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 to 12.44% 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·ha⁻¹) gave a statistically similar yield to all combinations including sole stand (4.48 t·ha⁻¹). Significant row arrangement effect showed that the row (1:2) gave the highest yield for mung bean (0.35 t·ha⁻¹), while the lowest was recorded from row arrangement (1:1) (0.16 t·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.
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,
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 in the 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 m². 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 P₂O₅ 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 P₂O₅ 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 m² 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 m² and 19.5 m²) 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
yield of crop 'A' in mixture
yield of crop 'A' in sole

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.

\[
\text{SEY} = \frac{\text{Ym}}{\text{Ps}} \times \text{Pm} + \text{Ys},
\]

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 ha\(^{-1}\)) was obtained from sole Sorghum while the lowest was obtained under 50% Sorghum and 50% mung bean mixed planting (3.78 t 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 reduction 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 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  | 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|
| 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   |

* Significance 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 (day to maturity) | PHT (plant height) | HDL (head length) | GY (tha⁻¹) | TSW (%) |
|------------------------------------|----------------------|--------------------|-------------------|------------|---------|
| Sorghum (sole)                     | 105.33               | 205.27             | 21.08             | 4.48       | 26.58   |
| Mung bean (sole)                   | —                    | —                  | —                 | —          | —       |
| 1Sorghum + 1mung bean (1:1)        | 105.21               | 206.53             | 20.76             | 3.87       | 27.00   |
| 1Sorghum + 2mung bean (1:2)        | 105.50               | 208.08             | 21.17             | 3.93       | 27.17   |
| 2Sorghum + 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      |

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 (day to maturity) | PHT (plant height) | NPP | NSP | BIO (tha⁻¹) | GY (tha⁻¹) | TSW (%) |
|------------------------------------|----------------------|--------------------|-----|-----|-------------|------------|---------|
| Sorghum (sole)                     | —                    | —                  | —   | —   | —           | —          | —       |
| Mung bean (sole)                   | —                    | —                  | —   | —   | —           | —          | —       |
| 1Sorghum + 1mung bean (1:1)        | 73.63                | 64.13¹               | 11.52¹           | 7.12       | 3.64¹         | 1.11¹       | 48.08¹  |
| 1Sorghum + 2mung bean (1:2)        | 73.71                | 67.90¹               | 7.57¹           | 7.08       | 1.19¹         | 0.29¹       | 48.33¹  |
| 2Sorghum + 1mung bean (2:1)        | 73.96                | 69.62¹               | 7.99¹           | 6.80       | 1.45¹         | 0.35¹       | 46.92¹  |
| 50% Sorghum and 50% mung bean mix  | 74.00                | 68.11¹               | 7.46¹           | 7.07       | 0.64¹         | 0.16¹       | 49.28¹  |
| 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  | 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| <0.0001| <0.0001| <0.0001|
| Loc                 | 2   | <0.0001| 0.1736 | <0.0001| <0.0001| <0.0001| <0.0001| 0.2261 | 0.5023 |
| Year×loc            | 2   | 0.1433 | 0.0191 | <0.0001| <0.0001| <0.0001| <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   |

* Significance 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 pod, BIO = above ground biomass, GY = grain yield, and TSW = thousand seed weight.
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·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·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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