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EFFECT OF SORGHUM/PULSES INTERCROPPING ON THE PRODUCTIVITY OF FARMLANDS IN THE MOISTURE DEFICIT AREAS OF BELESA DISTRICT, NORTH WEST ETHIOPIA

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ABSTRACT

Intercropping is considered for increasing and stability of yield per unit land. In order to study the effects of different intercropping arrangements on sorghum and different pulses yield and to find the land use advantage in the intercropping system, an experiment was carried out based on a randomized complete block design with nine treatments and three replications at East and West Belesa in 2017. The treatments were as follows: sole cropping of sorghum, sole cropping of mung bean, haricot bean, and three intercropping patterns of sorghum: mungbean, sorghum: haricot bean with ratios 1:1, 1:2, 2:1 respectively. The results showed that the maximum grain yield was obtained from both species in monoculture treatment. Land equivalent ratio (LER) in all evaluated treatments was more than one. The highest land equivalent ratio (1.54) was obtained in treatment (1:1sorghum-haricot bean intercropping). Also, the highest intercropping advantage (4837 and 4601) was related to treatment (1:2 and 1:1 sorghum-haricot bean intercropping) respectively. ATER 31% advantage in 1:1 sorghum-haricot bean combinations whilst 2:1 and 1:2 sorghum-mungbean combinations showed 90-95 % disadvantages. The result of economic analysis maximum net benefit (ETB35967) was obtained at 1:1sorghum-haricot bean row ratio. Thus, according to the productivity and economic evaluation indices, a 1:1 sorghum-haricot bean row ratio is recommended for East and West Belesa districts and similar conditions with this study.

Contribution/Originality: This study contributes to the impacts of sorghum /pulse intercropping for the different farming systems to increase production and productivity for moisture deficit areas.

1. INTRODUCTION

Ethiopia is characterized by poor soils with declining fertility due to continuous cereal cropping without adequate use of fertilizers [1]. Farmers in the sub-Saharan African region including Ethiopia are being denied high crop yields because they cannot afford to purchase inorganic fertilizers to replenish nutrient-depleted soils. The declining soil fertility, as well as unreliable rain, has increased the chance of failure in sole cropping systems within the region [2]. The decline in yields because of population increments, low soil fertility, and erratic rainfall presents the requirement for smallholder farmers within the sub-Saharan African region to develop many sustainable production systems [3].

Intercropping is one of the potential strategies that have long time practices by farmers in various tropical and sub-tropical regions and worldwide [4]. This system involves two or more crops simultaneous or sequential growing in the same piece of land and at the same time [5] and is a potential beneficial system of crop production which could insurance against the vagaries of weather [2] and improved seed quality and soil fertility [6].

As compared to a sole cropping practice, cereal-legume intercrops have shown to recover soil fertility and increase yields, improve seed quality, control weeds, diseases, and insects, preserve soil moisture, decrease soil erosion, improve soil microbiology [7] and improving yield stability, socioeconomic and some other merits [8]. Cereal-legume intercropping boost yields as compared with sole crops [7] as a result of one component that can increase the survival and growth of the other component within the system [9].In general, intercropping has been shown to be more productive than mono-cropping [10].

In Sub-Saharan Africa, erratic rainfall and poor soil fertility are the most biophysical bottlenecks to rising agricultural productivity and hence threatens food security [11]. Intercropping cereals with legumes are a common cropping practice [12] that helps to maintain and improve soil fertility, reduced diseases, pest, and weeds occurrence and decreased crop failure [13]. Cereal crops such as pearl millet [*Pennisetumglaucum* (L.) R. Br.], maize (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moech] and Teff [Eragrostistef (Zucc.) Trotter] is the dominant cereal crops [14] and often intercropped with legume crops such as beans (*Phaseolus vulgaris* L.) Walp.], soybean [*Glycine max* (L.) Merr.], Haricot bean (*Phaseolus vulgaris* L.), pigeon pea [*Cajanuscajan*(L.) Millsp.] and Mungbean [*Vigna radiata* L. Wilczek] [9].

Previous studies reported that additionally to improving soil fertility, cereal-legume intercropping has higher land-use efficiency, lower water consumption, and more ecological and environmental benefits compared to a sole or cereal-cereal intercropping [15].

Intercropping is an essential practice for utilization of recourse, gets additional income, reduced the occurrence of insect pests, and remedies the soil fertility [16]. But the practice of intercropping in our study area is not a well-assimilated system. Farmers always use cereal with cereal intercropping systems which could not increase production and productivity for the farmer and it is very suitable for pest occurrence and nutrient depletion. Due to this system, the farmers are limited in economic potential, and still, in the area, the study of intercropping is not conducted so far. Therefore, this study was designed with the objectives of investigating the effect of sorghum/pulse intercropping on farmland productivity under moisture stress area, Belesa district.

2. MATERIAL AND METHODS

2.1. The Experimental Site

The study was conducted at two farmer's fields in East and West Belesa *District* of North Gondar Administrative Zone, Ethiopia Figure 1 during the main rainy season in 2017. East Belesa D*istrict* has a latitude of about 13º12′35″N and longitude of 38º8′25″E. The elevation of the *District* is 900 meters above sea level. The mean annual rainfall in the district is 611.7 mm. The annual temperatures range from 13-36.2˚C, respectively [17]. West Belesa has a latitude of 13.133ºN and a longitude of 37.900°E and an elevation ranging from 1100 to 1680 meters above sea level. The district receives an annual rainfall ranging from 700 to 823 mm. The annual temperature ranges from was13-28°C. The soil type of study sites is characterized by black vertisol.

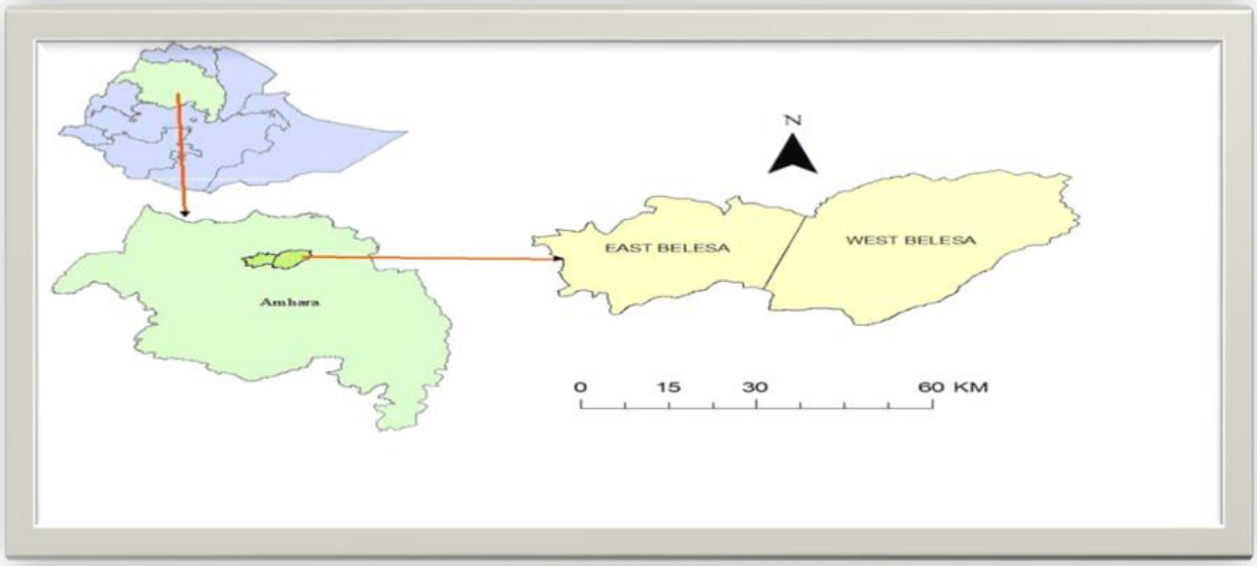

Figure-1. Map of the study areas: (1st) Map of Ethiopia, (2nd) Map of Amhara National Regional State in Ethiopia, and (3rd) Map of East and West Belesa districts in North Gondar.

2.2. Experimental Design

Nine treatments (sole sorghum, sole mungbean, sole haricot bean, 1:1row ratio of sorghum mungbean, 1:1 row ratio of sorghum x haricot bean, 1:2 row ratio of sorghum mungbean, 1:2 row ratio of sorghum haricot bean, 2:1row ratio of sorghum-mung bean and 2:1 row ratio of sorghum haricot bean intercropping) were arranged in Randomized Complete Block Design (RCBD) with three replications.

Each treatment occupied 3.0 m × 4.5 m plot, spaced 0.5 m apart. Sole treatments were spaced as follows; sorghum at 75 cm (inter-row) × 15 cm (intra-row); haricot bean at 40 cm (inter-row) × 10 cm (intra-row) and mungbean at 30 cm (inter-row) x 5 cm (intra-row). Each crop seed was sown by drillings across the slope. The intercropped mung bean and haricot bean were planted 15 days after the planting of sorghum. Figure 2 showed and described the performance of the intercropping trial on the field. The experimental design showing the clear difference between intercropping and sole cropping under field conditions.

ATA soil-based fertilizer recommendation of 100 kg ha^{-1} NPSZnB (N: 17.8, P: 35.7, S: 7.7, Zn: 2.2, and B: 0.1) was applied for sorghum, mung bean and haricot bean each at planting. Urea at 50 kg ha^{-1}rate was top-dressed for sorghum at knee height to satisfy the additional nitrogen requirement. Thinning was conducted 15 days after sowing for all crops in order to keep the appropriate plant density. All other agronomic managements were applied uniformly for each plot.

2.3. Measured Parameters

Days to emergence, stand count at emergence, Days to heading, Striga biomass, Days to maturity, plant height, head length, stand count at harvest, harvestable head number, 1000 seed weight, biomass yield, grain yield, harvest index, for sorghum, and data like days to flowering, days to maturity, nodule number per plant, numbers of pod per plant, number of seed per pod, pod length, 100 seed weight for pulses were collected. Land equivalent ratio, area time equivalent ratio, actual yield loss, intercropping advantage, and partial budget analysis were done to compare different cropping systems. Pre and post-harvest soil analyses were collected for each treatment to characterize the experimental site and to see additional benefits from the intercrop.

2.4. Data Analysis

Collected data were subjected to analysis of variance (ANOVA) using SAS 9.0. Where a significant F-test was used and means comparison tests carried out using the Least Significant Difference (LSD) at $p \leq 0.05$.

Also to evaluate the intercropping, indices such as land equivalent ratio (LER) Equation 1 area time equivalent ratio (ATER) Equation 2, actual yield loss, or gain (AYL) Equation 3 and intercropping advantage (IA) Equation 4 were used.

$$LER = (Yam/Yas) + (Ybm/Ybs) \qquad (1)$$

Where, Yam and Ybm are the yields of two crops in intercropping, and Yas and Ybs are the yields of each crop in a monoculture system. If LER is greater than one, intercropping would be better than monoculture [18].

$$ATER = \frac{Liti + Ljtj}{T} \qquad (2)$$

Where Li and Lj are partial LER of component crops i and j, ti and tj are the duration (days) for crops i and j, and T is the duration (days) of the whole intercropping system [19].

$AYL = AYLa + AYLb$

$AYLa = [LERx\,(100/Zab) - 1]$

$$AYLb = [LER\ x\ (100/Zba) - 1] \qquad (3)$$

Where, AYLa is sown partial actual yield loss or gain of species a, AYLb is sown partial actual yield loss or gain of species b, Zab is sown proportion of species an in intercropping and Zba is sown proportion of species b in intercropping.

$$IA = [(Pa/Pa+Pb)\ x\ AYLb] + [(Pb/Pa+Pb)\ x\ AYLa] \qquad (4)$$

In this equation, Pa is the price of species a, Pb is the price of species b, AYLa is the partial actual yield loss or gain of species a and AYLb is the partial actual yield loss or gain of species b.

3. RESULT AND DISCUSSION

3.1. Soil Data

3.1.1. Pre-Planting Soil Analysis

According to Zemichael and Dechassa [20] the result indicated that the soil comprised a total N of 0.062 and 0.076% Table 1 at E and W/Belesa respectively. The available phosphorous result at both locations could be rated as medium Table 1 according to Bargali, et al. [21]. The organic matter analysis of the soil was taken as a crude measure of fertility status. It is estimated indirectly from the organic carbon determination (OM% = 1.724 X % OC). The composite soil sample gave 3.4 and 4.0% soil OM at E and W/Belesa Table 1 which is rated as medium. This was in agreement with the findings of Zemichael and Dechassa [20] who reported that soils having OM value in the range of 0.86-2.59% are considered low. Thus, it needs a supplement or addition of materials that can increase the organic matter in the soil. Moreover, the pH value of E and W/Belesa experimental soil was 8.1 and 7.8 respectively.

According to Zemichael and Dechassa [20], soils having pH value in the range of 7.4 to 8.0 are considered moderately alkaline soils. The pH value of the experimental soil was in the optimum range for the successful growth of sorghum and pulse crops [22]. The cation exchangeable capacity of E and W/Belesa soil was67.8 and 68.8Cmol kg^{-1} recorded respectively Table 1. This showed that the experimental soil had a high capacity of the soil to retain cations in exchangeable form for the plant. The electrical conductivity of the experimental soil was 0.21 and 0.17dsm^{-1} at E and W/Belesa respectively which was classified as non-saline soil according to Alemu, et al. [23]. The soil of E and W/Belesa have a proportion of 26.16 and 22.16% sand, 45.3 and 41.3% clay, and 28.6 and 36.6% silt respectively that can be texturally classified as clay soil Table 1 Pal and Selassie [24] and [2].

3.2. Post-Harvest Soil Analysis

The post-harvest soil analysis Table 1 based on the treatments composite samples of the three replications showed a substantial increment in total nitrogen except for sole sorghum. The highest value of total N 0.152 and

0.254% and 0.12 and 0.285% were obtained in treatments of sole mungbean and haricot bean in E and W/Belesa respectively. However, sole mungbean and haricot bean showed that 0.086 and 0.088% and 0.044 and 0.209% increment in total nitrogen percentage at both locations. On the other hand, the lowest total nitrogen value (0.019 and 0.073%) was achieved at sole sorghum which showed a total reduction (depletion) of 0.047 and 0.003% nitrogen from the total nitrogen registered at pre-planting in E and W/Belesa respectively Table 1. As it can be observed from the result, there was a general increment in the total nitrogen of the experimental soil. This could be most probably due to the excretion, decomposition of nitrogen-fixing nodules, and roots of the component legume. This finding similar to Balemi and Tufa [25].

Cereal crops generally a high user of major nutrients especially N during most of their growth period [26]. In this study, the sole sorghum plots scored the lowest total nitrogen (0.019 and 0.073%) which implies that the sorghum plants were high feeders of the available soil nitrogen. In agreement with this finding [25].

Results after harvest showed that there was an increment in the amounts of available phosphorous at both locations and in almost all treatments. The highest available phosphors were recorded at 1:1 and 1:2 sorghum-haricot bean row ratio 17.1 and 18.9 (ppm) at E/Belesa and 15.3 and 17.7 (ppm) sole mungbean and 1:2 sorghum-haricot bean row ratio at W/Belesa Table 1. This might be due to the fact that plants used applied phosphorous and large amounts of P from the soil. In general, the properties of the experimental soil and the weather conditions at the site were conducive to the growth of each crop.

Figure-2. The performance of intercropping trial on the field under moisture deficit area of North Weast region of Amhara, Belesa district 2017.

3.3. Sorghum Component

3.3.1. Striga Biomass

The analysis of variance revealed that the *Striga* count at the sorghum heading stage was significantly ($P<0.01$) affected by the intercropping pattern at both East and West Belesa Table 2. At East Belesa the maximum *Striga* count (84) at sorghum heading stage was recorded from the plots which received sole sorghum, while the lowest *Striga* count (16) was recorded from treatment 1:2 sorghum-haricot bean row ratio. At West Belesa the highest *Striga* count (9) at the heading stage was obtained from the plots which received sole sorghum treatments, whereas the minimum *Striga* count (4) was recorded from the plot that received 1:2 sorghum-mung beans. Generally, the results of a comparison between intercropped and sole cropped treatments at both locations revealed that more *Striga* population was recorded from sole sorghum treatment which showed that the intercropping system can have reduced Striga weed pressure. The result of this investigation also gets supported by those obtained by Abate [8] and Lamessa, et al. [27].

Table-1. Some Physco-chemical properties of the soil before and after harvest experimental field.

Pre-planting soil analysis												
Location	TRT	pH	Total N%	Available P (ppm)	K+ Cmol/kg	Organic Matter	EC mS/cm	CEC Cmol/kg	Particle Size distribution			
									% 0f sand	% 0f clay	% 0f silt	%0f textural class
E/Belesa	CS	8.1	0.06	6.1	0.9	3.4	0.2	67.2	26.2	45.3	29	Clay
W/Belesa	CS	7.8	0.08	10.1	1	4	0.2	68.8	22.2	41.3	37	Clay

Post-harvest soil analysis

Location	IP	Total N%	Available P(ppm)
E/Belesa	SS	0.019	13
	SM	1.019	16
	SH	2.019	16
	1S:1M	3.019	13
	1S:1H	4.019	17
	1S:2M	5.019	9.9
	1S:2H	6.019	19
	2S:1M	7.019	11
	2S:1H	8.019	11
W/Belesa	SS	9.019	12
	SM	10.019	15
	SH	11.019	12
	1S:1M	12.019	14
	1S:1H	13.019	12
	1S:2M	14.019	12
	1S:2H	15.019	18
	2S:1M	16.019	13
	2S:1H	17.019	14

***Note:** TRT= treatment, CS= composite soil, IP= intercropping pattern, SS=Sole sorghum, SM=sole mung bean, SH=Sole haricot bean, 1S:1M=1:1Sorghum mung bean row ratios, 1S:1H=1:1Sorghum haricot bean row ratios, N=Total nitrogen %, P= Available Phosphors (ppm), EC=Electric conductivity (mS/cm), OM=Organic matter and CEC=cation exchange capacity (Cmol/kg).

Table-2. Effects of locations and intercropping treatments on Striga weed population in sorghum- pulses intercropping at E and W/Belesa.

Treatments	E/Belesa	W/Belesa
SS	84^{a}	9.00^{a}
SM	-	-
SH	-	-
1S:1M	28^{c}	4.30^{bc}
1S:1H	18^{d}	4.00^{c}
1S:2M	16.3^{d}	3.66^{c}
1S:2H	16^{d}	4.00^{c}
2S:1M	58^{b}	7.66^{a}
2S:1H	56.7^{b}	7.00^{bc}
LSD (0.05)	5.67	2.72
CV (%)	8.05	27.04
Mean	10.15	2.34
LS	**	**

Note:**= Highly significant difference, *=significant differences, NS=Non significant differences, CV=coefficient of variation, LSD=List significant differences, LS=List significant, SS=Sole sorghum, M=sole mung bean, SH=Sole haricot bean, 1S:1M=1:1Sorghum mung bean row ratios, 1S:1H=1:1Sorghum haricot bean row ratios.

3.4. Head Length

Crops with higher head length could have a higher grain yield. The combined analysis of variance indicated that head length was significantly ($P<0.05$) affected by intercropping patterns and systems. The maximum head length (27.96cm) was recorded at sole sorghum and the minimum recorded (25.9cm) in 1:2 sorghum-haricot bean intercropping row ratios Table 3. The sole cropping improved panicle length as compared to intercropping. This finding is in conformity with the result of Sibhatu [28].

3.5. 1000 Seed Weight

The combined analysis of variance indicated that 1000 seed weight was significantly (P<0.01) affected by cropping pattern and system. As displayed in Table 3 the highest sorghum 1000 seed weight (24.57 gm) was obtained from the 1:1 sorghum-haricot bean intercropping pattern, while the lowest 1000 Seed weight (21.73gm) obtained from the sole sorghum. The most probable reason for this variation could be due to the use of resources like soil nutrients and water in the intercropped sorghum. The sunlight was probably not penetrating to the soil because of haricot bean density was highly branched, leafy, and used as mulching. This finding is confirmed with the result of Singh, et al. [29] and Lesoing and Francis [30].

3.6. Above-Ground Dry Biomass

The combined analysis of variance indicated that sorghum above-ground dry biomass was significantly (P<0.01) affected by cropping pattern and pulses density. The highest overall mean value of dry biomass accumulation (15358.5 kg ha^{-1}) was obtained from sole sorghum and the lowest dry matter accumulation (10691.1 kg ha^{-1}) was obtained from treatments of 1:2 sorghum-haricot bean intercropping pattern. The result indicated that the above-ground dry biomass weight of sole sorghum was higher than the intercropping treatments Table 3. This could be related to the general fact that crop density decreases the vegetative part of plants to give a higher biomass weight because there was no computation of nutrient, space, sunlight, and moisture. This finding is confirmed with the result of Sibhatu [28] and Iqbal [31].

3.7. Sorghum Grain Yield

The combined analysis of variance indicated that grain yield was significantly (P<0.01) affected by planting patterns and cropping systems. Furthermore, the planting pattern and cropping system showed a highly significant difference (P<0.01) on the grain yield of sorghum. The highest grain yield (4498.5 kg ha^{-1}) was obtained from the sole sorghum treatment, while the lowest grain yield (3269.7 kg ha^{-1}) was obtained from the 2:1 sorghum-haricot bean row ratio intercropping pattern. The most probable reason for this variation could be due to interspecific competition for resources like soil nutrients, sunlight, space and water in the intercropped sorghum Lulie, et al. [22] and Mthembu, et al. [32] and Iqbal [31] reported a similar result in Table 3.

Table-3. The combined mean value of head length, harvest index, thousand seed weight, dry biomass and grain yield of sorghum intercropping at E and W/Belesa.

Treatments	Parameter				
	HL(cm)	**HI (%)**	**TSW (gm)**	**DB(kg/ha)**	**GY(kg/ha)**
SS	27.96^{a}	29.25^{bc}	21.73^{c}	15358.5^{a}	4498.5^{a}
SM	-	-	-	-	-
SH	-	-	-	-	-
1S:1M	27.1^{ab}	34.22^{a}	22.69^{bc}	12391.7^{cd}	4236.2^{a}
1S:1H	27.8^{a}	35.56^{a}	24.57^{a}	12114.7^{cd}	4304.4^{a}
1S:2M	26.2^{b}	30.80^{b}	22.00^{c}	11190.6^{de}	3408.9^{c}
1S:2H	25.9^{b}	30.61^{b}	24.24^{ab}	10699.1^{e}	3269.7^{c}
2S:1M	26.26^{b}	27.93^{bc}	22.88^{bc}	13690.8^{b}	3811.6^{b}
2S:1H	26.63^{ab}	27.1^{c}	22.25^{c}	13203.7^{cd}	3532.5^{bc}
LSD(0.05)	1.42	3.12	1.65	1281.9	355.81
CV (%)	4.5	8.6	6.09	8.5	7.8
Mean	26.84	30.79	22.91	12664.15	3865.97
LS	*	**	**	**	**

Note: **= Highly significant difference, *=significant differences, NS=Non significant differences, HL=Head length, HI=Harvesting index TSW=Thousand seed weight, DB=Dry biomass, GY=Grain yield, T=treatment, CV=coefficient of variation, LSD=List significant differences, LS=List significant, SS=Sole sorghum, SM=sole mung bean, SH=Sole haricot bean, 1S:1M=1:1Sorghum mung bean row ratios, 1S:1H=1:1Sorghum haricot bean row ratios.

3.8. Harvest Index

The harvest index of sorghum was significantly (P<0.01) affected by different sowing patterns Table 3. The highest (35.56%) and the lowest (27.1 %) harvest index of sorghum was achieved in (1:1 sorghum-haricot bean) and (2:1sorghum-haricot bean), respectively Table 3. This result in line with Zerihun, et al. [33] and Herrero, et al. [34] and Singh and Stoskopf [35].

3.9. Pulses Component

3.9.1. Dry Biomass

Dry biomass of pulses significantly (P<0.01) influenced by different sowing patterns. Sole cropping mungbean and haricot bean give the highest (4976.80 and 3388.9kgha^{-1}) dry biomass yield respectively, while the lowest dry biomass (606.10and 747.10 kgha^{-1}) was also obtained from 2:1 sorghum-mungbean and 2:1 sorghum-haricot bean row ratio intercropping respectively Table 4. This result due to the absence of interspecific competition like shading effects. Different findings confirmed the resent study Lulie, et al. [22] and Gutu, et al. [36] and Hidoto, et al. [37].

3.10. Grain Yield

The combined analysis of variance indicated that pulses grain yield had a significant (P<0.01) difference among cropping patterns Table 4. Sole mungbean and haricot bean had higher grain yield (1920.46 and 1460.32 kgha^{-1}) than the intercropped treatments 169.79 and 266.31 kgha^{-1}, respectively at 2:1sorghum-mungbean and 2:1sorghum-haricot bean row arrangements. This result might be due to competition for light and other environmental growth resources at intercropping of a pulse Table 4. In conformity with this result, Lulie, et al. [22] and Zerihun, et al. [33] and Sibhatu [28] and Gebrekidan, et al. [38].

Table-4. The combined mean value of dry biomass and grain yield on mung bean and haricot bean at E and W/Belesa.

	Mung bean		Haricot bean	
Treatment	**DB(kgha^{-1})**	**GY(kgha^{-1})**	**DB(kgha^{-1})**	**GY(kgha^{-1})**
SS	-	-	-	-
SM	4976.80^{a}	1920.46^{a}	-	-
SH	-	-	3388.90^{a}	1460.32^{a}
1S:1M	1252.10^{c}	410.83^{c}	-	-
1S:1H	-	-	1673.80^{c}	851.29^{c}
1S:2M	1835.00^{b}	586.43^{b}	-	-
1S:2H	-	-	2588.60^{b}	1109.90^{b}
2S:1M	606.10^{d}	169.79^{d}	-	-
2S:1H	-	-	747.10^{d}	266.31^{d}
LSD (0.05)	538.44	72.11	248.29	70.91
CV (%)	20.06	7.54	9.54	6.21
Mean	2167.5	771.87	2099.61	921.95
LS	**	**	**	**

Note: **= Highly significant difference, *=significant differences, NS=Non-significant differences, DB=Dry biomass, GY=Grain yield, CV=coefficient of variation, LSD=List significant differences, LS=List significant, SS=Sole sorghum, SM=sole mung bean, SH=Sole haricot bean, 1S:1M=1:1Sorghum mung bean row ratios, 1S:1H=1:1Sorghum haricot bean row ratios.

3.11. Productivity and Evaluation of Intercropping

3.11.1. Partial LER of Sorghum (PLERS)

According to the result Table 5 maximum Partial LER of sorghum (0.98) was obtained from the intercropping pattern of 1:1 sorghum-mungbean followed by 1:1 sorghum-haricot bean row ratio (0.96) while the minimum value (0.73) was obtained from the intercropping patterns of 1:2 sorghum-haricot bean intercropping row ratio arrangements. According to Lulie, et al. [22].

3.12. Partial LER of Pulses (PLERP)

The maximum Partial LER value among (0.76) pulse components was obtained from the intercropping pattern of 1:2sorghum-haricot bean row ratio while the minimum (0.08) was obtained from the intercropping pattern of 2:1sorghum-mungbean row ratio Table 5. This finding confirmed with the result of Bitew [39] and Lulie, et al. [22].

3.13. Land Equivalent Ratio (LER)

The highest LER (1.54) had been achieved from 1:1 sorghum-haricot bean intercropping pattern. Nevertheless, the lowest LER (0.93) was recorded on treatments having a 2:1sorghum-mungbean intercropping ratio Table 5. Concerning the result in Table 5, in all combinations, the LER was more than unity except in the treatment that received 2:1sorghum-mungbean and 2: a 1sorghum-haricot bean intercropping pattern which in turn validating that intercropping was less density and limited soil fertility significantly reduces the productivity of the intercropping system. The result of land equivalent ratio more than unity implied that intercropping is advantageous in many instances rather than sole planting with respect to land area. A value of LER more than one is perhaps because of fixing atmospheric nitrogen into usable forms in intercropping sorghum and pulses. This finding confirmed with the result of Lulie, et al. [22] and Sibhatu [28] and Nourbakhsh, et al. [40] and Iqbal [31] and Mead and Willey [18].

3.14. Area Time Equivalent Ratio (ATER)

ATER values showed an advantage of (1.31) was recorded in the combination of 1:1 sorghum-haricot bean row ratios Table 5 but the lowest (0.90) also recorded in the combination of 2:1 sorghum-mung bean and 2:1 sorghum-haricot bean row ratio. Whereas, 1:1 sorghum mungbean, 2:1 sorghum-mungbean, and 2:1 sorghum-haricot bean intercropping showed less than 1.00 thus indicated the disadvantage. This was in agreement with Reddy, et al. [41] and Bitew [39] and Khonde, et al. [42] and Hiebsch and McCollum [19].

3.15. Actual Yield Loss or Gain

In this study, the highest amount of AYL was obtained in treatment (1:2sorghum-haricot bean) with 4.8 and followed by (1:1sorghum-haricot bean) with 4.1 while the lowest obtained treatments (2:1sorghum-mungbean and 2:1sorghum-haricot bean row ratios) with 2.2 and 2.4 respectively Table 5. The reason for this result was due to the exhaustive effect of sorghum and early shading in the early growth stage of pulses. Similar results were also reported by Assefa, et al. [43] and Ghosh [44].

3.16. Intercropping Advantage

According to Khonde, et al. [42] and Ghosh [44] this index, in addition to expressing the advantage or disadvantage of intercrops, can be an indicator of the economic feasibility of intercropping systems. The maximum intercropping advantage (IA) was related to treatment (1:1 sorghum-haricot bean and 1:2 sorghum-haricot bean row ratio) with 4601 and 4837 respectively and lowest IA was obtained in treatments combination (2:1 sorghum-haricot bean raw ratios) with 2972 Table 5. The reason for this result was due to better use of resources such as light, water, and nutrients in this treatment, probably.

3.17. Economic Analysis

A study was conducted on intercropping of sorghum with mungbean and haricot bean crops to get a higher net benefit and higher marginal rate of return over sole cropping of sorghum in E and W/Belesa. A partial budget analysis was done to compare the financial feasibility of each treatment. The result of partial budget analysis in Table 6 indicates that the lowest cost and benefit was obtained from control treatment that was sole sorghum crop production while the highest cost and benefit was recorded when sorghum intercropped with haricot bean and mung bean crops treatments. To do the dominance analysis, the total cost that varies in each treatment with its net benefit was listed in order. Treatment that contains intercrops 1:1 sorghum-haricot bean intercrop pattern was the highest marginal return rate than others.

Table-5. The results of Partial land equivalent ratio, Land equivalent ratio, Area time equivalent ratio, Actual yield loss/gain, and intercropping advantage on sorghum intercropping.

Treatment	Parameter					
	PLERS	PLERP	LER	ATER	AYL	IA
1S:1M	0.98[a]	0.215[d]	1.2[b]	1.11[b]	2.8[c]	3757[b]
1S:1H	0.96[a]	0.583[b]	1.547[a]	1.31[a]	4.1[b]	4601[a]
1S:2M	0.762[c]	0.303[c]	1.07[c]	0.95[c]	2.8[c]	3130[c]
1S:2H	0.732[c]	0.767[a]	1.498[a]	1.18[b]	4.8[a]	4837[a]
2S:1M	0.852[b]	0.088[f]	0.938[d]	0.90[c]	2.2[d]	3689[b]
2S:1H	0.793[bc]	0.183[e]	0.973[d]	0.90[c]	2.4[d]	2973[c]

Note: PLERS=Partial land equivalent ratio for sorghum, PLERP=Partial land equivalent ratio for pulses, LER=Land equivalent ratio, AYL=Actual yield loss or gain, ATER= Area time equivalent ratio IA=Intercropping advantage, 1S:1M=1:1Sorghum mung bean row ratios, 1S:1H=1:1Sorghum haricot bean row ratios

Table-2. Result of intercropping of sorghum with haricot bean and mung bean combination treatments in E and W/Belesa district.

Treatments	SS	SM	SH	1S:1M	1S:1H	1S:2M	1S:2H	2S:1M	2S:1H
Gross yield sorghum (kg/ha)	4905	0	0	4440	4481	3415	3332	4093	3486
Adjusted 10% sorghum yield (kg/ha)	4414	0	0	3996	4033	3073	2998	3684	3138
Gross benefit sorghum (ETB/ha)	39729	0	0	35965	36296	27658	26986	33154	28240
Gross yield mungbean (kg/ha)	0	1962	0	420	0	638	0	164	0
Adjusted 10% mungbean yield (kg/ha)	0	1765	0	378	0	574	0	147	0
Gross benefit mungbean (ETB/ha)	0	31778	0	6802	0	10332	0	2650	0
Gross yield haricot bean (kg/ha)	0	0	1519	0	825	0	916	0	264
Adjusted 10% haricot bean yield (kg/ha)	0	0	1367	0	743	0	825	0	238
Gross benefit haricot bean (ETB/ha)	0	0	17767	0	9653	0	10722	0	3093
Total gross benefit (ETB/ha)	39729	31778	17767	42767	45949	37991	37708	35805	31333
Seed cost (ETB/ha)	170	800	1700	490	1092	810	2014	330	633
Fertilizer cost (ETB/ha)	2430	1976	1976	3247	3520	4065	4610	2838	2975
Labor cost (ETB/ha)	5333	5926	5185	5370	5370	9630	8889	5556	4444
Total cost (ETB/ha)	7933	8702	8861	9108	9982	14505	15512	8724	8053
Net benefit (ETB/ha)	31796	23076	8906	33660	35967	23486	22196	27081	23280
Dominance analysis		D	D			D	D	D	D
Marginal cost (ETB/ha)				1175	2049				
Marginal net benefit (ETB/ha)				1863	4170				
The marginal rate of return (%)				159	204				

Note: Price Birr/kg: Sorghum=9Birr, Mungbean=18Birr, Haricot bean=13Birr, D= Dominance analysis, SS=Sole sorghum, SM=sole mung bean, SH=Sole haricot bean, 1S:1M=1:1Sorghum mung bean row ratios, 1S:1H=1:1Sorghum haricot bean row ratios.

Therefore, the marginal rate of return (MRR) was calculated for treatment comparisons. The MRR result showed that intercropping of 1:1 sorghum-haricot bean had 204 % MRR. This means that one Ethiopian birr spending on the treatment (application of 1:1 sorghum-haricot bean intercropping on the production of sorghum and haricot bean crops) over control treatment that was sole cropping of sorghum can cover the cost and have a return of birr 2.04. The intercropping system was economically feasible relative to a sole crop of maize as reported from different intercrop studies including [43] maize white lupine, and Addo-Quaye, et al. [45] maize soybean, and maize common bean.

4. CONCLUSION

The results indicated that 1:1 sorghum-haricot bean intercropping systems produced greater partial budget analysis. The maximum Harvest index for sorghum obtained in 1:1sorghum-haricot bean intercropping treatment. As regards the LER in almost all intercropping treatments were more than one so, as a result, 1:1 sorghum-haricot bean intercropping is higher and recommended for moisture deficient areas of North Gondar at East and West Belesa and similar conditions with this study.

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