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Research Article

Effect of *Sorghum*-Mung Bean Intercropping on *Sorghum*-Based Cropping System in the Lowlands of North Shewa, Ethiopia

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Due to decreasing land units and a decline in soil fertility, integrating mung beans into the *Sorghum* production system is a viable option for increasing productivity and producing cash crops. The experiment was conducted during the 2017 and 2018 cropping seasons in order to evaluate the effect of a *Sorghum*-mung bean intercrop arrangement on a *Sorghum*-based cropping system that would maximize intercropping advantage without reducing *Sorghum* performance. The treatments were combinations of sole *Sorghum*, sole mung bean, one *Sorghum* by one mung bean row (1 : 1), one *Sorghum* by two mung bean rows (1 : 2), two *Sorghum* by one mung bean row (2 : 1), and mixed planting of *Sorghum* and mung bean (50/50), which were tested in a randomized complete block design replicated four times. The highest yield reduction was observed from intercropping mixed planting (15.63%), in addition, the mean intercropped *Sorghum* yield showed up to12.44% reduction compared to sole stand. On the other hand, best-intercropped *Sorghum* yields that were produced under combinations of 2 : 1 row arrangement (4.11 $t{\cdot}ha^{-1}$) gave a statistically similar yield to all combinations including sole stand (4.48 $t{\cdot}ha^{-1}$). Significant row arrangement effect showed that the row (1 : 2) gave the highest yield for mung bean (0.35 $t{\cdot}ha^{-1}$), while the lowest was recorded from row arrangement (1 : 1) (0.16 $t{\cdot}ha^{-1}$). The highest total LER was obtained at 1 : 2 row (1.23) arrangements. The highest net return and marginal return (MRR) (341.23%) was obtained from one-row *Sorghum* alternated with two-row mung bean (1 : 2). Therefore, farmers around the research area can get additional income from intercropping *Sorghum* with bean crops without adversely affecting *Sorghum* yield by using one-row *Sorghum* alternated two-row mung bean (1 : 2) row arrangement.

1. Introduction

Sorghum (*sorghum bicolor* L.) is the fifth most important cereal in the world, preceded by wheat, rice, maize, and barely. It is major stable diet of people of semiarid tropics. It has also been used as an energy source for animal feed.

Mung bean (*Vigna radiate* L), which is also called as green gram, is an important annual legume widely grown in the study area. Even though both *Sorghum* and mung bean are food crops, mung bean is widely produced for sale in the lowlands of Shewarobit and Ensaro.

Sorghum and legumes are essential crops for small-scale farmers in Ethiopia. Likewise, pulses such as common bean, pigeon pea, and mung bean are important food and cash crops.

Sorghum and pulses are compatible for intercropping to reduce the risk of total crop failure and help to avoid dependency on one crop. Intercropping systems play an important role for subsistence food production in developing countries [1]. Currently, the cultivated land per household is declining every year, with the population increasing at an alarming rate. Some farmers practice intercropping as a means to increase productivity from their limited land holdings and as security against crop loss from various environmental disasters. Intercropping is a common practice in the existing cropping systems of North Shewa, Ethiopia. Usually, mung bean is intercropped with *Sorghum* simultaneously, about three weeks after *Sorghum* planting or when *Sorghum* approaches physiological maturity.

Mung bean is extra early maturing and, hence, may not compete for a long time for resources with *Sorghum*. If any

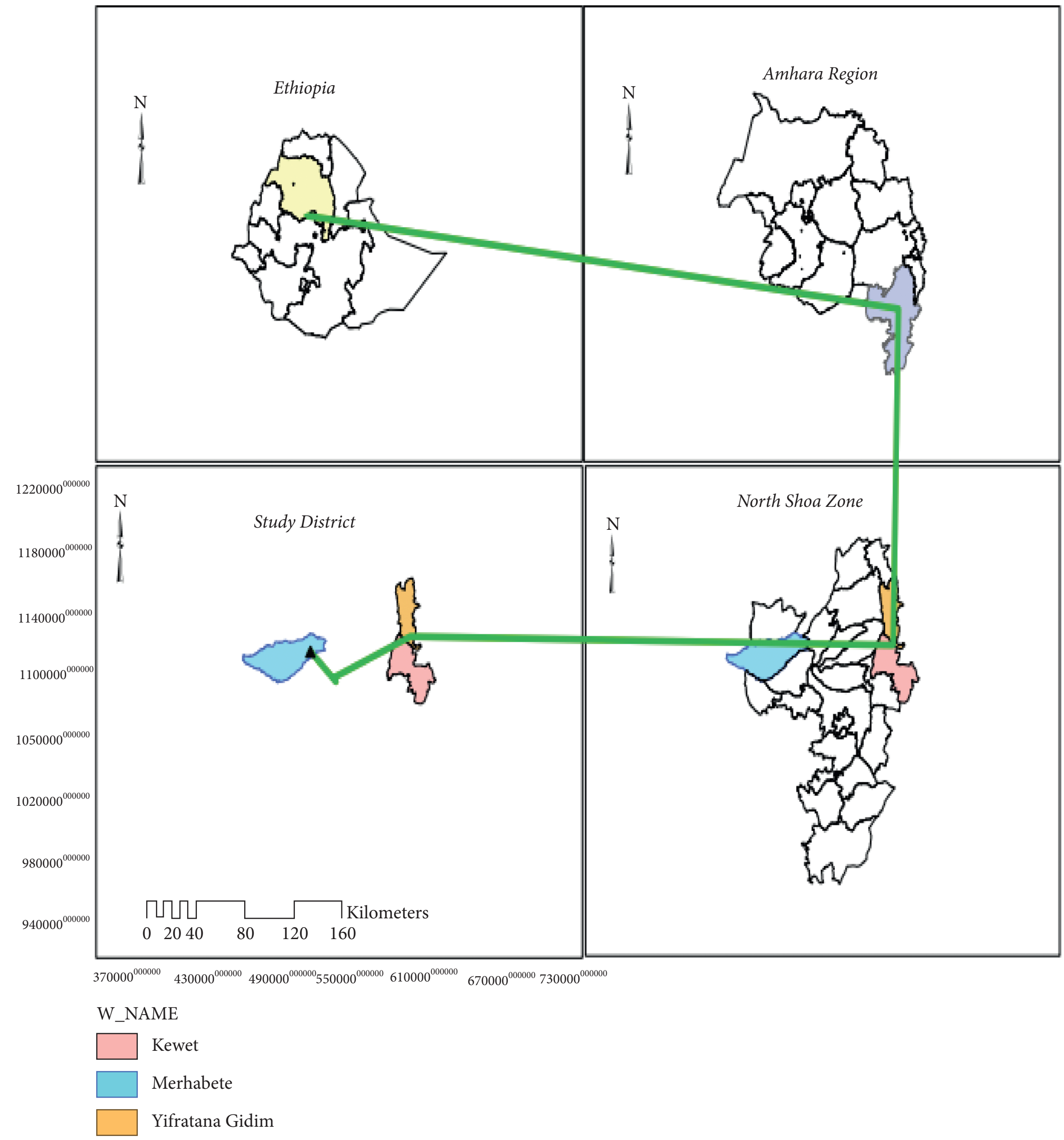

Figure 1: Location map of the study district.

intercropping is to be productive, it has to be complementary and/or compatible in resource utilization (resources being light, water, and soil nutrients). As mung bean grows fast, it can use resources early that otherwise be wasted before the slow growing *Sorghum* establishes to use them. At the time when *Sorghum* is in a position to demand resources, the resource demand of mung bean declines as it approaches maturity, and hence the two crops become compatible in resource utilization. Moreover, mung bean does not demand nitrogen fertilizer as it fixes for its own, and therefore, this nature of mung bean makes the cropping system compatible with the nitrogen fertilizer-demanding *Sorghum*.

However, the arrangement of crops in mixture in the traditional farming systems around the North Shoa area is random and without any sufficient attempt to pattern the crops for effective interception of essential resources. So, to alleviate this problem, which has a great impact to smallholder farmers, by maximizing the productivity of the *Sorghum*-mung bean intercropping system through appropriate intercrop arrangement. Therefore, this study was conducted to evaluate the effect of the *Sorghum*-mung bean intercrop arrangement on a *Sorghum*-based cropping system.

2. Materials and Methods

2.1. Description of Experimental Site. The experiment was conducted on farmers' fields at three locations: Shewarobit,

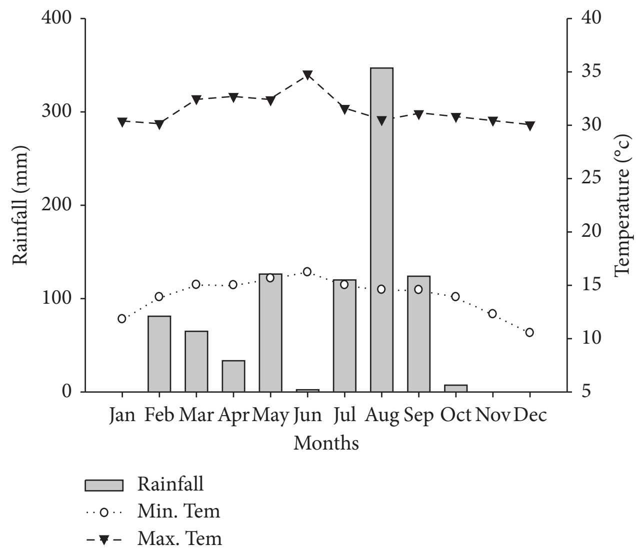

Figure 2: Monthly mean maximum and minimum temperature (°C) and total rainfall (mm). Due to the absence of full data for the season 2018, we used 2017 data.

Ataye, and Merhabete (Jemma valley) during the main growing season for two consecutive years (2017–2018). The experimental sites are located at 10° 03′ 51.7″ N and 38° 59′ 12.0″ E to 10° 17′ 44.2″ N and 39° 54′ 04.3″E and altitude ranged from 1277–1541 m.a.s.l (Figure 1). The 2017 year average annual rainfall, maximum and minimum temperatures of the areas were 915.33 mm, 31.46°C, and 14.40°C, respectively (Figure 2). Some physical and chemical characteristics of soil inthe study area are presented in Table 1.

2.1.1. Soil Data. The mean values of physicochemical properties of the soil are given as follows:

2.1.2. Weather Data. A total of 915.33 mm of rainfall was recorded at the experimental area during the season of 2017.

2.2. Treatments, Experimental Design, and Procedure. The experiment was laid out in a randomized complete block design (RCBD) with four replications. There were 6 treatment combinations consisting of sole *Sorghum*, sole mung bean, one-row *Sorghum* with one-row mung bean, one-row *Sorghum* with two-row mung bean, and two-row *Sorghum* with one-row mung bean intercrop arrangements (1 : 1, 1 : 2, 2 : 1), respectively, and broadcast mixed planting of 50%/50% of the recommended sole plant population of the component crops. Crop varieties Grana-1 for *Sorghum* and N26 for mung bean were used. The plot size of each treatment was 4.5 m × 5 m = 22.5 m^2. A spacing of 75 cm between rows and 15 cm between plants was used for both intercropped and sole *Sorghum* which consisted of a total of six rows of *Sorghum* for sole mung bean, 30 cm interrow and 5 cm intrarow spacing. Sole mung bean spacing which comprises 15 rows in a plot, whereas intercropped mung beans were planted between *Sorghum* rows.

2.2.1. Agronomic Management. To ascertain full stand in a plot, two seeds per hill were planted by hand and thinned to an appropriate stand a week after emergence.

For sole crops of *Sorghum*, mung bean and for the intercropped *Sorghum*, the recommended *N* and *P* rates were applied. Accordingly, phosphorus fertilizer was applied on intercropped and sole *Sorghum* plots at a rate of 46 kg P_2O_5 ha^{-1} (100 kg DAP ha^{-1}) as a one-time application at the time of planting. Nitrogen was applied on the same plots at the rate of 41 kg·ha^{-1}·N (50 kg·ha^{-1}urea) as split application. Half the rate of nitrogen was applied with phosphorus and the remaining half was given a month after emergence of *Sorghum*. For broadcast mixed plot recommended fertilizer for sole *Sorghum* was used. Sole mung bean plots received phosphorus at the rate of 23 kg P_2O_5 ha^{-1} (50 kg DAP ha^{-1}) as single dose at planting whereas no fertilizer was applied for intercropped mung bean.

2.3. Data Collection and Measurement. The data including days to emergence, heading/flowering and maturity, plant height, grain yield, and thousand seed weight were collected for both component crops. Head length for *Sorghum*, number of pods per plant, number of seeds per pod, biomass yield, and harvest index for mung bean were also collected. Days to emergence were counted from the date of sowing until 50% of seedlings emerged. Days to heading/flowering were recorded from the date of emergence to the date when more than 50% of the plants produced head/flowers in each plot. Days to maturity were recorded from the date of emergence to the date on which 50% of the pods on the plot reached physiological maturity.

Plant height—the average height of ten randomly sampled plants in the central rows of each plot was measured from the ground level to the top of the main stem at maturity. Head length is the average length of ten randomly sampled plants' heads in each plot, measured at harvest. Number of pods per plant average number of pods was counted from the same ten randomly selected plants at the end of harvest in each plot. Number of seeds per pod average number of seeds was taken from the same ten randomly selected pods at the end of harvest and each of seeds were counted manually in each plant. Biomass yield is the weight of the total above-ground biomass of each plot and is expressed as ton ha^{-1}. *Sorghum* grain yields were measured from the net plot area of 15 m^2 for both sole and intercropped *Sorghum*, and expressed as ton ha^{-1}. It was adjusted to a 12.5% moisture level to give an adjusted yield. Grain yield bean yields were measured from the net plot area (11.25 m^2 and 19.5 m^2) for intercropped and sole mung bean, respectively, and expressed as ton ha^{-1}. It was adjusted to 10% moisture level to give adjusted yield. A thousand seed weights were weighed in gram for randomly sampled 1000 seeds from each plot using a sensitive balance. The harvest index of mung beans was calculated as the ratio of grain yield to above-ground biomass.

2.3.1. Land Equivalent Ratio (LER). The land equivalent ratio is the most common index adopted in intercropping to measure land productivity. It is often used as an indicator to

Table 1: Mean value of some physicochemical properties of the soil of experimental locations from a depth 0–30 cm.

Soil pH	% Organic carbon	% Total nitrogen	% Organic matter	Available phosphorus	Texture			Texture class
					Sand	Clay	Silt	
6.54	1.06	0.11	1.82	31.53	29	53	18	Clay

determine the efficiency of intercropping [2]. The LER is a standardized index that is defined as the relative area required by sole crops to produce the same yield as intercrops [3]. The LER was determined according to the following formula:

$$\text{LER} = \frac{\text{yield of crop } 'A' \text{ in mixture}}{\text{yield of crop } 'A' \text{ in sole}} + \frac{\text{yield of crop } 'B' \text{ in mixture}}{\text{yield of crop } 'B' \text{ in sole}}. \quad (1)$$

If LER is equivalent to 1, it implies that the overall yield per unit area of intercrop is equivalent to the sole crop yield. However, if LER is greater than 1, it implies that intercropping out-yields the sole crops and would justify the intercropping. If LER is less than 1, this suggests that intercropping is yielding less than sole crops, and hence intercropping is not justified.

2.3.2. Sorghum Equivalent Yield (SEY). *Sorghum* equivalent yield (SEY) is calculated on the basis of prevailing market prices of both *Sorghum* and mung beans.

$$\text{SEY} = \frac{\text{Ym}}{\text{Ps}} * \text{Pm} + \text{Ys}, \quad (2)$$

where, Ym =yield of mung bean as intercrop, Ys = yield of *Sorghum* (of the same treatment or intercrop), Pm = price of mung bean, and Ps = price of *Sorghum*.

2.3.3. Economic Feasibility. A partial budget analysis was carried out following the method in [4]. Economic analysis among treatments involving gross return, variable cost, and net return were calculated to assess the profitability of intercropping as compared to sole cropping of *Sorghum*. The variable costs included cost of seed, cost of labor for weeding, harvesting, threshing, winnowing, and transporting were considered. The average yield was adjusted downward to 10% assuming yield reduction by 10% if farmers managed the same trial.

Mean grain and straw yields were used to calculate gross benefit by multiplying with their respective field prices. The mean field price was obtained by a simple assessment of farmers' prices in the vicinity of the experimental field after harvest (November–December 2018). Accordingly, the prices of grain yield of *Sorghum* and mung bean were found to be Ethiopian birr (ETB) 12 and 22 per kilogram, respectively, and the prices of straw of *Sorghum* and mung bean were found to be Ethiopian birr (ETB) 1.5 and 2.5 per kilogram, respectively.

2.3.4. Data Analysis. Treatment effects were evaluated by a combined analysis of variance using the General Linear Models of the Statistical Analysis System (SAS, 2000, version 9.0). Mean separation was carried out using the least significance difference (LSD) test at $P < 0.05$.

3. Results and Discussion

3.1. Sorghum. Grain yield and yield-related traits of *Sorghum* were not significantly influenced by the intercropping effect of row arrangements (Table 2). However, the highest mean grain yield (4.48 $t{\cdot}ha^{-1}$) was obtained from sole *Sorghum* while the lowest was obtained under 50% *Sorghum* and 50% mung bean mixed planting (3.78 $t{\cdot}ha^{-1}$) (Table 3). The nonsignificant effect could be due to relatively less competition for available resources. Mixed broadcast intercropping showed up to a 15.63% yield reduction of intercropped *Sorghum* compared to sole *Sorghum*. Similarly, [5] reported that sole-cropped maize has a significantly higher grain yield than the intercropped one by 13%. The reason could be the 50% lower *Sorghum* population of the mixed planting and the lower intraspecific competition of sole *Sorghum* for growth resources compared to the intercropped *Sorghum* which has to face both intraspecific and interspecific competition. From the intercropped treatments, the two *Sorghum*: one mung bean (2 : 1) arrangements gave higher *Sorghum* yields than those of the 1 : 1 and 1 : 2 row arrangements, but they gave statically similar yields (Table 3). Similarly, [6] reported that *Sorghum* yield is reduced due to the effect of component crop arrangement under *Sorghum*-soybean intercropping.

In addition, [7] reported no significant effect of bean density on maize grain yield under maize-common bean intercropping. This could be partly attributed to the delayed entry of beans into the intercropping systems in their study.

On the other hand, [8] reported that bean density significantly affected the grain yield of maize, indicating that as common bean density increased, the total grain yield of maize decreased. A yield redaction of 12.8% was observed as the proportion of common bean increased from 25% to 75% of the sole density. [9] also reported a 16% maize yield loss due to simultaneous maize-bean intercropping.

3.2. Mung Bean. Sole bean gave the highest grain yield (1.11 $t{\cdot}ha^{-1}$) compared to intercropped bean (Table 4). Row arrangement significantly influenced mung bean grain yield

Table 2: Summary of probability values of *Sorghum* combined analysis of variance over environments (year*loc) and treatments.

Source of variation	DF	Probability value					
		DH	DM	PHT	HDL	GY	TSW
Rep	3	0.516	0.2118	0.0667	0.0268	0.6388	0.0028
Year	1	1	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Loc	2	<0.0001	<0.0001	<0.0001	<0.0001	0.0074	<0.0001
Tret	3	<0.0001	0.8221	0.8738	0.0722	0.6886	0.845
Year*loc	2	1	<0.0001	0.0023	0.3286	0.0003	0.0012
Year*tret	3	0.5247	0.7966	0.4517	0.7049	0.6553	0.4606
Loc*tret	6	0.0104	0.1512	0.3949	0.6766	0.7884	0.7545
Loc*tret*year	6	0.6097	0.9971	0.7146	0.5987	0.8878	0.2389
CV%		1.98	2.86	6.33	7.97	24.41	9.94

*, ** Significant at 0.05 and 0.01 level, respectively, ns: nonsignificant, NR = nitrogen rate, SR = seed rate, DM = days to maturity, PHT = plant height, HDL = head length, GY = grain yield, and TSW = thousand seed weight.

Table 3: *Sorghum*-mung bean intercropping effect on growth, yield related parameters and productivity of *Sorghum*, combined over locations and years (2017 and 2018).

Treatment	DM	PHT	HDL	GY (t ha^{-1})	TSW (%)
Sorghum (sole)	105.33	205.27	21.08	4.48	26.58
Mung bean (sole)	—	—	—	—	—
1*Sorghum* + 1mung bean (1 : 1)	105.21	206.53	20.76	3.87	27.00
1*Sorghum* + 2mung bean (1 : 2)	105.50	208.08	21.17	3.93	27.17
2*Sorghum* + 1mung bean (2 : 1)	104.75	208.51	21.15	4.11	27.17
50% *Sorghum* and 50% mung bean mix	104.88	205.77	20.04	3.78	27.67
LSD (0.05)	NS	NS	NS	NS	NS

DM (days to maturity), PHT (plant height), TSW (thousand seed weight), HDL (head length), and GY (grain yield) = values within a column followed by the same letter are not significantly different at 5% probability level. LSD = least significant difference; NS = none significant.

Table 4: *Sorghum*-mung bean intercropping effect on growth, yield-related parameters, and productivity of mung bean, combined over locations and years (2017 and 2018).

Treatment	DM	PHT (cm)	NPP	NSP	BIO (t ha^{-1})	GY (t ha^{-1})	TSW (%)
Sorghum (sole)	—	—	—	—	—	—	—
Mung bean (sole)	73.63	64.13^{b}	11.52^{a}	7.12	3.64^{a}	1.11^{a}	48.08^{ab}
1*Sorghum* + 1mung bean (1 : 1)	73.71	67.90^{a}	7.57^{bc}	7.08	1.19^{c}	0.29^{b}	48.33^{a}
1*Sorghum* + 2mung bean (1 : 2)	73.96	69.62^{a}	7.99^{bc}	6.80	1.45^{bc}	0.35^{b}	46.92^{b}
2*Sorghum* + 1mung bean (2 : 1)	74.00	68.11^{a}	7.46^{c}	7.07	0.64^{d}	0.16^{c}	48.92^{a}
50% *Sorghum* and 50% mung bean mix	73.63	69.10^{a}	8.73^{b}	6.88	1.56^{b}	0.34^{b}	49.17^{a}
LSD (0.05)	NS	3.80	1.17	NS	0.26	0.08	1.29

Values within a column followed by the same letter are not significantly different at the 5% probability level. LSD = least significant difference; NS = none significant, DM (days to maturity), PLH (plant height), NPP (number of pods per plant), NSP (number of seeds per pod), BIO (biomass), GY (grain yield), and TSW (thousand seed weight).

Table 5: Summary of probability values of mung bean combined analysis of variance over environments (year*loc) and treatments.

Source of variation	DF	Probability value							
		DH	DM	PHT	NPP	NSP	BIO	GY	TSW
Rep	3	0.0116	<0.0001	<0.0001	0.5201	0.0003	0.0027	0.3428	0.0581
Year	1	0.0098	0.0114	<0.0001	<0.0001	<0.0001	0.0223	<0.0001	<0.0001
Loc	2	<0.0001	0.1736	<0.0001	<0.0001	<0.0001	0.2261	0.5023	<0.0001
Tret	3	0.4341	0.1903	0.8274	0.0649	0.9430	<0.0001	<0.0001	0.0053
Year*loc	2	0.1433	0.0191	<0.0001	<0.0001	0.0009	<0.0001	<0.0001	<0.0001
Year*tret	3	0.3636	0.2964	0.2626	0.0439	0.5405	0.6376	0.0003	0.0070
Loc*tret	6	0.0783	0.4527	0.5598	<0.0001	0.8641	<0.0001	<0.0001	0.0218
Loc*tret*year	6	0.4692	0.4527	0.7985	<0.0001	0.4990	<0.0001	0.2523	0.2158
CV%		3.13	1.81	9.59	20.74	18.22	23.25	20.07	4.49

*, ** Significant at 0.05 and 0.01 level, respectively, ns: nonsignificant, NR = nitrogen rate, SR = seed rate, DM = days to maturity, PHT = plant height, NPP = number of pod per plant, NSP = number of seed per plant, BIO = above ground biomass, GY = grain yield, and TSW = thousand seed weight.

Table 6: Dominance and marginal rate of return analysis for treatment effect, combined locations, and years (2017 and 2018).

Treatment	Adj. Sor. GY t/ha	Adj. Mb. GY t/ha	GB ETB/ha (GY)	GB ETB/ ha (SY)	TGB ETB/ha (GY + SY)	TVC ETB/ha	NB ETB/ha	MC ETB/ha	MNB ETB/ha	MRR (%)
Sole *Sorghum*	4.48	—	53760	2250	56010	0	56010			
Sole mung bean	—	1.11	24420	4406	28826	400	28426	D		
50% and 50% mix	3.78	0.34	52800	3173	55973	1279	54694	D		
2 to 1	4.11	0.16	52840	8192	61032	3354	57678	2075	1668	80.38
1 to 1	3.87	0.29	52820	10259	63079	4100	58979	746	1301	174.40
1 to 2	3.93	0.35	54860	21809	76669	7180	69489	3080	10510	341.23

GB = gross benefit, TVC = total variable cost, NB= net benefits, MC = marginal cost, MNB = marginal net benefit, MRR = marginal rate of return, and D = dominated. The treatments were arranged in ascending order by their TVC for the purpose of marginal analysis.

(P value <0.0001) (Table 5). The analysis showed that among the three arrangements and mixed, the combination of one *Sorghum* with two mung bean rows (1 : 2) gave the highest grain yield (0.35 $t \cdot ha^{-1}$) and the lowest was recorded from a combination of (2 : 1) row arrangements. The highest yield of 1 : 2 row arrangement was due to increasing levels of bean density. Under these row arrangements, increasing bean density improved the interspecies competitive ability of beans.

From maize-common bean intercropping, bean yield reduction of 45 to 56% have been reported from various studies ([5, 8, 10]). On the other hand, [9] reported a yield reduction of 18% under maize-common bean simultaneous additive intercropping. Differences in the magnitude of yield loss on the associated bean could be attributed to variation in the component densities, time of bean introduction and availability of growth resources.

3.3. Intercropping Efficiency. Total land equivalent ratio was greater than one in all treatments indicating that it is advantageous to grow *Sorghum* and mung beans in association rather than in pure stands. The highest total LER was obtained at 1 : 2 row (1.23) arrangements. This indicated that *Sorghum*-mung bean intercropping gave up to a 23% yield advantage compared to planting a sole crop of *Sorghum* and a sole crop of mung bean. A similar result was reported by [5], where a three-crop association involving simultaneous planting of maize with mung bean followed by common bean (MZ + MB – CB) gave the highest mean total LER of 1.66.

3.4. Sorghum Equivalent Yield (SEY). Sorghum equivalent yield (SEY) was calculated on the basis of prevailing market prices of both *Sorghum* and mung beans. The highest total productivity in terms of *Sorghum* equivalent yield (SEY) was recorded with a 1 : 2 row ratio of *Sorghum* + mung bean intercropping pattern (4.56 $t \cdot ha^{-1}$). Higher *Sorghum* equivalent yield under intercropping systems was attributed to yield advantages achieved in intercropping system [11]. The difference in SEY was mainly as a consequence of differences in the yield of *Sorghum* and mung bean, and price of individual component crops.

3.5. Economic Analysis. The net benefit from intercrop combinations was markedly higher except mixed cropping compared to both of the sole crop alternatives. The 1 : 2 row arrangement gave the highest MRR value (341.23%) (Table 6). Thus, though intercropping is labor-intensive and costly, it is much more beneficial than growing the components separately.

4. Conclusion

The results showed the feasibility of *Sorghum*-mung bean intercropping in terms of biological efficiency and economic return. The highest net return and marginal return (MRR) were obtained from one-row of *Sorghum* alternated with two-row mung bean (1 : 2). Therefore, farmers around the research area can get additional income from intercropping *Sorghum* with bean crops without sacrificing *Sorghum* yield by using one-row *Sorghum* alternated with two-row mung bean (1 : 2). Thus, intercropping is also useful for allowing independent cultivation of the two component crops and for its reduced demand on labor and time during harvesting and other related activities. The cropping system becomes more advantageous during abnormal seasons when there is a medium-to-low amount and distribution of rainfall.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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