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Effect of Nitrogen Levels on Yield, Competitive, Economic indices and Efficiency of Sorghum cultivars and Common Bean Intercropping

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Abstract

To evaluate the effect of nitrogen level on the yield, nitrogen utilization, competitive, economic indices, and efficiency of sorghum cultivars-common bean intercropping in the southern highland region (SHR) Ibb (Yemen). Two experiments were conducted, the first one was conducted during two sequence rainy season (2009 and 2010) and arranged in a split plot design with three replicates; where the main plots were: sole sorghum cultivars local (SV1) and recommended cultivar SC-93-7-2 (SV2), sole bean and intercropped sorghum cultivars with bean cultivar (Taiz-305), the subplot were five N levels of mineral N were 0 , 46, 92, 138 and 164 kg ha^{-1} (N0, N46, N92, N138 and N164) and the second experiment was conducted to evaluate the yield stability of the efficient intercropping sorghum - common bean under optimum nitrogen levels in comparison with farmers intercropping practice at nine locations representing different environments of the region representing in SHR-Ibb Yemen on 2011, 2012 and 2013 during rainy seasons. Maximum yield and forage of sorghum and bean were obtain by nitrogen application nitrogen level N138 under monoculture cropping and N92 under intercropping but further application had no effect on yield and forage. At these nitrogen levels intercropping provided many benefits through increased efficiency of nitrogen uptake (NU), physiological nitrogen efficiency (PNE), efficiency of nitrogen utilization ENU and leaf area index (LAI) by both crops in relation to sole crops. The results also clearly showed that intercropped yield of sorghum Yab associated strongly with CR while yield of bean Yba was associated strongly with land equivalent ratio (LER) and Advantage of intercropping (AI). Moreover, economic evaluation indices RVT, AYL, RYT and MAI, can be used as good indicators of the economic feasibility of intercropping systems. On the other hand, the results also indicated that (SV2) were more responsive to high yielding environmental change than (SV1), while intercropped common bean (Taiz-305) with (SV1) was more responsive and stable under wide range of environments (locations and years).

Keywords: Intercropping efficiency; (NU); (PNE); (ENU); (LAI); Economic evaluation indices

Introduction

Intercropping is one of the most common practices used in sustainable agricultural systems which have an important role in increasing the productivity and stability of yield in order to improve resource utilization and environmental factors Hashemi et al. [1]. Therefore, intercropping became an attractive strategy for increasing productivity and labour utilization per unit area of available land and to intensify land use in the southern highland region Ibb (Yemen) in the last decades. Intercropping cereals and legumes is also important due to some potential benefits including the enhancement of forage quality through the complimentary outcome of two or more crops grown instantaneously on the same part of land Hamdollah (2012) and high productivity and profitability Yildirin & Guvence [2].

In general, most published intercropping mixture with significant yield advantage were from legume/non legume combination Li et al. [3]. The yield advantages have been reported in various crop species namely: maize-common bean Molaaldoila & Al-Sabri [4], maize-faba bean Oskoii et al. [5], maize-lablab bean Muna et al. [6], maize-lima bean Brink & Belay [7]; also sorghum- mungbean Koohi [8], Sorghum-soybean, Sorghum-mung bean or guar Rashid et al. [9]. wheat-Mungbean Chowduury & Rosaria [10], and barley-Pea Chen et al. [11].

A general assumption in intercropping cereals with legume crops is that the legume, when associated with the specific *Rhizobium*, may have most of its N need supplied through fixation of atmospheric N, leaving the soil available N for the companion cereal. There is evidence that leguminous plants can benefit the intercrop cereals in the same season through N excretion Eaglesham et al. [12] and nodule decomposition Saito [13], Bonetti 1991. There is marked variation in the N supplying ability among legume species Senaratne et al. [14]. Common bean is among the most important legume crops native from the temperate regions cultivated in these regions to produce seeds; Common bean can establish a symbiotic relation with the soil rhizobium Hashemi et al. [1].

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. [15]. Cereal/legume intercropping system may be increase soil fertility via raising its organic content and available nitrogen fixed by legume Hashemi et al. [1]. Although, sorghum utilizes nitrogen more efficiently than corn and is more resistant to drought and higher temperatures Young & Long [16] but inadequacy of N fertilizer reduces congregation of dry matter and leads to growth reduction Zhao et al. [15]. 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. [17]; Chui & Shibles [18]; Ofori & Stern [19]; Rao et al. [20].

Nitrogen application treatments had significant effect on sorghum total dry matter of fodder (160 urea kg ha^{-1}) and total yield of lima bean (80 urea k ha^{-1}) seed Reza et al. [21]. The application of nitrogen fertilizer to cereal rows mitigated the efficiency intercropping and benefited the associated legume by increasing grain yields as reported by Li et al. [3] that nitrogen acceptance by maize in an intercrop with bean is greater as relate to sole cropping. However, the application of NP fertilizer improve grain maize and seed bean yield of intercropping to certain level and the significant and optimum amounts of nitrogen was varied with locations in the range of 69-115 Kg h^{-1} Molaaldoila [4]. On the other hand, Forage sorghum displayed a positive reaction to increasing nitrogen to about 200 kg ha^{-1} but further application had no effect on yield increase Gupta & Sing [22].

The greater N acquisition by a non-legume crop intercropped with a legume is often reported in literature Francis [23], Vandermeer [24]. This may probably be due to the effect of competition. Nitrogen is needed in greater amount than other elements, it can be supplied as a chemical fertilizer or fixed naturally by legumes which grow in a symbiotic relationship with nitrogen-fixing bacteria (Rhizobia) and this reduces the cost of production, compared to chemical nitrogenous fertilizers.

On the other hand, uptake of nitrogen with green gram (284 kg ha^{-1}) was significantly developed than with cowpea (239 kg ha^{-1}) and soybean (247 kg ha^{-1}) as intercrops, the nitrogen uptake was maximum in 1:1 row ratio (274 kg ha^{-1}) compared to 1:2 row ratio (251 kg ha^{-1}) Kanakeri [25]. Further, among different intercrops, cowpea noted maximum uptake of nitrogen (68 kg ha^{-1}) and phosphorus (2 kg ha^{-1}) followed by soybean with 60 and 2 kg ha^{-1} NP, separately. Nitrogen utilization efficiency (EU) was generally poor in all crop stands, particularly at a high N application rate.

The morphological and physiological differences between non-legumes and legumes benefit their mutual association Akuda [26].The cereal component crop is usually taller and has a faster growing or more extensive root system of fine roots Lehmann et al. [27] and very competitive for soil nitrogen than the legumes which usually fix atmospheric N Jensen 1996. 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 Reza et al. (2013). Grain yields of maize and beans were affected by intercropping and the effect was more detrimental to the legume mainly at the highest maize plant population Morgado &Willey [28].

A number of indices such as land equivalent ratio (LER), increases, remains unchanged or decreases under application of increasing levels of N fertilizer Akter et al. [29], Reza et al. [21], Koohi [8]. However, NP fertilizer levels minimize the competitive ratio and aggressivity index values and maximum intercropping monetary advantage, actual yield loss and intercropping advantage Molaaldoila [4]. Recently, the efficiency of cereal-legume intercrop systems, expressed as actual yield loss (AYL), monetary advantage index Matusso et al. [30], and intercropping index Ariel et al. [31], relative yield totals, relative value total, actual yield loss or gain and intercropping advantage Ariel et al. [31]. Such indices have not been used for sorghum and common bean intercropping to evaluate the competition among species and also economic advantages of each intercropping system in the southern highland region Ibb (Yemen).

In the southern highland region Ibb (Yemen), very little information has been published regarding the effects of nitrogen fertilization on yield and other related of sorghum-common bean intercropping. This paper is undertaken: (a) to study the effects of, nitrogen fertilizer levels on yield on competition for growth resources, economic benefits of sorghum cultivars intercrops with common bean, (b) to estimate the correlation coefficients of yield, competition and economic indices and nutrient parameter and (c) to examine adaptability and performance stability of sole and intercrop systems over locations and years.

Materials and Methods

Experimental design and treatments

The experiment was carried out at the Southern Highlands Region (SHR)-Ibb station (Yemen) in 2009 and 2010. The experiment was arranged in a split plot design with three

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replicates comprising a factorial combination of three factors; where the main plots were: sole sorghum cultivars local (SV1) and SC-93-7-2 (SV2), sole bean and intercropped sorghum cultivars with bean cultivar (Taiz-305), the subplot were five N levels of mineral N were 0, 69, 92, 115 and 138 kg ha^{-1} (N0, N46, N92, N138 and N164). Mineral N were applied to sole and sorghum-bean intercropping system rows as urea (46% N) in two split halves at 30 and 45 days after sowing (DAS) whereas one dose of P_2O_5 were applied in only (69 kg ha^{-1}) to sole and intercropped sorghum and bean rows as super phosphate (46% N) before sowing both sorghum and bean.

The soil of SHR-Ibb station was a silt loam soil with low fertility (1.2% Organic manure, 0.19% N, 11% CaCO3, 0.47 ms/cm EC (1:1), and pH 7.8 the research station-Ibb (latitude: 13°36' N, longitude: 44°01' E, altitude: 1966 m). The average annual rainfall is 778.1 and 911.4 mm with a good distribution for the year 2011, 2011 and 2013, respectively. The mean temperature was 24.9°C with maximum and minimum of 13.1 °C and 7.3 °C, respectively.

The arrangement of intercropping was in one row of sorghum for one row of beans (1:1), A constant row spacing and plants of 0.70 m x 0.25 m and 0.60 m x 0.20 m were maintained for sorghum and bean in sole cropping system, respectively. Meanwhile, a constant row spacing and plants of 1.20 m x 0.25 m and 1.20 m x 0.20 m were maintained for sorghum and bean in intercropping system, respectively. Thus a uniform population of sorghum and bean of sole crop were 57143 and 833333 plant ha-1, respectively, while the plant population of sorghum and bean in the intercropping arrangement were 33333 and 41667 plant ha^{-1}, respectively. All plots were 42 m^2 (4.2 x10 m).

Agronomical and physiological nitrogen efficiency

After (60-75 DAS) fresh weight and dry weight of the roots and shoots were taken to determine the dry materials of above ground freshly harvested after they were dried in an aerated oven at 80 °C. Successive weight was carried out until the constant dry weight of each sample reached. N was determined according to the method adopted by Lowry et al. (1951). Agronomical efficiency (AE) was calculated as AE = (seed yield of fertilized crop in kg – seed yield of unfertilized crop in kg)/ quantity of fertilizer applied in kg. Physiological efficiency (PE) was calculated as PE = (total dry matter yield of sole crop in kg – total dry matter yield of intercropped crop in kg)/ (nutrient uptake by fertilized crop in kg - nutrient uptake by unfertilized crop in kg) Baumann et al. [32].

Yield and advantage of intercropping

The experimental area was ploughed and raked by tractor and fertilizers were uniformly broadcast before planting. Sorghum cultivars (local and SC-93-7-2) and bean cultivar (Taiz-305), were planted simultaneously on the end of May (rainy season), sorghum sown by a tractor drill and beans by hand after sowing sorghum. The plots were hand-weeded and there was no incidence of insect or disease in either crop. Outside rows of sole and intercropped sorghum and bean plots were discarded as border and two 4 m long middle rows were harvested. Bean and sorghum were harvested at 110 and 150 days after swing (DAS), respectively. Pants were cut at soil level and the grains and seeds were collected for the two crops. The land equivalent ratio (LER) had been calculated to assess effectiveness of intercropping for using the resources of the environment compared to sole cropping Mead and Willey [33] & Koohi et al. [8] by the equation: LER = Yab/Yaa + Yba/Ybb, where Yab = Yield per unit area of crop a in mixture, Yaa = Yield per unit area of sole crop a, Yba = Yield per unit area of crop b in mixture, Ybb = Yield per unit area of sole crop b. Calculation of individual LER for sorghum crop considered yields of sole and intercropping systems at the same N level. For bean crop, calculation included a single sole cropping without nitrogen.

Competitive Indices

The first coefficient was the relative crowding coefficient (K) which is a measure of the relative dominance of one species over the other in a mixture Banik et al. [34]. When the value of K is greater than1, there is a yield advantage; when K is equal to 1, there is no yield advantage; and, when it is less than 1.00, there is a disadvantage Koohi et al. [8]. The second index was aggressivity (A) which is often used to determine the competitive relationship between 2 crops used in the mixed cropping Willey [35]. For cereal example; if A cereal = 0, both crops are equally competitive, if A cereal is positive, then the cereal species is dominant, if A cereal is negative, then the cereal is weak. Also, competitive ratio (CR) is another way to assess competition between different species. The third index was competitive ratio which gives more desirable competitive ability for the crops Koohi et al. [8]. The competition index was suggested by Donald [36]. The basic process is the calculation of two "equivalence factor is the number of plants of species 1 that is equally competitive to one plant of species 2. If a given species has an equivalence factor of less than 1, it means it is more competitive (on a plant-for –plant basis) than the other species.

Economic benefits and intercropping advantage indices

To evaluate the economic and advantage of intercropping several induces were calculated. The first one is the actual yield loss (AYL) index, the AYL is the proportionate yield loss or gain of intercrops in comparison to the respective sole crop, i.e. it takes into account the actual sown proportion of the component crops with its sole stand. In addition, partial $AYL_{legumes}$ or AYL_{cereal} represent the proportionate yield loss or gain of each species when grown as intercrops in relative to their yield in sole planting Koohi et al. [8]. The AYL can have positive or negative values indicating an advantage or disadvantage remained in intercrops when the main aim is to compare yield on a per plant basis. The second one is monetary advantage index (MAI), since none of the above competition indices provides any information on the

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economic advantage of the intercropping system. The calculation of MAI was as calculated by the formula of Ghosh [37]; the higher the MAI value, the more profitable the cropping system is Ghosh [37] Additionally, intercropping advantage (IA) was calculated using the following formula Banik et al. [34]: $IA_{legume} = AYL_{bean} \times P_{bean}$, and $IA_{sorghum} = AYL_{sorghum}\ P_{sorghum}$ where P_{bean} and $P_{sorghum}$ are the commercial value of common bean and sorghum (the current priceare 1.50 and 0.50 $ for common bean seed yield/kg and sorghum grain/kg, respectively.

Yield stability in intercropping of sorghum - bean under different fertility levels

Yield stability of the efficient intercropping sorghum - common bean under optimum nitrogen levels was evaluated in comparison with farmers intercropping practice at nine locations representing different environments of the region representing in SHR-Ibb Yemen on 2011, 2012 and 2013 during rainy seasons. The experiment was conducted in a completely randomized block design and sorghum and bean intercropping arrangement in the ratio 1:1 and farmers intercropping practice. The treatment were as sorghum farmer (SV1) and recommended (SV2) cultivars and common bean variety (Taiz-305) were grown ether monoculture or intercropping system and with farmer (FNF) or recommended (RNF) nitrogen fertilizer. The field experiment was laid out in one replication in each location. The selected locations were Maitam, Mashwarh, and Al-Sahool Shaban, Giblah, Wadi Al-Dhahr, Al-Qaydah, Al-Aodian, Al-Soani.

Statistical analysis

Statistical analysis was carried out with the aid of S.A.S. statistical package (SAS institute Inc., USA) and Statistical analysis was carried out for analysis of variance (ANOVA) and mean separation test done using to Duncan Multiple Range Test (DMRT) at $P < 0.05$. Simple correlation coefficients among different nutrients efficiency parameters, completive and economic advantage indices were also determined by using the same SAS software. Mean yield (x) and coefficient of regression (b-value) were used as measures of yield response of sole, intercropping, farmer and recommended sorghum variety and nitrogen fertilizer in varying environments (8 locations x 3 years) and three stability parameters were estimated using also SAS soft program, the first one was the mean square deviation from regression (s^2d), the second; was coefficient of determination (r^2). The third stability parameter was Ecovalence (W). In this paper we are focusing on the overall average of the years for all the studied parameters and also the data which is related to the percentage of reduction or increase of different parameters as compared with controls were not shown in tables.

Results and Discussion

Biomass production and leaf area index

Nitrogen fertilizer increased total biomass yield in sole and intercropped sorghum and bean to certain level thereafter it decline. However, under monoculture cropping, sorghum biomass production increased to the extent 41.7% and 36.4% in the cultivars SV1 and SV2 at N164, respectively, whereas common bean biomass production increased significantly to the level 16% at N92. Similarly, the sorghum biomass production increased to the extent 33.2.7% and 22.8% in the cultivars SV1 and SV2 at N138, respectively, whereas common bean biomass production increased significantly to the level 19.4% and 21.7% at N92 when intercropped with SV1 and SV2 at N164, respectively. These results indicated that the respond of the sorghum cultivar SV2 was higher than the cultivar SV2 under intercropping system while common bean responded higher than SV2 in comparison with SV1 (Table 1). Our results were in accordance with results of Reza et al. [21] who found that 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. On the other hand, Forage sorghum displayed a positive reaction to increasing nitrogen to about 200 kg ha^{-1} but further application had no effect on yield increase Gupta & Sing [22]. In contrast Abusuwar and Al-Solimani [38] found that the chemical fertilizers had no significant effects ($P \le 0.05$) on productivity but significantly improved forage quality in terms of CP and nutrients contents, while intercropping of Panar and Lab lab significantly ($P \le 0.05$) increased forage productivity and improved forage quality.

Table 1: Biomass yield of sorghum and bean as influenced by intercropping and nitrogen levels at IBB research station during the rainy season in the 2009 and 2010.

Year	Cultivars	Monoculture			Intercropping			
	N level	Sorghum		Sole	Sorghum		Bean	
		SV1	SV2	Bean	SV1	SV2	SV1	SV2
2012	N0	5.913	5.812	4.754	6.033	6.059	3.913	4.334
	N46	6.922	6.377	4.918	7.467	7.276	4.391	4.226
	N92	8.922	8.246	5.472	7.624	7.644	4.735	4.785
	N138	9.436	8.683	5.632	8.124	7.96	4.928	5.407
	N164	9.916	9.384	5.797	8.537	7.977	5.038	4.823
Mean		8.222	7.7	5.315	7.557	7.383	4.601	4.715
DMRT at 5%		0.401	0.389	0.342	0.383	0.463	0.487	0.354

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CV%		19.6	17.3	15.6	13.6	19.6	10.8	11.8
2013	N0	5.362	6.477	5.275	4.856	6.771	4.732	4.558
	N46	6.928	7.823	6.028	5.956	7.223	5.319	5.681
	N92	8.551	9.299	6.352	7.33	9.399	5.507	5.714
	N138	8.841	9.733	6.435	7.226	8.523	5.797	5.949
	N164	9.42	9.951	6.522	7.764	8.651	5.203	4.861
Mean		7.82	8.657	6.122	6.626	8.114	5.312	5.353
DMRT at 5%		0.449	0.468	0.418	0.47	0.463	0.349	0.354
CV%		10.6	21.6	17.2	13.1	13.5	13.8	17.6
	N0	5.638	6.145	5.014	5.445	6.415	4.322	4.446
	N46	6.925	7.1	5.473	6.712	7.25	4.855	4.954
	N92	8.736	8.773	5.912	7.477	8.522	5.121	5.249
	N138	9.138	9.208	6.033	7.675	8.242	5.362	5.678
	N164	9.668	9.667	6.159	8.15	8.314	5.12	4.842
Mean		8.021	8.179	5.718	7.092	7.748	4.956	5.034
DMRT at 5%		0.493	0.415	0.374	0.408	0.402	0.365	0.335
CV%		19	13.2	18.2	21.2	18.1	14.1	17

Regarding the LAI of sorghum, there were significant differences between intercropping and monoculture, but intercropping had higher LAI values than monoculture sorghum particularly at N138. By contrast, the LAI of bean recorded significant differences between intercropping and monoculture particularly at N92 the growth stimulation of intercropped sorghum. LAI measurements, stimulating intercropping systems sorghum yield and depressing bean growth, particularly at N92 (Table 2). Recently in the Argentina Pampas, Echarte et al. 2011 found advantages in the production of corn-soybean intercropping compared to their monocultures. It is hypothesized that the practice of intercropping corn-soybean lead to changes in the availability of key nutrients for these crops, N and P, and due to a more efficient use of resources is more biologically productive than the corresponding sole crops. Quaye et al. (2011) found that maize planted simultaneously with soybean or before soybean recorded significantl higher values of leaf area index (LAI) compared to when it was later.

Table 2: LAI sorghum and bean as influenced by intercropping and nitrogen levels at IBB research station during the rainy season in the 2009 and 2010.

Year	Cultivars	Monoculture			Intercropping			
	N level	SV1	SV2	Bean	SV1	SV2	SV1	SV2
2012	N0	3.59	3.41	2.54	2.65	2.32	2.34	2.54
	N46	5.28	3.96	3.51	3.28	3.4	2.95	2.82
	N92	6.1	6.86	3.91	5.53	5.82	3.63	4.28
	N138	7.14	5.66	4.64	6.79	5.43	4.33	4.37
	N164	7.75	7.22	4.41	7.34	6.75	2.72	5.19
Mean		5.97	5.42	3.8	5.12	4.74	3.19	3.84
DMRT at 5%		1.42	1.74	1.31	1.66	2.07	1.23	1.33
CV%		13.2	18	16.1	18.3	12.1	16.2	17
2013	N0	5.8	5.15	3.52	6	5.13	2.92	2.78
	N69	6.7	5.57	4.02	5.03	5.84	3.59	3.04
	N92	8.07	7.58	5.61	6.53	6.6	4.7	4.68
	N138	8.57	7.64	5.14	7.69	6.7	5.49	4.25
	N164	9.66	9.19	6.92	8.56	8.53	5.22	3.88
Mean		7.76	7.03	5.04	6.76	6.56	4.38	3.73
DMRT at 5%		2.59	1.46	2.04	2.6	2.97	1.43	1.93
CV%		17.6	16.3	19.3	1.6	14.3	14.9	16.9

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	N0	4.7	4.28	3.03	4.32	3.73	2.63	2.66
	N69	5.99	4.76	3.76	4.15	4.62	3.27	2.93
	N92	7.09	7.22	4.76	6.03	6.21	4.16	4.48
	N138	7.85	6.65	4.89	7.24	6.06	4.91	4.31
	N164	8.7	8.2	5.66	7.95	7.64	3.97	4.54
Mean		6.87	6.22	4.42	5.94	5.65	3.79	3.78
DMRT at 5%		1.66	1.87	1.52	1.65	2.35	1.4	1.38
CV%		16.9	17.7	15.8	18.5	16.5	18.9	12.6

Nitrogen uptake, agronomical and physiological nitrogen efficiency

Average nitrogen uptake of the two sequence experiments seasons (2011 and 2012) were increasing significantly by increasing nitrogen levels and reach to its maximum and significant at nitrogen level of 138, 138 and 92 kg ha^{-1} in the monoculture of both sorghum cultivars SV1 (230.2 kg ha^{-1}), SV2 (228.7 kg ha^{-1}) and bean (135.9 kg ha^{-1}) but further application had no effect on nitrogen uptake increase. At these levels, the increase in nitrogen uptake were to the extent of 58%, 52% and 44.5%, respectively. However, uptake of nitrogen by sorghum and bean was found to increase significantly due to intercropping. The nitrogen uptake were (261.8 kg ha^{-1}) and (297.4 kg ha^{-1}) when sorghum cultivars SV1 and SV2 intercropped with bean (Table 3). These results indicated that there are magnitude increase in nitrogen uptake when bean intercropped with sorghum. The extent of reduction in N uptake was about 60% and 33%. On the other hand, N uptake with developed cultivar SV1was higher than the cultivar SV2 when intercropped with bean whereas no significant increase when grown in monoculture cropping. Kanakeri [25] found that uptake of nitrogen with green gram (284 kg ha^{-1}) was significantly developed than with cowpea (239 kg ha^{-1}) and soybean (247 kg ha^{-1}) as intercrops. Further, among different intercrops, cowpea noted maximum uptake of nitrogen (68 kg ha^{-1}) followed by soybean with 60 kg ha^{-1} NP, separately. In these results N uptake of the intercropping was higher than the monoculture cultivation.

Table 3: Nitrogen Uptake orghum and bean as influenced by intercropping and nitrogen levels at IBB research station during the rainy season in the 2009 and 2010.

Year	Cultivars/	Monoculture			Intercropping	
	N level	SV1	SV2	Bean	SV1	SV2
2012	N0	102.3	112.2	62.7	135.2	149.6
	N46	143.5	142.2	99.9	238.1	253.5
	N92	207	200.4	116.2	275.8	289.3
	N138	237.7	212	152.1	322.4	298.7
	N164	243.4	225.4	155.9	338.3	319.9
Mean		186.8	178.4	117.4	262	262.2
DMRT at 5%		85.5	66.9	55.7	42.9	59.7
CV%		14.8	10.7	17.1	15.7	11.5
2013	N0	87.4	105.6	88.1	122.3	182.2
	N69	133.7	151	118.7	188.6	232
	N92	190.7	207.4	155.6	247.8	305.6
	N138	222.8	245.3	162.8	274.8	335.6
	N164	224	264.7	176.7	341	354.7
Mean		171.7	194.8	140.4	234.9	282
DMRT at 5%		115.8	111.3	66.4	77.8	646.1
CV%		12.7	16	18.6	18.6	17.2
Average	N0	94.9	108.9	75.4	128.7	165.9
	N69	138.6	146.6	109.3	213.4	242.8
	N92	198.8	203.9	135.9	261.8	297.4
	N138	230.2	228.7	157.4	298.6	317.2
	N164	233.7	245.1	166.3	339.7	337.3

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Mean	179.2	186.6	128.9	248.4	272.1
DMRT at 5%	82.8	76.9	64.2	96.7	98.4
CV%	15.2	16.3	18.8	17.5	19.2

Agronomical and physiological nitrogen efficiency

The results showed that both agronomical nitrogen efficiency (ANE) was reduced with increasing nitrogen application in monoculture cropping and intercropping. However, ANE reduced significantly in both sorghum cultivars SV1 (1.97 kg ha^{-1}), SV2 (2.05 kg ha^{-1}) and bean (1.87 kg ha^{-1}) when nitrogen was applied in the level N138 for both sorghum cultivars and N92 for bean in comparison with the low level of nitrogen N46 when grown monoculture (Table 4). However, ANE also reduced significantly in the intercropping with both sorghum cultivars SV1 (1.88 kg ha^{-1}), SV2 (2.19 kg ha^{-1}) at nitrogen level N138. Similarly, physiological nitrogen efficiency (PNE) was reduced with increasing nitrogen application in monoculture cropping and intercropping. However, PNE reduced significantly in both sorghum cultivars SV1 (24.3 kg ha^{-1}), SV2 (24.0 kg ha^{-1}) and bean (11.0 kg ha^{-1}) when nitrogen was applied in the level N138 for both sorghum cultivars and N92 for bean in comparison with the low level of nitrogen N92 in case of sorghum cultivars and N46 in case of bean when grown in monoculture (Table 4). In contrast, PNE increased significantly in both monoculture sorghum cultivars SV1 (10.0 kg ha^{-1}), SV2 (27.4 kg ha^{-1}) at nitrogen level N138 while PNE of monoculture bean reduced significantly at the level N164. On the other hand, PNE was reduced significantly with the intercropping with both sorghum cultivars SV1 (31.6 kg ha^{-1}), SV2 (23.2 kg ha^{-1}) at nitrogen level N164 (Table 4). However, the (AE) and (PNE) were lower in case of bean in comparison with both sorghum cultivars.

Table 4: Agronomical and Physiological Efficiency sorghum and bean as influenced by intercropping and nitrogen levels at IBB research station during the rainy season in the 2009 and 2010.

		Agronomical Efficiency					Physiological Efficiency				
Cropping		Monoculture			Intercropping		Monoculture			Intercropping	
	N level	SV1	SV2	Bean	SV1	SV2	SV1	SV2	Bean	SV1	SV2
2012	N46	5.91	7.13	2.53	9.44	3.1	24.5	18.8	4.4	52.5	30.7
	N92	3.22	8.09	1.96	8.13	9.89	28.7	27.6	9	44	29.4
	N138	2.1	3.21	3.61	3.23	3.65	22.3	24.7	16.6	36.7	41.2
	N164	4.01	0.61	0.15	0.47	0.63	22.7	26.7	11.2	36.4	25.1
Mean		3.81	4.76	2.06	5.32	4.32	24.6	24.5	9.5	42.4	31.6
DMRT at 5%		1.76	3.65	0.56	3.86	3.87	4.7	5.3	3.2	5.5	1.8
CV%		19	11	18.8	17.1	15.4	17.7	19.1	17.3	12	16
2013	N46	5.3	7.6	2.69	6.02	12.3	36.5	29.6	24.6	51.2	60.7
	N92	4.65	6.4	1.78	10.05	10.15	31	27.7	18.9	48	60.6
	N138	1.83	0.89	1.76	0.38	0.74	26.2	23.3	15.5	43.6	45.5
	N164	0.18	0.83	0.43	0.83	0.97	26.8	21.8	14.1	26.9	21.4
Mean		2.99	3.93	1.67	4.32	6.04	26.3	25.6	17.5	42.4	47
DMRT at 5%		2.38	2.52	1.33	4.15	2.61	2.3	3.3	7	7.8	8.6
CV%		14.1	18.5	15.4	15.7	16	11.9	10.6	15.2	13.9	18.6
Average	N46	5.61	7.37	2.61	7.73	7.7	25.5	24.2	14.5	51.9	45.7
	N92	3.94	7.24	1.87	9.09	10.02	27.4	27.7	14	46	45
	N138	1.97	2.05	2.69	1.81	2.19	24.3	24	16	40.1	43.3
	N164	2.09	0.72	0.29	0.65	0.8	26.7	24.3	12.6	31.6	23.2
Mean		3.4	4.35	1.86	4.82	5.18	25.4	25	13.5	42.4	39.3
DMRT at 5%		1.86	3.2	2.86	3.13	5.12	1.4	7.7	3.5	3.2	7.3
CV%		17.4	19.7	18.9	17.3	18.6	17.1	14.3	11.9	13.1	12.2

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Fraction nitrogen recovery and efficiency of utilization

Fraction Nitrogen Recovery (FNR) of both sorghum cultivars SV1 (0.98 kg ha^{-1}) and SV2 (0.86 kg ha^{-1}) was significantly higher than that of bean (0.59 kg ha^{-1}) at the N138 when grown in monoculture cropping and intercropping but the values were high at monoculture cropping than intercropping. Thus, at N135 the FNR of N by the bean pure stand was < for sorghum cultivar SV2 < for sorghum cultivar SV2 and intercropping with SV2 < SV2 (Table 5). The results indicated that all crop stands used the lower N rate significantly and more efficiently than the higher one. Even though N recovery for the bean pure stand at the N46 level was significantly lower than that of the sorghum pure stand and the intercropping of both sorghum cultivars with bean, its increase in biomass production compared with the unfertilized treatment was not different from that of the other crop stands. In contrast, the results were significantly higher in nitrogen efficiency of utilization (ENU) for both sorghum cultivars SV1 (6.6 kg ha^{-1}) and SV2 (11.4 kg ha^{-1}) which was significantly higher than that of bean (8.0 kg ha^{-1}) at the level N138 when grown in monoculture cropping but the values were high at intercropping with SV1 (19.9 kg ha^{-1}) and SV2 (21.1 kg ha^{-1}) than monoculture cropping. Thus, the ENU of all crop stands was lower at the N164 level compared with the N46 level. Again, sorghum cultivar SV1 (6.6 kg ha^{-1}) and used N significantly better than bean and bean used N significantly better than SV2 if grown in monoculture. Meanwhile, sorghum cultivar SV2 (15.7 kg ha^{-1}) grown used N significantly better than SV1 (18.8 kg ha^{-1}) if grown in intercropping with bean (Table 5). Li et al. [3] that nitrogen acceptance by sorghum in an intercrop is greater as relate to sole cropping. The greater N acquisition by a non - legume crop intercropped with a legume is often reported in literature Francis [23] & Vandermeer [24]. This may probably be due to the effect of competition. However, nitrogen attainment by soybeans was not significantly affected by intercropping.

Table 5: Fraction Nitrogen Recovery and Efficiency Utilization sorghum and bean as influenced by intercropping and nitrogen levels at IBB research station during the rainy season in the 2009 and 2010.

Cropping		Fraction Nitrogen Recovery					Fraction Nitrogen Recovery				
Year	Cultivars	Monoculture			Intercropping		Monoculture			Intercropping	
	N level	SV1	SV2	Bean	SV1	SV2	SV1	SV2	Bean	SV1	SV2
2009	N46	0.9	0.65	0.81	2.24	2.12	6.6	10.9	3.1	11.1	9
	N92	1.14	0.96	0.68	1.43	1.52	5.4	12.2	4.7	21.7	19.1
	N138	1.08	0.8	0.54	1.36	1.16	5.8	13.8	10.6	19.6	21
	N164	0.99	0.78	0.57	1.27	1.06	9.3	12.7	8.8	17.9	19.7
	Mean	1.03	0.8	0.65	1.57	1.47	6.8	12.4	6.8	17.6	17.2
DMRT at 5%		0.57	0.31	0.22	0.23	2.97	4.6	7.1	5.2	6.4	7.7
CV%		15.1	16.3	14.2	12.7	10.7	12.5	14.3	19.4	13.5	15.6
2010	N46	1.01	0.99	0.67	1.44	1.08	5.3	7.7	4	8.4	25.2
	N92	1.12	1.11	0.73	1.36	1.34	6.5	9.2	4.3	18.6	23.2
	N138	0.98	1.01	0.54	1.1	1.11	6.8	7.6	7.1	16.3	18.8
	N164	0.99	0.97	0.54	1.33	1.05	5.8	7.5	6.8	12.4	18.5
	Mean	1.03	1.02	0.62	1.31	1.15	6.1	8	5.5	13.9	21.4
DMRT at 5%		1.43	0.17	0.25	0.39	0.18	3.9	1.5	2.5	3	3.2
CV%		13.1	16.8	19.7	12.6	13.9	18.2	15.1	19.2	14.9	12.7
Average	N46	0.95	0.82	0.74	1.84	1.6	5.9	9.3	3.6	9.7	17.1
	N92	1.13	1.03	0.71	1.4	1.43	6	10.7	4.5	20.2	21.1
	N138	1.03	0.91	0.54	1.23	1.14	6.3	10.7	8.9	18	19.9
	N164	0.99	0.87	0.55	1.3	1.06	7.6	10.1	7.8	15.1	19.1
Mean		1.03	0.91	0.64	1.44	1.31	6.4	10.2	6.2	15.7	19.3
DMRT at 5%		3.73	0.37	0.15	0.46	0.51	1.9	7.9	3.2	6.3	7.5
CV%		19	16.8	15.6	20	18.6	13.1	16.9	17.8	15.1	18.8

Yield and advantage of intercropping

Nitrogen fertilizer increased grain yield in sole or sorghum–common bean intercrops to certain level thereafter it decline. However, under monoculture cropping, nitrogen application treatments had significant effect on sorghum grain yield of the cultivar SV1 (5.238 ton ha^{-1}) at N164 and the cultivar SV2 (5.197 ton ha^{-1}) at N132 and total seed yield of common bean (1.564 ton ha^{-1}) at N92. On the other hand, a significant response to crop stand and N interaction was found for sorghum and bean

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yield. Highest grain yield was achieved with sorghum grown in intercropping for the cultivar SV1 (3.949 ton ha^{-1}) at N138 and the cultivar SV2 (4.293 ton ha^{-1}) at N92 whereas seed yield of common bean also were highly significant when intercropped with SV1 (1.214 ton ha^{-1}) and with SV2 (1.289 ton ha^{-1}) (Table 6). These results showed clearly that sorghum-common bean cropping system reduced grain yield of sorghum and seed bean but nitrogen application reduced the percentage of reduction.

Table 6: Grain Yield sorghum and bean as influenced by intercropping and nitrogen levels at IBB research station during the rainy season in the 2009 and 2010.

Cropping		Monoculture			Intercropping			
Year	Cultivars	Sorghum		Bean	Sorghum		Bean	
	N level	SV1	SV2		SV1	SV2	SV1	SV2
2009	N0	3.707	3.656	1.116	2.635	2.986	0.733	0.839
	N46	3.979	3.984	1.233	2.974	3.039	0.829	0.929
	N92	4.276	4.728	1.413	3.351	3.643	1.199	1.234
	N138	4.566	5.171	1.911	3.704	4.086	1.293	1.296
	N164	5.224	5.271	1.936	3.777	4.186	1.296	1.299
Mean		4.35	4.562	1.522	3.288	3.588	1.07	1.119
DMRT at 5%		0.374	0.313	0.286	0.255	0.29	0.26	0.249
CV%		16.8	17.8	15.7	15.5	19.3	15	12.5
2010	N0	4.299	4.728	1.427	3.383	3.443	0.843	0.943
	N46	4.543	5.078	1.551	3.512	3.929	0.991	1.023
	N92	4.971	5.667	1.715	4.2	4.543	1.228	1.343
	N138	5.223	5.789	1.958	4.194	4.729	1.286	1.259
	N164	5.252	5.925	2.028	4.322	4.857	1.294	1.289
Mean		4.858	5.437	1.736	3.922	4.3	1.128	1.171
DMRT at 5%		0.402	0.454	0.346	0.306	0.357	0.346	0.272
CV%		14.2	19.2	16.2	13.4	16.7	16.1	12.2
	N0	4.003	4.192	1.272	3.009	3.214	0.788	0.891
	N46	4.261	4.531	1.392	3.243	3.484	0.91	0.976
	N92	4.623	5.197	1.564	3.775	4.093	1.214	1.289
	N138	4.895	5.48	1.935	3.949	4.407	1.289	1.277
	N164	5.238	5.598	1.982	4.05	4.521	1.295	1.294
Mean		4.604	5	1.629	3.605	3.944	1.099	1.145
DMRT at 5%		0.476	0.42	0.308	0.376	0.259	0.208	0.272
CV%		15.8	14.4	21.8	17.4	15.6	12.2	17.6

The magnitude of reduction was at nitrogen level N92 and lower and higher this level the reduction percent increased, the reduction percent in local sorghum and cultivar (SV1) was 18.3% and in (SV1) was 21.3% where as common been reduced by seed yield by 22.4% and 17.6% when intercropped with both (SV1) and cultivar (SV1), respectively. Furthermore, the reduction in bean was more than sorghum and the effect of intercropping on grain sorghum cultivars was similar where as the effect of intercropping on seed yield of bean was higher than sorghum and the reduction percent in seed yield of bean was high when intercropped with (SV1) than (SV1) (Table 6). Sorghum/soybean cropping system reduced sorghum grain yield by 23.9% where as sorghum/cowpea reduced by grain yield by 40.3%. However, The application of nitrogen fertilizer to cereal rows mitigated the efficiency intercropping and benefited the associated legume by increasing grain yields as reported by Li et al. [4]

One of the main measures to evaluate yield advantage and efficiency in intercropping is the land equivalent ratio (LER), which considers the performance of a component of the mixture with respect to the its yield achieved at sole crop Franci [23]; when the LER is greater than 1 facilitation is contributing to a greater extent than the phenomena of competition. The partial LER of sorghum and bean was similar between the two sorghum cultivars weather intercropped (SV1) or (SV1). However, the higher partial LER value of common bean crop was significantly higher at the N92 and this value decrease below and above this

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nitrogen level, leading to a high value of overall LER at the latter. Partial LER values also showed that, common bean appears to have more beneficial land use efficiency than sorghum in all nitrogen level and. Higher total LER values obtained were 1.66 and 1.77 at the N92 when bean intercropped with (SV1) and (SV1) respectively, indicating a production advantage of intercropping. were higher than one showing the advantage of intercropping over sole stands in regard to the use of environmental sources for plant growth (Table 7). Many LER values were achieved due to intercropping in barley and pea 1.26 Chen et al. [11] wheat and lentil 1.52 Akter et al. [29], sorghum and lima bean Reza et al. [21], sorghum/cowpea 1.55 Lamessa et al. [39]. Moreover, nitrogen application increase LER but high N rates could decrease the LER and result in toxic levels of nitrate in the forage Chen et al. [11].

Competitive indices

Competitive ratio (CR) which gives more desirable competitive ability for the crops was suggested by Donald [36]. The competition index is the product of the two equivalence factor. If the competition index is less than 1, there has been an advantage of mixing. According to Willey (1979), this index has the disadvantage that the single crops have to be present at a range of plant populations so that equivalent plant numbers can be estimated. Our results indicated that intercropping of both sorghum cultivars and bean were equally competitive at the nitrogen level N92 because overall average CR of intercropped sorghum cultivars SV1 (0.98) and SV2 (1.10) and of intercropped bean with sorghum cultivars SV1 (1.03) and SV2 (0.91) equal to one (Table 7).

Table 7: LER and CR of sorghum and bean as influenced by intercropping and nitrogen levels at IBB research station during the rainy season in the 2009 and 2010.

		LER						CR					
Year	Cultivars/	Sorghum		Bean		Total		Sorghum		Bean		Total	
	N level	SV1	SV2	SV1	SV2	SV1	SV2	SV1	SV2	SV1	SV2	SV1	SV2
2012	N0	0.71	0.86	0.66	0.75	1.37	1.61	1.06	1.13	0.94	0.89	2	2.01
	N46	0.75	0.91	0.67	0.75	1.42	1.67	1.09	1.19	0.92	0.84	2.01	2.03
	N92	0.78	0.92	0.85	0.87	1.63	1.8	0.91	1.03	1.1	0.97	2.01	2
	N138	0.81	0.94	0.68	0.68	1.49	1.62	1.18	1.36	0.85	0.74	2.03	2.09
	N164	0.72	0.8	0.67	0.67	1.39	1.47	1.06	1.17	0.94	0.85	2	2.02
Mean		0.77	0.89	0.72	0.74	1.48	1.64	1.06	1.19	0.95	0.85	2.01	2.04
DMRT at 5%		0.14	0.12	0.16	0.11	0.14	0.17	0.15	0.29	0.12	0.14	0.13	0.22
CV%		11.8	17.3	18.7	15.6	16.6	10.2	17.3	14.3	14.3	15.1	16.3	14.2
2013	N0	0.79	0.85	0.59	0.66	1.38	1.51	1.31	1.26	0.77	0.8	2.07	2.05
	N46	0.77	0.86	0.64	0.66	1.41	1.52	1.19	1.29	0.84	0.78	2.03	2.06
	N92	0.76	0.93	0.72	0.78	1.48	1.72	1.05	1.17	0.96	0.86	2	2.02
	N138	0.8	0.91	0.66	0.64	1.46	1.55	1.2	1.38	0.83	0.72	2.03	2.1
	N164	0.81	0.91	0.64	0.64	1.45	1.54	1.24	1.4	0.81	0.71	2.05	2.11
Mean		0.79	0.82	0.66	0.68	1.45	1.58	1.17	1.31	0.86	0.77	2.03	2.08
DMRT at 5%		0.12	0.11	0.12	0.11	0.11	0.15	0.57	0.16	0.1	0.11	0.03	0.08
CV%		11.1	18.5	17.1	14.5	15.7	17.2	17.3	1.2	2.8	3.5	0.6	0.5
Average	N0	0.75	0.85	0.62	0.7	1.37	1.56	1.19	1.2	0.84	0.84	2.03	2.03
	N46	0.76	0.89	0.66	0.71	1.42	1.6	1.14	1.24	0.88	0.81	2.02	2.05
	N92	0.77	0.93	0.78	0.83	1.56	1.76	0.98	1.1	1.03	0.91	2.01	2.01
	N138	0.81	0.92	0.67	0.66	1.47	1.58	1.19	1.37	0.84	0.73	2.03	2.1
	N164	0.77	0.85	0.65	0.65	1.42	1.51	1.15	1.29	0.88	0.78	2.02	2.07
Mean		0.78	0.86	0.69	0.71	1.47	1.61	1.11	1.25	0.91	0.81	2.02	2.06
DMRT at 5%		0.11	0.11	0.1	0.09	0.12	0.11	5.65	2.82	0.12	0.12	0.13	0.07
CV%		18.1	13.7	11.9	13.4	14.8	18.4	16.7	12.9	16.4	15.3	18.1	15.6

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Other competitive index is crowding coefficient (K), when the value of K is greater than1, there is a yield advantage; when K is equal to 1, there is no yield advantage; and, when it is less than 1.00, there is a disadvantage Koohi et al. [8]. Our results indicated that at the nitrogen levels N0 to N138 crowding coefficient (K) values of both cultivars and bean was equal to 1.00 indicating that the advantage of both cultivars and bean was equal but at the nitrogen level N164 the crowding coefficient (K) of intercropped bean with SV1 was lower than one indicating that no a disadvantage was expected at this nitrogen level (Table 8).

Table 8: Aggressivity (A) and crowding coefficient (K) of sorghum and bean as influenced by intercropping and nitrogen levels at IBB research station during the rainy season in the 2009 and 2010.

		A				K			
	Cultivars/	Sorghum		Bean		Sorghum		Bean	
Year	N level	SV1	SV2	SV1	SV2	SV1	SV2	SV1	SV2
2012	N0	0.03	-0.03	0.06	-0.06	0.92	1.02	0.65	0.83
	N46	0.04	-0.04	0.08	-0.08	0.85	0.99	0.6	0.83
	N92	-0.03	0.03	-0.02	0.02	0.79	0.68	0.71	0.65
	N138	0.07	-0.07	0.08	-0.08	0.74	0.98	0.72	0.97
	N164	0.03	-0.03	0.06	-0.06	0.89	0.99	0.77	0.99
Mean		0.02	-0.02	0.05	-0.05	0.82	0.91	0.7	0.86
2013	N0	0.1	-0.1	0.06	-0.06	0.78	1.19	0.81	1.01
	N46	0.07	-0.07	0.06	-0.06	0.8	1.07	0.8	1.02
	N92	0.02	-0.02	0.02	-0.02	0.82	0.9	0.73	0.78
	N138	0.07	-0.07	0.08	-0.08	0.76	1.02	0.76	1.06
	N164	0.08	-0.08	0.15	-0.15	0.75	1.07	0.59	1.07
Mean		0.06	-0.06	0.07	-0.07	0.78	1.01	0.72	0.98
Average	N0	0.07	-0.07	0.06	-0.06	0.84	1.11	0.74	0.93
	N46	0.05	-0.05	0.07	-0.07	0.83	1.03	0.7	0.92
	N92	0	0	0	0	0.8	0.79	0.72	0.71
	N138	0.07	-0.07	0.08	-0.08	0.75	1	0.74	1.02
	N164	0.06	-0.06	0.1	-0.1	0.82	1.03	0.68	1.03
Mean		0.04	-0.04	0.06	-0.06	0.8	0.96	0.71	0.92

Aggressivity (A) is also often used to determine the competitive relationship between 2 crops used in the mixed cropping Willey [35]. For cereal example; if A cereal = 0, both crops are equally competitive, if A cereal is positive, then the cereal species is dominant, if A cereal is negative, then the cereal is weak. Our results indicated that at all nitrogen levels Aggressivity (A) values were equal to zero indicating that the aggressivity of both sorghum cultivars and bean was equal (Table 8).

Economic analysis and intercropping advantage

Also to evaluate the economic and advantage of intercropping, indices such as relative value total (RVT), relative yield totals (RYT), actual yield loss or gain (AYL) and intercropping advantage (IA) were also used.

Relative value total (RVT) of the crop mixtures is relevant for the farmer that has monetary value as his farming goal Vandermeer [24]. If RVT is bigger than 1, the intercropping is economically preferable; whereas if RVT is smaller than 1, the pure cropping is preferable. Provided that RVT is equal to 1, neither of the methods is economically superior to the other. Our results showed that the RVT of both sorghum cultivars and bean in all nitrogen level of intercropping was more than one, but the maximum and significant RVT was achieved at the nitrogen level N92. However, RVT of intercropped bean was higher than RVT of both sorghum cultivars and RVT of SV2 was higher than SV1. This results indicates that economical advantage of sorghum and common bean intercropping more than the sole cropping of sorghum at the nitrogen level N92 and when the sorghum cultivar SV2 is used (Table 9).

Actual yield loss or gain (AYL) index, gave more accurate information about the competition than the

Other indices among components of intercropping system. The AYL is the proportionate yield loss or gain of intercrops compared to sole crop Banik [34]. The AYL can have positive

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or negative values indicating an advantage or disadvantage remained in intercrops when the main aim is to compare yield on a per plant basis. Consequently, the AYLsorghum had positive values and the maximum and significant was obtained at the nitrogen levels N92 both cultivars. In contrast, AYLbean had minimum values significant was obtained at the nitrogen levels N92 for both cultivar SV1 and SV2. It may be noted here that partial AYLlegumes or AYLcereal represent the proportionate yield loss or gain of each species when grown as intercrops, relative to their yield in sole planting Koohi et al. [8]. Moreover, total AYL was positive coefficient indicates the advantage of intercropping over monoculture at the nitrogen levels N92 because total AYL was more than one. In this study, no significant differences among the nitrogen levels for the intercropping with SV1 but the highest amount of AYL was obtained at N92 when SV2 was intercropped with bean (Table 9).

Table 9: Relative value total (RVT) and actual yield loss (AYL) of sorghum and bean as influenced by intercropping and nitrogen levels at IBB research station during the rainy season in the 2009 and 2010.

		RVT				AYL			
	Cultivars	Sorghum		Bean		Sorghum		Bean	
Year		SV1	SV2	SV1	SV2	SV1	SV2	SV1	SV2
2010	N0	1.15	1.39	1.71	2.03	0.78	1.16	0.09	0.25
	N46	1.21	1.44	1.75	2.07	0.87	1.29	0.12	0.26
	N92	1.41	1.42	1.91	2.12	0.96	1.31	0.41	0.46
	N138	1.44	1.39	1.54	1.68	1.03	1.35	0.13	0.13
	N164	1.28	1.35	1.54	1.64	0.81	1	0.12	0.12
Mean		1.34	1.4	1.69	1.88	0.92	1.24	0.19	0.24
DMRT at 5%		0.11	7.56	3.83	6.15	17.4	17.6	14.3	15
CV%		19.4	17.5	15.6	12.8	19.9	12.5	14.1	13
2011	N0	1.23	1.22	1.65	1.8	0.97	1.12	-0.02	0.1
	N46	1.26	1.22	1.65	1.79	0.93	1.16	0.06	0.1
	N92	1.32	1.35	1.71	1.99	0.91	1.34	0.19	0.31
	N138	1.35	1.27	1.61	1.72	1.01	1.26	0.09	0.07
	N164	1.35	1.48	1.59	1.71	1.02	1.27	0.06	0.06
Mean		1.32	1.33	1.64	1.8	0.97	1.26	0.1	0.13
DMRT at 5%		6.43	9.95	2.67	9.61	8.1	7.8	12.5	11.4
CV%		13.9	18.6	14.3	16.2	15.3	18.1	19	13.7
average	N0	1.19	1.3	1.68	1.92	0.87	1.14	0.04	0.18
	N46	1.24	1.33	1.7	1.93	0.9	1.22	0.09	0.18
	N92	1.36	1.38	1.81	2.06	0.94	1.32	0.3	0.38
	N138	1.4	1.33	1.58	1.7	1.02	1.3	0.11	0.1
	N164	1.31	1.41	1.57	1.67	0.91	1.14	0.09	0.09
Mean		1.33	1.36	1.66	1.84	0.94	1.25	0.15	0.19
DMRT at 5%		6.38	5.06	2.68	7.08	7	12	8.6	17.8
CV%		17.8	18.6	18.1	17.3	13.7	16.5	10.5	10.3

The most important index of biological advantage is the relative yield total (RYT) that was used to quantify the yield advantages in a replacement series Mead [33] RYT in all intercropping nitrogen levels was more than one. The highest significant value of RYT was observed 1.60 at nitrogen level N92 (Table 9). When RYT was values > 1 indicate that the species make different demands on resources or avoid competition in some way, while values of RYT < 1 imply mutual antagonism, RYT values of 1 indicate that the components fully share the same limiting resource Harper [40]. It means the competing species use partially different growing resources or utilize the same resources, but more efficiently due to differences in plant architecture, physiology or growing cycle Bulson et al. [41]. The highest value of RYT for mung bean and sorghum intercropping (1:1) was 1.36 Koohi [8] and for alfalfa and wheatgrass intercropping was 1.15 and the maximum RYT in single cropping) for alfalfa and wheatgrass was 1.02 and 0.36, respectively Ghaderi et al. [42].

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The values of monetary advantage index MAI was significantly highly significant for the cultivar SV2 (1.46) in comparison with SV1 (1.32) at N138. However, the application of nitrogen increase the MAI significantly with the intercropping with SV2 While application of nitrogen has significant increase MAI at the level of N138 (Table 10). Thus, at N138 levels the higher MAI value indicates that the intercropping system is more profitable and showed economic advantage of the intercropping system as reported by Ghosh [37]. Recently Osman et al. [43] reported that by using monetary advantage index (MAI), intercropping with two rows of cowpea and one row of millet gave significantly higher economic benefit than mixture with one row of each of the crops. These results suggest that intercropping could improve the system's productivity, increase the income for smallholder farmers, and compensate losses. In intercropping, monetary advantage index (MAI) are used to assess the productivity and its economic benefits. In our study, we can conclude that the value of MAI depends on the genotypic variation more than the application of nitrogen fertilizer. Ghosh [37] and Koohi et al. [8] reported that if LER and K values were higher, there was also economic benefit expressed with MAI values.

Another pivotal observation here was intercropping advantage (IA) that application of nitrogen caused significant increase in AI at the nitrogen levels N92 for both cultivars (Table 10). According to Banik et al. [34], this index, in addition to expressing the advantage or disadvantage of intercrops, can be an indicator of the economic feasibility of intercropping systems. The season of this result was due to better use of resources such as light, water and nutrients in this treatment, probably. The intercropping advantage (IA) affirmed that the most advantageous nitrogen fertilizers level were observed at N92 for both sorghum cultivars and bean in all nitrogen level of intercropping but IA value of cultivar SV2 was higher than SV1.

Table 10: RYT, MAI and AI of sorghum and bean as influenced by intercropping and nitrogen levels at IBB research station during the rainy season in the 2009 and 2010.

	Cultivars	RYT		MAI		AI		
Year		SV1	SV2	SV1	SV2	SV1	SV2	Total
2012	N0	1.59	1.53	1.08	1.15	24.3	34.3	58.6
	N46	1.66	1.59	1.11	1.21	25.6	36.4	61.9
	N92	1.62	1.68	0.85	1.06	26.8	36.7	63.5
	N138	1.64	1.51	0.86	1.38	27.8	37.3	65.1
	N164	1.52	1.46	0.9	1.19	24.7	31.8	56.6
Mean		1.61	1.56	0.93	1.21	26.2	35.6	61.8
DMRT at 5%		0.3	0.26	0.26	0.26	3.14	5.22	5.09
CV%		18.4	14.4	16.8	16.3	14.3	12.9	15.6
2013	N0	1.56	1.36	1.33	1.28	26.9	33.7	60.6
	N46	1.55	1.41	0.89	1.31	26.5	34.4	60.9
	N92	1.58	1.54	0.82	1.19	26.2	37.2	63.3
	N138	1.6	1.45	0.89	1.41	27.5	36	63.5
	N164	1.74	1.57	0.89	1.43	27.6	36.1	63.7
Mean		1.62	1.49	0.96	1.24	26.9	35.9	62.9
DMRT at 5%		0.13	0.16	0.23	0.14	1.77	3.29	6.34
CV%		18.9	11.9	14.8	18.8	13.5	13.9	14.3
Average	N0	1.57	1.44	1.11	1.22	25.7	34	59.7
	N46	1.6	1.49	1.1	1.26	26	35.4	61.4
	N92	1.6	1.6	1.23	1.32	26.5	36.9	63.4
	N138	1.62	1.48	1.32	1.46	27.6	36.7	64.3
	N164	1.63	1.51	0.9	1.31	26.2	34	60.2
Mean		1.61	1.53	1.13	1.32	26.6	35.7	62.3
DMRT at 5%		NS	0.1	NS	0.17	1.79	4.46	6.56
CV%		16.9	19.3	12.9	17.2	12.5	18.1	15.8

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Correlation of yield and parameters of intercropping efficiency

Under monoculture cropping, Yaa and Ybb were associated positively and highly significant with LAIaa, NUaa and PNEaa while that of ANEaa, FNRaa and ENUaa were high and negatively correlated with Yaa and Ybb (Table 11). Under intercropping, Yab and Yba were also correlated positively and highly significant with LAIab, LAIba, NUaa, NUab, PNEba and ENUa+b but negatively correlated with ANEa+b, FNRa+b and ENUa+b. Also these parameters LAIaa, NUaa, PNEaa and were positively and highly significant with each other (Table 12). These results indicated that the leaf area index, the nitrogen uptake and physiological use efficiency can be considered as selection criteria to identify genotypic differences suitable and efficient in nitrogen uptake and utilization for sole both sorghum cultivars and common bean and also intercropping, while utilization of nitrogen can be used a good indicator for selection suitable genotypes for sorghum and bean intercropping only.

Table 11: Correlation coefficients of yield, leaf area index, nitrogen uptake, agronomical, physiological nitrogen efficiency and nitrogen recovery and efficiency of utilization indices of sole sorghum and bean.

	Traits	Yaa	LAIaa	NUaa	ANEaa	PNEaa	FNRAaa	ENUAaa
Sole sorghum	Yaa	1						
	LAIaa	0.965*	1					
	NUaa	0.799**	0.809**	1				
	ANEaa	-0.538*	-0.651**	-0.609**	1			
	PNEaa	0.735**	0.793**	0.868**	-0.429*	1		
	FNRaa	-0.760**	-0.791**	-0.971**	0.550*	-0.944**	1	
	ENUaa	-0.787**	-0.830**	-0.961**	0.524*	-0.965**	0.984**	1
Sole Been	Traits	Ybb	LAIbb	NUbb	ANEbb	PNEbb	FNRbb	ENUbb
	Ybb	1						
	LAIbb	0.845**	1					
	NUbb	0.921**	0.924**	1				
	ANEbb	-0.058	-0.168	-0.127	1			
	PNEbb	0.870**	0.785**	0.822**	0.286	1		
	FNRbb	-0.789**	-0.757**	-0.913**	-0.083	-0.760**	1	
	ENUbb	-0.771**	-0.759**	-0.909**	-0.089	-0.760**	0.998**	1

Table 12: Correlation coefficients of yield, leaf area index, nitrogen uptake, agronomical, physiological nitrogen efficiency and nitrogen recovery and efficiency of utilization indices of intercropped sorghum and bean.

Traits	Yab	Yba	LAIab	LAIba	NUab	NUba	ANEa+b	PNEa+b	FNRa+b	ENUa+b
Yab	1									
Yba	0.861**	1								
LAIab	0.933**	0.852**	1							
LAIba	0.850**	0.741**	0.722**	1						
NUab	0.737**	0.947**	0.808**	0.559*	1					
NUba	0.791**	0.929**	0.816**	0.654**	0.967**	1				
ANEa+b	-0.21	-0.193	-0.438*	-0.106	-0.356	-0.384	1			
PNEa+b	0.713**	0.891**	0.588**	0.688**	0.749**	0.724**	0.19	1		
FNRa+b	-0.778**	-0.949**	-0.728**	-0.713**	-0.902**	-0.913**	0.178	-0.888**	1	
ENUa+b	0.483*	0.712**	0.396*	0.455*	0.616**	0.558**	0.29	0.837**	-0.599*	1

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The yield of sorghum Yab and yield of bean Yba was significantly and positively correlated with each other. However, Yab and Yba was significantly and positively correlated with RVT, AYL, RYT and MAI. Interestingly, it was clear that intercropped yield of sorghum Yab associated strongly with CR while yield of bean Yba was associated strongly with LER and AI. On the other hand, LER was significantly and positively correlated with RVT, AYL, RYT and AI and significantly and negatively correlated with CR, KS, KB and MAI whereas CR significantly and positively correlated with KS, KB and MAI and significantly and negatively correlated with RVT, AYL and AI. These results indicated that intercropped sorghum and bean responded differently, While LER, RVT, AYL, RYT and AI can be good indicators for selecting bean genotypes suitable for intercropping, CR, KS, KB and MAI could be useful selection criteria for screening sorghum lines for suitable genotypes for sorghum-bean intercropping (Table 13).

Table 13: Correlation coefficients of competitive and economic indices of sorghum and bean intercropping.

Traits	Yab	Yba	LER	CR	KS	KB	RVT	AYL	RYT	MAI	AI
Yab	1										
Yba	0.883**	1									
LER	0.255	0.540**	1								
CR	0.482*	0.068	-0.520**	1							
KS	-0.648**	-0.534*	-0.467*	0.635**	1						
KB	0.096	0.061	-0.861**	0.825**	0.858**	1					
RVT	0.447*	0.418*	0.967**	-0.623**	-0.668**	-0.873**	1				
AYL	0.350*	0.589**	0.985**	-0.483*	-0.809**	-0.816**	0.936**	1			
RYT	0.352*	0.394*	0.790**	0.225	-0.848*	-0.707**	0.839**	0.637**	1		
MAI	0.526**	0.433**	-0.633**	0.936*	0.901**	0.870**	-0.766*	-0.630**	-0.467**	1	
AI	-0.01	0.365*	0.915**	-0.635*	-0.876**	-0.905**	0.925*	0.836**	0.792**	-0.771*	1

Yield stability in monoculture and intercropping of sorghum-bean under farmer and recommended nitrogen fertilizers

The results of cropping performance and nitrogen fertilizers response overall the locations and years showed that yield of sorghum cultivar SV2 was higher than SV1 under both monoculture cropping and intercropping system and also the recommended nitrogen fertilizer (N138 for monoculture cropping and N92 for intercropping system yielded grain sorghum and seeds bean were higher than of farmer nitrogen fertilizer (varies from no nitrogen application to organic manure 5 ton ha^{-1}). However, the sole monoculture crop of farmer cultivar SV1 and the recommended cultivar SV2 and common bean (Taiz-305) were more stable overall locations and years under recommended nitrogen dose as they recorded high average yield with b-value of 1.00 and a very low standard deviation (s2d) approaching zero and highly significant coefficient of determination (r2). However, common bean (Taiz-305) intercropped with SV2 were stable in comparison with SV1 as they meet criteria of high average yield with b-value of 1.00 and a very low standard deviation (s2d) approaching zero and highly significant coefficient of determination (r2) under intercropping (Table 14). These results indicated that sorghum cultivar were more responsive under monoculture in comparison with common bean that were less responsive to environmental change. However, recommended sorghum cultivar (SV2) were more responsive to high yielding environmental change than local sorghum cultivar (SV1) by resulting an increasing in yield. On the other hand, intercropped common bean (Taiz-305) with recommended sorghum cultivar (SV1) was more responsive and stable under wide range of environments (locations and years) in comparison with farmer bean intercropped.

Table 14: Stability indices and average yield of the years 2011, 2012 and 2013 of sorghum and bean as influenced by sole and intercropping and nitrogen fertilizers at eight locations.

Cropping	Cultivars	Average Mean		Slop (*b*)		R^2		S^2d	
		FNF	RNF	FNF	RNF	FNF	RNF	FNF	RNF
Monoculture	SV1	4.038	4.803	0.734	1.059	0.829	0.753	0.045	0.042
	SV2	4.235	5.075	0.61	0.835	0.688	0.732	0.083	0.02
	Bean	1.523	1.977	1.977	1.05	0.376	0.745	0.014	0.081
	Average	3.065	3.952	1.107	0.981	0.631	0.743	0.047	0.048

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Intercropping	SV1	4.118	4.535	1.275	0.451	0.576	0.526	0.017	0.006
	SV2	4.517	4.933	0.64	0.791	0.726	0.787	0.054	0.014
	BSV1	0.546	0.757	0.523	0.368	0.487	0.734	0.016	0.03
	BSV2	0.911	1.523	0.881	0.896	0.776	0.763	0.037	0.045
	Average	1.991	2.404	0.681	0.685	0.663	0.761	0.036	0.03

These results were close to the findings of Faris [44] who found that pulses were less responsive to environmental change while cereals were more responsive to improvement in the environment resulting in increased yield. The regression lines of the intercropping patterns and sole cereals were closer to each other, due to the low yield contribution of the pulses to the intercropping total yield. However, the slopes of the intercropping pattern lines were closer to b : 1.0. On the basis of mean yield and regression slope, it was demonstrated that sole cereals or intercropping have better performance stability than sole pulses in northeastern Brazil [45-49].

Conclusion

From the results we can conclude the following:

A. Intercropping of sorghum and bean recorded less grain yield as compared to sole crop yields of sorghum and bean. However, The application of nitrogen fertilizer to sorghum rows mitigated the efficiency intercropping and benefited the associated common bean by increasing grain yields.

B. Yield and forage also displayed a positive reaction to increasing nitrogen to about 138 kg ha^{-1} sorghum cultivars SV1 and SV2 and 92 for bean cultivar Taiz-305 but further application had no effect on yield and forage increase. Grain yields and forage of sorghum and beans were affected by intercropping and the effect was more detrimental to the cultivar SV1 in comparison to SV2.

C. Intercropping systems provided many benefits through increased efficiency of nitrogen uptake (NU), physiological nitrogen efficiency (PNE), efficiency of nitrogen utilization ENU and leaf area index (LAI) by both crops in relation to sole crops, and maximum stimulation of these parameters reach to its magnitude at N138 for monoculture cropping and N92 for intercropping practice.

D. The common bean suffers competition from the sorghum which results in lower yield in intercropping compared with sole-cropping; moreover addition of N fertilizer reduced strongly the inhibition of growth especially at the nitrogen level N92. Interestingly, it was clear that intercropped yield of sorghum Yab associated strongly with CR while yield of bean Yba was associated strongly with LER and AI.

E. Economic evaluation indices RVT, AYL, RYT and MAI, in addition to expressing the advantage of intercrops, can be used as indicators of the economic feasibility of intercropping systems.

F. LER, RVT, AYL, RYT and AI can be good indicators for selecting bean genotypes suitable for intercropping, while CR, KS, KB and MAI could be useful selection criteria for screening sorghum lines for suitable genotypes for sorghum-bean intercropping.

G. The results also indicated that recommended sorghum cultivar (SV2) were more responsive to high yielding environmental change than local sorghum cultivar (SV1), while intercropped common bean (Taiz-305) with recommended sorghum cultivar (SV1) and optimal dose of nitrogen was more responsive and stable under wide range of environments (locations and years) in comparison with farmer bean intercropped.

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