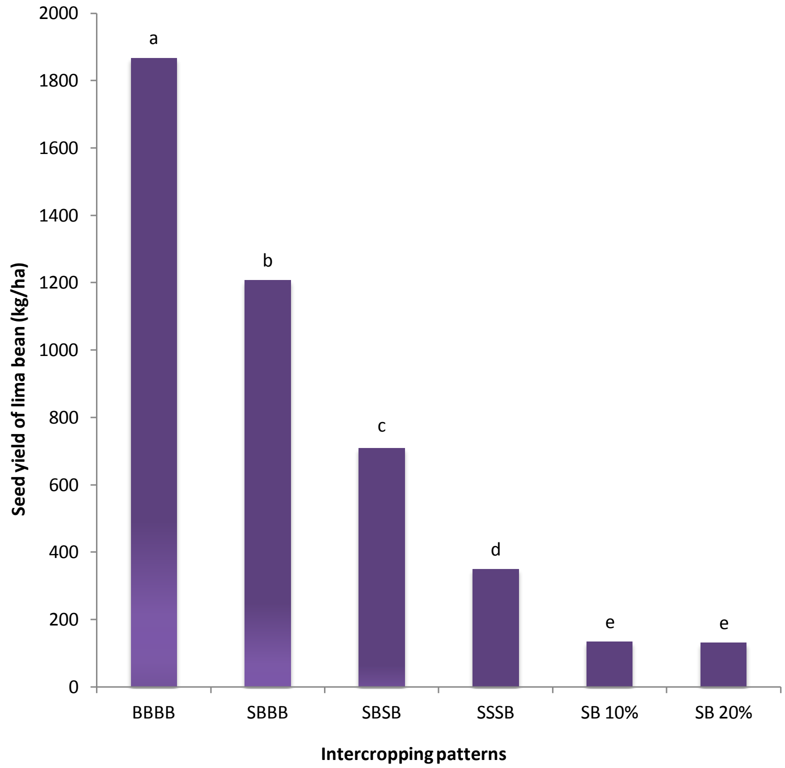

Figure 4. Yield comparison of lima bean under different planting patterns.

Table 7. Land equivalent ratio of forage sorghum and lima bean under different planting patterns and nitrogen fertilizer.

Nitrogen fertilizer levels (kg ha^{-1})	Intercropping patterns	Forage sorghum	Lima bean	Total LER
	SSSB	0.84	0.19	1.03
	SBSB	0.63	0.36	0.99
N_0	SBBB	0.32	0.69	1.01
	SB 10%	1.04	0.05	1.09
	SB 20%	1.09	0.04	1.13
	SSSB	0.87	0.2	1.07
	SBSB	0.63	0.38	1.01
N_1	SBBB	0.32	0.79	1.11
	SB 10%	1.1	0.06	1.16
	SB 20%	1.12	0.09	1.21
	SSSB	0.89	0.29	1.18
	SBSB	0.75	0.37	1.12
N_2	SBBB	0.36	0.8	1.16
	SB 10%	1.16	0.05	1.21
	SB 20%	1.15	0.1	1.25
	SSSB	0.79	0.2	0.99
	SBSB	0.64	0.37	1.01
N_3	SBBB	0.35	0.73	1.08
	SB 10%	0.99	0.03	1.02
	SB 20%	1.01	0.03	1.04

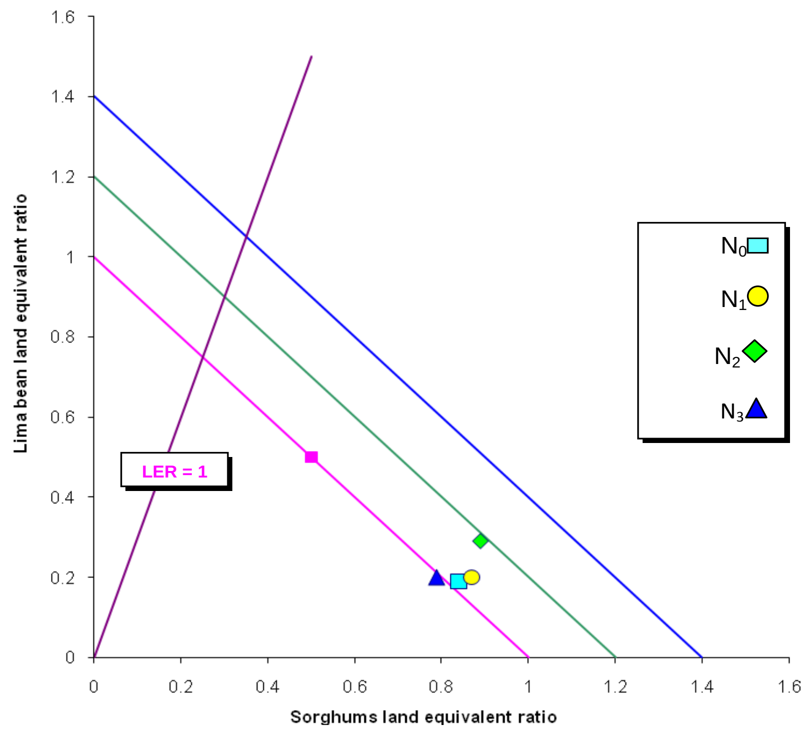

Figure 5. Land equivalent ratio at 75%S + 25%B.

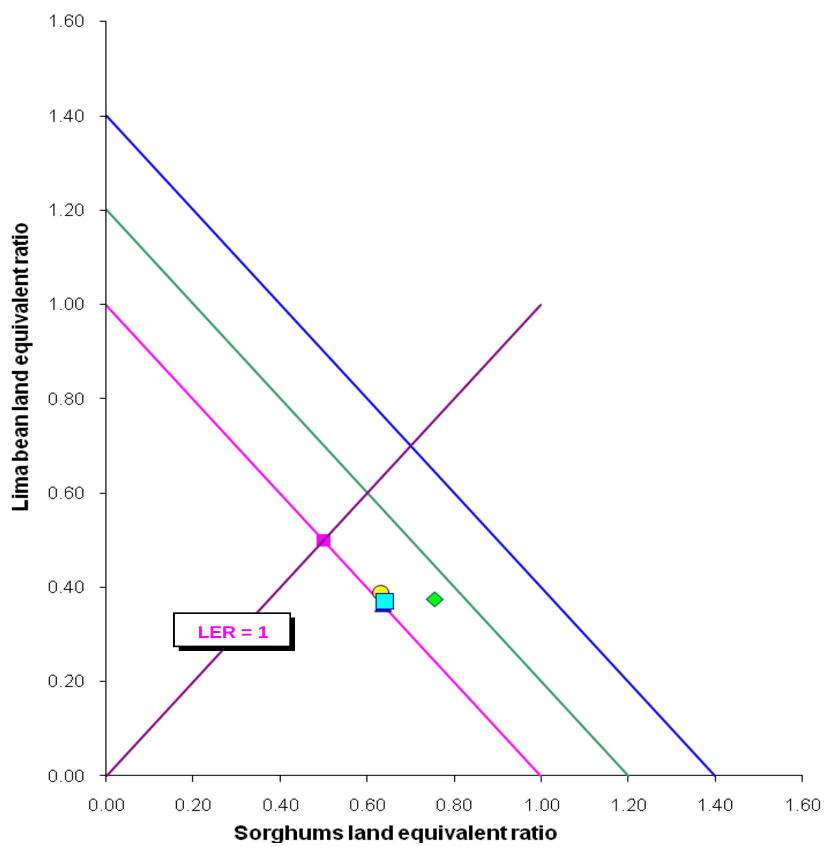

Figure 6. Land equivalent ratio at 50%S + 50%B.

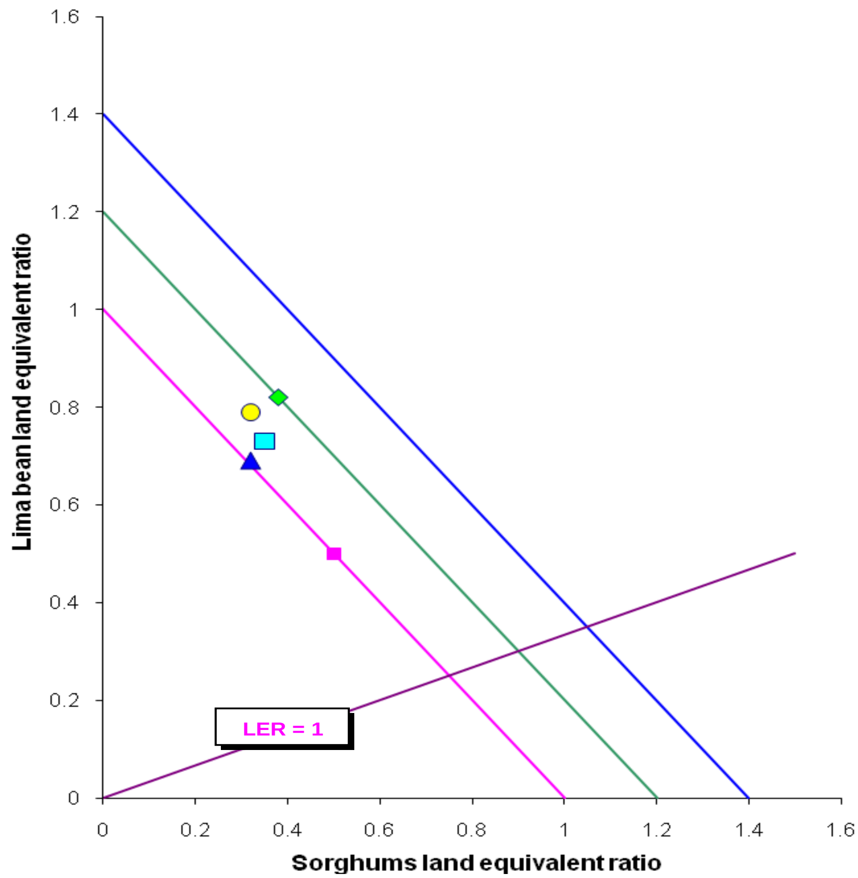

Figure 7. Land equivalent ratio at 25%S + 75%B.

Intercropping resulted in higher sorghum forage quantity,because of more N supply for sorghum, induced by complementary interaction between forage sorghum and lima bean. In order to have a higher dry matter yield, the rate, time and application of N fertilizer should be taken into consideration so that without disturbing the biological function of legumes, the objectives can be achieved.

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