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Effect of Wheat-Haricot Bean Intercropping on Performance of Component Crops and System Productivity Under Two Tillage Practices

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Abstract: Declining land productivity associated with diminishing farm size is a significant issue for intensive and sustainable crop production in Ethiopia. An intercropping of cereals such as wheat with grain legumes may provide a farm wide production system that achieves both economic and environmental concerns. Therefore, a field trial was carried out to evaluate the effect of different crop combinations of wheat-haricot bean on the productivity of wheat and haricot bean under two tillage practices at Alem Tena during 2016-2017 cropping seasons. The experiment was conducted by using split-plot design with three replications. The treatments comprised of two tillage practices (conventional and minimum tillage) assigned as the main plot and five wheat-haricot bean intercropping combinations (1:0, 1:1, 2:1, 1:2 and 0:1) assigned as the subplot. The results showed that tillage practices had a significant effect on growth and yield parameters of wheat, but not on growth and yield parameters of haricot bean. Minimum tillage increased biomass and grain yield of wheat over conventional tillage. Intercropping combination had a significant effect on both growth and yield parameters of both crops. The highest yield of wheat (3396 kg/ha) and haricot bean (4257.1 kg/ha) were observed in sole wheat and sole haricot bean, followed by 2:1 and 1:2 wheat-haricot bean combination, respectively. However, competitive indices showed that wheat-haricot bean in any of the combinations found to be more profitable and productive compared to sole wheat and haricot bean. Among intercropping combinations, 1:2 wheat-haricot bean gave the highest LER, ATER, MAI, IER. Therefore, 1:2 wheat-haricot bean intercropping combinations with a minimum tillage may provide a new opportunity in a low-input small grain production system for the study area, one that accomplishes both environmental and economic benefits through higher land productivity, improved grain and biomass productions.

Keywords: Intercropping, Haricot Bean, Tillage, Wheat, Yield

1. Introduction

Wheat (Triticumaestivum L.) is one of the worldwide produced and marketed cereal crops which cover 15% of the total producing areas of cereal crops in the world [1]. Ethiopia is one of the major wheat producers in terms of total production and cultivated areas in Africa [2]. The crop ranks fourth in area coverage after tef, maize and sorghum and third in total production after maize and tef [2, 3]. The leading wheat-growing areas are central highlands, northwest and south-eastern parts of the country. In those areas wheat-based cropping systems are dominated by monocropping, hence; farmers usually use intensive high inputs to maintain crop yields. Continues cropping of wheat on a monocropping basis has resulted in many disadvantages such as deprivation of natural resources, accumulation of diseases and pests, and decline productivity factors [4, 5]. Therefore, it is imperative to replenish mono-cropping systems by incorporating other crops like pulses or new crops in the wheat-based mono-cropping systems. The incorporation of food legumes into cereal-based cropping systems characterizes the main technology in the drive towards sustainable agricultural intensification [6]. Besides legume is a source of protein-rich food and feed, they have a high potential for conservation agriculture, improve soil fertility, and also contributes to climate change by reducing greenhouse gases emission [7, 8]. Haricot bean is a warm-season food and export crop playing an important role in human and animal nutrition as well as soil fertility improvement. It is a significant food legume grown and distributed in wide parts of Ethiopia [9]. The crop has been planted as a sole crop and/or intercropped with either cereal or perennial crops.

Intercropping is cultivation of crops that involves the growing of two or more different crop species at the same time in separate row combinations on the same portion of land [10]. It creates an opportunity to enhance agricultural sustainability through diversification and intensification [11], enhanced soil fertility [12], and substantial saving labor [13]. Normally, component crops in intercropping are from various + species or families, with one crop of major importance (e.g., food production), while the other provides further benefits (e.g., N_2 fixation for legume species). Besides, the system is recognized by low inputs, specifically, fertilizers, pesticides, and hence safe, and high-quality food under an environmentally friendly cropping system. An ideal intercropping combination is the one that obtained higher cumulative yield on a unit area and efficient uses of resources than as each crop is grown as a sole crop [14]. Yield advantages of an intercropping system are maximized by optimizing the population density of the component crops. Therefore, productivity and long-term maintenance of wheat-haricot bean mixtures depend on the crop combination in the intercropping systems.

Soil moisture conservation through tillage practices is an essential management factor for crop production in moisture-stress areas. Selection of the best tillage practices could improve rainwater infiltration and conserve sufficient soil moisture for plant development and thus improve crop yield [15]. Research has been proved that the use of conservation agriculture (CA) has a huge potential for conserving soil moisture and sustained high crop yields. The central Rift Valley of Ethiopia, such as Alem Tena, is characterized by high rainfall variability [16] and usually, the rainfall has terminated early at the crop critical stage [17]. Thus, conservation agriculture practices are very important to sustain crop yield in the area. However, there is a lack of information about its feasibility on wheat or haricot bean production.

Therefore, this study is aimed to evaluate the effect of different crop combinations on the productivity of wheat and haricot beans under two tillage practices.

2. Materials and Methods

2.1. Experimental Sits

The field experiment was conducted at Alem Tena, East shewa zone of Oromia Region, Ethiopia. It is located at a latitude and longitude of 8.30°N 38.95°E with an elevation of 1,611 meters. Total annual rainfall in the year 2016 and 2017 were 867.8 mm and 706.3 mm, respectively (Figures 1 and 2). The average min and max temperatures 17.64 and 29.9 for 2016 and 12.3 and 28.77 for 2017, respectively.

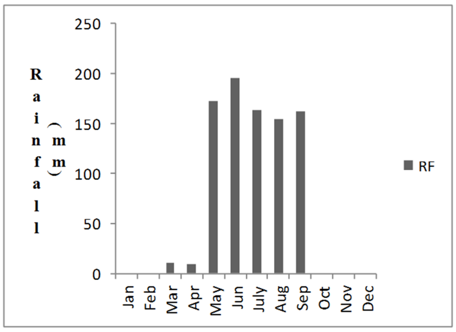

Figure 1. *Monthly rainfall distribution during 2016 at Alem Tena.*

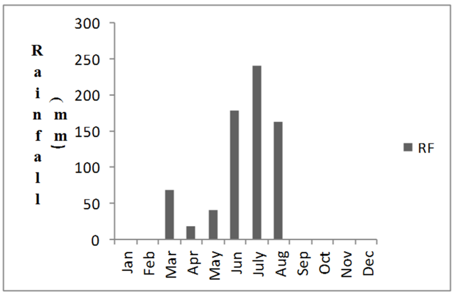

Figure 2. *Monthly rainfall distribution during 2017 at Alem Tena.*

Before planting, the soil samples at depth 0–30 cm from ten spots across the experimental field were collected, composited and analyzed for determining selected physicochemical properties of soil at Debre Zeit Agricultural Research Center following standard procedure. Values for the selected physicochemical properties of the experimental field are presented in Table 1.

Table 1. *Soil physio-chemical properties analysis (0-30 cm depth) of the experimental site.*

	2016	2017
Clay (%)	14	14
Silt (%)	26	26
Sand (%)	50	50
pH (1: 2.5 H_2O)	7.3	7.4
CEC [meq/100 g soil]	27	25
Organic matter (%)	1.43	1.40
Total N (%)	0.10	0.11
Available P (mg kg-1)	18.88	19.0
Soil type	Andisols	Andisols

2.2. Experimental Design, Treatments and Crop Management

The experiment was established using a split-plot design with three replications. The treatments comprised of two tillage practices (conventional and minimum tillage) assigned as the main plot and wheat-haricot bean intercropping combinations assigned as sub-plot treatments. The intercropping treatments of wheat-haricot bean consisted of five crop combination ratios based on replacement design 1:0, 1:1, 2:1, 1:2 and 0:1. The subplot size of 5 m x 5 m=25 m^2 was used for all treatments. The spacing between the main plots and subplots was 1 and 0.5 m, respectively.

For conventional tillage treatment, the tillage was practiced according to farmer practice. The first tilling was started in mid-April. For minimum tillage treatments, the post-emergence herbicide recommended for the area was applied before planting. Wheat variety Ude and haricot bean variety Awash-1 were used. For both sole and intercropped wheat and haricot bean, the planting date was on July 14 and July 16 in 2016 and 2017, respectively. The seed of wheat was sown with hand drilling in 20 cm rows spacing, while haricot bean was planted in a spacing of 40 cm between rows and 10 cm between plants. The recommended rate of 18 kg/ha N and 46 kg P_2O_5 ha^{-1} in the form of DAP was applied to both sole and intercropped haricot beans at planting. For wheat, N fertilizer at a recommended rate of 69 kg/ha and P fertilizer at a recommended rate of 46 kg/ha were applied. Urea (46% N) and DAP (46% P_2O_5) were used as the source of N and P respectively. The full dose of P and one-third of N fertilizer was applied at the sowing time. The remaining two-thirds of N fertilizer was applied at tillering stage as a top dressing. Other agronomic practices were kept uniform for all treatments. The crops were harvested manually at physiological maturity, and samples were taken from a sampling quadrat of 2 m x 2 m for monocrop and from central rows for intercropping.

2.3. Data Collection

Data such as plant height, number of tillers per plant, spike length, grain yield, above-ground biomass, and harvest index were collected for wheat. For the haricot bean, data such as plant height, the number of branches per plant, the number of pods per plant, seeds per pod, seed yield, above-ground biomass and harvest index were determined.

2.4. Competition Indices

Land equivalent ratio (LER) was used to measure the efficiency of the intercropping treatments and quantify according to Willey and Osiru [18].

$$LER=(Yab / Yaa) + (Yba / Ybb)$$

Where *Y*aa and *Y*bb are yields as sole crops and *Y*ab and *Y*ba are yields in intercrops. LER values greater than 1 indicate an advantage of intercropping over monoculture.

Area time equivalent ratio (ATER) - ATER which considers growth periods of the individual intercrops, is more suitable to compare sole and intercropping in this experiment since the growth period (life cycle) of wheat and haricot bean were different. The land occupancy period of wheat was 91 days while that of haricot bean was 83 days. Area time equivalent ratio was calculated by the formula given by Hiebsch & McCollum, [19]:

$$ATER = \frac{(Lwtw + Lhth)}{T}$$

Where Lw and Lh are relative yields of partial LER's for wheat and haricot bean component crops,

While tw and th are durations (days) for wheat and haricot bean crops,

T is the duration (days) of the whole intercrop system.

Monetary advantage index (MAI) - The economic feasibility of the intercropping system was quantified by Monetary Advantage Index (MAI). MAI was calculated as described by Ghosh et al. [20]:

$$MAI = \frac{(\text{Value of combined intercrops}) \times (LER - 1)}{LER}$$

The price of a grain of wheat (25 Birr/kg) and haricot bean (35 Birr/kg) produced were valued based on the average dominant prices during 2016 and 2017 from the local market in the study area.

Income equivalent ratio (IER): IER is similar in thought to LER, except that yield is determined in terms of net income, rather than crop productivity. Since income is a function of both crop price and yield, the agronomic response is constant. IER for intercrops could vary in different years as crop prices vary. LER (or IER) can be determined for systems comprising more than two crops by including the intercrop to sole crop yield (or net income) ratios of each crop involved in the intercropping system. To calculate the IER market price or gross income (GI) obtained from intercropping a hectare of land was used. It was calculated by the formula developed by Ghaffarzadeh [21].

$$IER = \frac{\text{GI of intercropped wheat}}{\text{GI of sole cropped wheat}} + \frac{\text{GI of intercropped haricot bean}}{\text{GI of solecropped haricot bena}}$$

2.5. Statistical Analysis

The data subjected to the combined analysis of variance (ANOVA) over years after confirmation of homogeneity of error variance using SAS software program. The means were compared by the Least Significant Difference (LSD) method at 0.05 probability level.

3. Result and Discussion

3.1. Wheat

Plant height of wheat was significantly ($P<0.05$) affected by the main effect of both tillage practices and intercropping combinations (Table 2). However, the number of tillage per plant and spike length of wheat was significantly ($P<0.05$) affected by only intercropping combinations (Table 2). The interaction effect of tillage practices and intercropping was not significant ($P>0.05$) on plant height, number on tillers and spike length of wheat (Table 2).

The tallest plant (77.4 cm) of wheat was obtained at minimum tillage as compared to conventional tillage. The activities of minimum soil disturbances improved organic matter, enhanced soil matter that improved soil fertility and conserved soil moisture content, which results in better crop performance. This result is in agreement with Gezahegn et al. [22] who reported the highest growth parameters of tef in minimum tillage than conventional tillage at Alem Tena.

The highest plant height (78.25 cm) and numbers of tillers per plant (4.40) of wheat were obtained when wheat was planted in 2:1 wheat-haricot bean combination, which was not significantly different (p>0.05) from 1:2 wheat-haricot bean combinations. In contrast, the lowest plant height (73.46) and numbers of tillers per plant (3.6) were obtained in sole wheat and 1:1 wheat-haricot bean intercropping, respectively. The improvement in growth of wheat in haricot bean intercropping may be due to a better environment, nutrient availability, interception, absorption and utilization of solar radiation. Das et al. [23] also reported the highest growth at intercropped wheat with lentil than sole wheat. Similarly, Singh et al. [24] found significantly taller wheat in 2:1 row ratio of wheat + lentil intercropped than sole wheat.

Table 2. *Effect of tillage practices and wheat-haricot bean intercropping combination on growth parameters of wheat.*

Tillage practices (T)	PH (cm)	NT	SL (cm)
Conventional tillage (4 times)	77.40b	3.55	4.86
Minimum Tillage (one time)	73.36a	3.90	4.76
LSD (0.05)	1.75	ns	ns
Intercropping combination (I)			
Wheat+Haricot bean (1:1)	74.71c	3.61c	4.64b
Wheat+Haricot bean (2:1)	79.84a	4.10a	4.83ab
Wheat+Haricot bean (1:2)	68.23b	3.98bc	4.64b
Sole wheat (1:0)	78.80a	4.32a	5.25a
LSD (0.05)	2.47	0.43	0.43
T x I	ns	ns	ns
CV (%)	3.95	8.22	4.16

PH=plant height; SL=spike length; NT=number of tillers; Means with the same letter in columns are not significantly different at 5% level of significance

The effect of tillage practices and wheat-haricot bean intercropping combination on yield and yield components of wheat is presented in Table 3. The main effect of tillage practices and intercropping combinations had a significant effect (P<0.05) on thousands of grain weight, biomass yield, and grain yield, but had not a significant effect on the harvest index of wheat. The interaction effect of tillage and intercropping combinations was not significant. Minimum tillage gave higher thousands grain weight, seed yield and biomass yield of wheat as compared to conventional tillage. This might be because minimum tillage effectively reduces water erosion, enhance soil total porosity and saturated water conductivity [25, 26], thereby increasing rainfall infiltration and soil water holding capacity [27], and enhancing crop growth and yield [28]. However, Pittelkow et al. [29] reported that conservation tillage methods could not enhance the grain yield of cereals in humid regions due to the impact of conservation tillage on yield varies among climatic zones.

The highest thousands grain weight (54.04 gm) and biomass yield (8058.3 kg/ha) of wheat were obtained in sole wheat but were not significantly (P>0.05) different from 2:1 wheat-haricot bean intercropping combination. Similarly, the highest seed yield (3396 kg/ha) of wheat was observed in sole wheat than intercropping wheat, followed by 2:1 wheat-haricot bean intercropping combination (2633 kg/ha). In contrast, the lowest thousands grain weight, biomass and seed yield were obtained in 1:2 wheat-haricot bean intercropping but were not significantly (P>0.05) different from 1:1 wheat-haricot bean intercropping combination. The highest grain and biomass yield in 2: 1 as compared to 1:1 and 1:1 wheat-haricot bean intercropping combinations might be due to greater competition exerted by the dominant wheat crop for light, space and nutrients than haricot bean. Among the intercropping combinations, grain and biomass yield of wheat showed significantly decreased as row ratio of wheat decreased. This showed that yields of wheat are directly related to its population in the intercropping system and greater competition exerted by the dominant wheat crop for resources over haricot bean. The result is in line with Chapagain and Riseman [30] who reported lower grain yields of wheat in wheat/ common bean intercrop plots compared to monoculture due to reduced plant densities. But the same author reported higher wheat grain yields from 2:1 wheat–faba bean arrangement as compared to monocropped wheat. Similarly, Yahuza [31] stated that biomass yield of wheat was greater in wheat/bean intercrop compared to their associated mono crops due to their variances in their physiological and morphological characteristics, which may imply resource use by the two crops.

Table 3. *Effect of tillage practices and wheat-haricot bean intercropping combination on yield and yield components of wheat.*

Tillage practices (T)	TGW (g)	BY (kg/ha)	GY (kg/ha)	HI
Conventional tillage (4 times)	55.87a	7468.8 a	2855.8a	0.39
Minimum Tillage (one time)	42.26b	5817.4 b	2084.1b	0.38
LSD (0.05)	3.42	1305	431.87	ns
Intercropping combination (I)				
Wheat+Haricot bean (1:1)	47.37b	5939.8bc	2119.1bc	0.36
Wheat+Haricot bean (2:1)	50.65a	7294.7ab	2633.2b	0.36
Wheat+Haricot bean (1:2)	44.02b	5279.5c	1731.2c	0.33
Sole wheat	54.02a	8058.3a	3396.3a	0.42
LSD (0.05)	3.45	1846.4	617.5	ns
T x I	ns	ns	ns	ns
CV (%)	7.59	13.83	23.9	8.5

TGW=thousands grain weight, BY=biomass yield; GY=grain yield; Means with the same letter in columns are not significantly different at 5% level of significance

3.2. Haricot Bean

Plant height, numbers of branches per plant and numbers of pods per plant were significantly (P<0.05) affected by the main effect of intercropping combinations, but not significantly (P>0.05) effected by main effect of tillage and interaction of tillage with intercropping combinations (Table 4). The number of seeds per pod was not significantly (P<0.05) affected by both the main and interaction effect of tillage and intercropping combinations. The tallest plant of haricot bean (62.38 cm) was recorded in 2:1 wheat-haricot bean, which was not significantly (P>0.05) different from other intercropping combinations. In contrast, the shortest haricot bean (48.74 cm) was observed in sole haricot bean. Competition for light under intercropping increased the plant height of haricot bean compared to sole haricot bean as plants are known to become etiolated under increasing shade [32]. Similar to the current result Temesegen et al. [33] reported the highest plant height of common bean in intercropping with maize than sole common bean. Almaz et al. [34] also found taller soybean plants in intercropping than monocrop. In contrary to this result Alemayehu et al. [35] and Getahun and Abady [36] found higher plant height of common bean in monocropped compared to intercrop with maize.

The maximum numbers of branches per plant (6.24) and pods per plant of haricot bean (31.19) were observed in sole haricot bean, which was not significantly different (p>0.05) from 1:2 and 1:1 wheat-haricot bean combinations. In contrast, the minimum numbers of branches per plant and pods per plant of haricot bean were observed in intercropping of haricot bean in 2:1 wheat-haricot bean combination. The lower number of effective branches per plant was attributed to the higher competition between plants for growth factors in intercropping system. Likewise, the decreased in the number of pods per plant was ascribed to the inhibition of initiation of pods due to higher interspecific competition between wheat and haricot bean for resources. This result is in line with Çiftçi et al. [37] who found significantly higher pods per plant in sole common bean. However, Nassary et al. [38] found a non-significant difference of numbers of pods per plant between intercropped and monocropped common bean.

Table 4. *Effect of tillage practices and wheat-haricot bean intercropping combination on plant height, numbers of branches per plant, numbers of pods per plant and numbers of seed per plant of haricot bean.*

Tillage practices (T)	PH (cm)	NBPP	NPPP	NSPP
Conventional tillage (4 times)	56.4	5.6	28.2	4.96
Minimum Tillage (one time)	53.9	5.4	26.9	4.93
LSD (0.05)	ns	ns	ns	ns
Intercropping combination (I)				
Wheat+Haricot bean (1:1)	55.41ab	5.54ab	27.71ab	4.93
Wheat+Haricot bean (2:1)	62.38a	4.88b	24.37b	5.16
Wheat+Haricot bean (1:2)	53.98ab	5.39ab	26.99ab	4.83
Sol haricot bean	48.74b	6.24a	31.19a	4.87
LSD (0.05)	10.2	1.02	5.1	ns
T x I	ns	ns	ns	ns
CV (%)	18.36	10.03	21.14	15.5

PH=plant height; NBPP=Number of pod per plant; NPPP=Number of pod per plant; NSPP=numbers of seeds per pod; Means with the same letter in columns are not significantly different at 5% level of significance

Effect of tillage practices and wheat-haricot bean intercropping combination on thousands seed weight, biomass yield, seed yield and harvest index of haricot bean is presented in Table 5. Biomass and seed yield of haricot bean were significantly (P<0.05) affected by the main effect of intercropping combination, but not significantly (P>0.05) affected by tillage practices. Thousands seed weight and harvest index of haricot bean were not significantly (P>0.05) affected by both tillage practices and intercropping combinations. The interaction effect of tillage practices and intercropping combination was not significant (P>0.05) in all the above-mentioned parameters. Though the yield of haricot bean was not significantly affected by tillage practices, the area has characterized by poor rainfall distribution and relatively high temperature with very light sandy soil and low moisture-holding capacity, thus conservation agriculture or minimum tillage could be a benefit to conserve soil moisture. Besides, the farmers in the area have large farm sizes and they have got struggle when tilled 5 times [17], therefore, minimum tillage would be preferable for cost and labour effective, since minimum tillage has not to yield penalty as compared to conventional tillage.

Table 5. *Effect of tillage practices and wheat-haricot bean intercropping combination on yield and yield components of haricot bean.*

Tillage practices (T)	HSW	BY (kg/ha)	SY (kg/ha)	HI
Conventional tillage (4 times)	18.9	7696.8	2827.8	0.4
Minimum Tillage (one time)	17.4	6561.3	2614.2	0.4
LSD (0.05)	ns	ns	ns	ns
Intercropping combination (I)				
Wheat+Haricot bean (1:1)	13.38c	5021b	2007.4c	0.42
Wheat+Haricot bean (2:1)	8.40d	3110b	1259.6d	0.4075
Wheat+Haricot bean (1:2)	22.40b	9260a	3359.9b	0.3767
Sole Haricot bean	28.38a	11125a	4257.1a	0.3992
LSD (0.05)	4.91	1924.9	737.23	ns
T x I	ns	ns	ns	ns
CV (%)	11.08	17.23	16.83	8.8

HSW=hundred seed weight; BY=biomass yield; SY=seed yield; HI=harvest index; Means with the same letter in columns are not significantly different at 5% level of significance; LSD=least significant differences at 5%; CV (%)=Coefficient of variation

The highest biomass (11125 kg/ha) and seed yield (4257.1 kg/ha) of haricot bean were higher in sole haricot bean. The biomass found in sole haricot bean was not significantly different (p>0.05) from 1:2 wheat-haricot bean intercropping. In contrast, the lowest biomass and seed yield of haricot bean were observed in 2:1 wheat-haricot bean intercropping. This might be due to a higher degree of interspecific competition between the intercrops. The intensity and quality of the intercepted light by the canopy are the most significant determinants of yield and yield components [39]. Besides, the reduction of haricot bean yield when intercropped with wheat was due to the reduction of yield component, in particular, the number of branches and pods per plant. Seed yield of haricot bean was highly correlated with yield components, hence any reduction in yield components can also reduce yield. The result is in agreement with Abera et al. [40] and Worku [41] who reported yield loss of common bean from simultaneous intercropping. Chapagain and Riseman [42] also reported that seed yield of common bean in intercrop plots were lower than their monoculture due to reduced seed densities.

3.3. Competition Indices

Effect of intercropping combinations on competitive indices is presented in Table 6. The partial LER of wheat and haricot bean were less than 1 under all intercropping combinations. Higher partial LER of wheat was recorded in 1:1 and 2:1 wheat-haricot bean intercropping, whereas higher partial LER of haricot bean was recorded in 1:2 wheat-haricot bean intercropping combination. This implies that a high proportion of a crop in intercropping system contributed for higher partial LER. The total LER in all intercropping combinations was greater than 1, indicating the yield advantage of the wheat-haricot bean intercropping system over sole cropping. Among intercropping combinations, 1:2 wheat-haricot bean intercropping gave the greater LER (1.31), followed by 1:1 wheat haricot bean combination. Intercropping combination 1:2 resulted in a 31% greater land productivity and 1:1 arrangement showed 9% higher land productivity than sole crops. The higher LER attributed to the better utilization of growth resources by component crops in intercropping systems. The difference in morphological and physiological features among intercrop components contributed for more efficient utilization of resources. The result is in line with Chapagain and Riseman [30] reported the highest LER (1.33) 2:1 wheat-bean intercropping arrangement. Similarly, Sahota and Malhi [42] reported that intercropping required 7 to 17% less land than monoculture crops to produce the same level of yield.

LER doesn't consider the term of the crops within the field and it is based on the harvested items, and not on craved surrender extent of the component crops. Besides, the selection of sole cropped yield for normalizing mixture yield in the estimation of LER is not clear [43]. Therefore, ATER offers a more realistic assessment of the yield advantage of intercropping over monocropping in terms of a difference in time occupied by the component crops of different intercropping systems [44]. The result showed all intercropping combinations gave ATER >1, indicate an advantage of intercropping. The height ATER (1.24) was recorded in a 1:2 wheat-haricot bean intercropping combination followed by 1:1 arrangement. In all wheat-haricot bean intercropping combinations, the ATER values were smaller than LER values showing the overestimation of resource utilization probably because of the wide differences in the maturity times of the crops of which wheat remained longer on the land and had adequate time to compensate for the haricot bean competition.

Substantial agronomic advantages from intercropping do not continuously guarantee an economic advantage and there is an essential for some economic determination and total yield comparisons of intercropping systems [45]. In all wheat-haricot bean intercropping combinations MAI values were positive, indicating the economic advantage of wheat-haricot bean intercropping over sole cropping. The highest MAI (323710 Birr) was recorded in 2:1 wheat-haricot bean intercropping combination. This may be due to the superior utilization of resources among wheat-haricot bean intercropping combinations. MAI was mainly influenced by the market price of produce and the economic yield harvested. Similarly, Almaz et al. [34] found positively related LER with an economic benefit that expressed MAI.. Banik et al. [46] also reported that maximum seed yield and benefit under planting arrangement with differed row ratios of wheat-chickpea may be elucidated in higher total productivity under intercropping with comparatively less input investment.

Income equivalency ratio (IER) is similar in concept to LER, except that yield is measured in terms of net income, rather than plant product productivity [47]. The combined yield advantage in terms of total IER indices was greatest (1.30) in the cases of 1:2 wheat-haricot bean intercropping, followed by 1:1 and 2:1 wheat-haricot bean intercropping combination, which were 1.10 and 1.07 IER value respectively. The value of IER, which is >1 shows an advantage from those intercropping arrangements over pure stands in wheat-haricot bean combinations in terms of the use of environmental resources for plant growth.

Table 6. *Effect of wheat-haricot bean intercropping combinations on competition indices.*

Treatment	Partial LER		TLER	ATER	MAI	IER
	Wheat	Haricot bean			Birr/ha	
Wheat+Haricot bean (1:1)	0.62	0.47	1.09	1.05	107932	1.10
Wheat+Haricot bean (2:1)	0.78	0.3	1.08	1.05	118201	1.07
Wheat+Haricot bean (1:2)	0.51	0.8	1.31	1.24	323710	1.30

PLER=partial land equivalent ratio, TLER=total land equivalent ratio, ATER=area time equivalent ratio, MAI=monetary advantage Index

4. Conclusion

The results showed that tillage practices and intercropping combinations had a significant effect on growth parameters of wheat, but not on haricot bean. Minimum tillage increased growth and yield parameters for wheat over conventional tillage but gave similar haricot bean with that of conventional one. Intercropping combination had a significant effect on the growth and yield parameters of both crops. The highest yield of wheat was observed in 2:1 wheat-haricot bean combination, while the highest haricot bean yield was observed in sole haricot bean. Based on competitive indices, wheat-haricot bean intercropping systems showed significant and positive responses from the interacting species on plant performance and overall system productivity. Among intercropping combinations, 1:2 wheat-haricot bean gave the highest LER, ATER, MAI and IER value. Therefore, 1:2 wheat-haricot bean intercropping combinations with a minimum tillage may provide a new opportunity in a low-input small grain production system, one that fulfills both economic and environmental interests through higher land productivity, improved grain and biomass yield.

References

[1] Kiss, I. (2011). *Significance of wheat production in world economy and position of Hungary in it. Abstract: Applied studies in agribusiness and commerce* [Thesis]. University of Debrecen.

[2] CSA (Central Statistical Agency). (2018). Agricultural Sample Survey 2017/2018, report on area and production of major crops, Addis Ababa, Ethiopia.

[3] Minot, N., Warner, J., Lemma, S., Kasa, L., Gashaw, A., & Rashid, S. (2015). *The wheat supply chain in Ethiopia: Patterns, trends, and policy options*. International Food Policy Research Institute (IFPRI).

[4] Ayyappan, S., & Arunachalam, A. (2014, November). Crop diversification for social security of farmer in India. In *Souvenir of the National Symposium onAgricultural Diversification for Sustainable Livelihood and Environmental Security' held on* (pp. 18-20).

[5] Behera, U. K., & France, J. (2016). Integrated farming systems and the livelihood security of small and marginal farmers in India and other developing countries. In *Advances in Agronomy* (Vol. 138, pp. 235-282). Academic Press.

[6] Vanlauwe, B., Coyne, D., Gockowski, J., Hauser, S., Huising, J., Masso, C.,... & Van Asten, P. (2014). Sustainable intensification and the African smallholder farmer. *Current Opinion in Environmental Sustainability*, *8* (0), 15-22.

[7] Jensen, E. S., Peoples, M. B., Boddey, R. M., Gresshoff, P. M., Hauggaard-Nielsen, H., Alves, B. J., & Morrison, M. J. (2012). Legumes for mitigation of climate change and the provision of feedstock for biofuels and biorefineries. A review. *Agronomy for sustainable development*, *32* (2), 329-364.

[8] Stagnari, F., Maggio, A., Galieni, A., & Pisante, M. (2017). Multiple benefits of legumes for agriculture sustainability: an overview. Chemical and Biological Technologies in Agriculture, 4 (1), 2.

[9] Tenaw, W. (1990, October). Review of Agronomic Studies on Haricot Bean in the Southern Zone of Ethiopia. In *Research on Haricot Bean in Ethiopia: an Assessment of Status, Progress, Priorities and Strategies, Proceedings of a National Workshop held in Addis Ababa*.

[10] Maitra, S., Palai, J. B., Manasa, P., & Kumar, D. P. (2019). Potential of Intercropping System in Sustaining Crop Productivity. *International Journal of Agriculture, Environment and Biotechnology*, *12* (1), 39-45.

[11] Hauggaard-Nielsen, H., B. Jornsgaard, J. Kinane, and E. S. Jensen. 2007. Grain legume-cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. Renew. Agr. Food Syst. 23 (1): 3-12.

[12] Lithourgidis, A. S., C. A. Dordas, C. A. Damalas, and D. N. Vlachostergios. 2011. Annual intercrops: an alternative pathway for sustainable agriculture. Aust. J. Crop Sci. 5 (4): 396-410.

[13] Thurston, D. 1996. Slash/mulch systems: Sustainable methods for tropical agriculture. Westview Press, Boulder, CO, USA.

[14] Inal, A., A. Gunes, F. Zhang, and I. Cacmak. 2007. Peanut/maize inter-cropping induced changes in rhizosphere and nutrient concentrations in shoots. Plant Physiol. Biochem. 45: 350-356.

[15] Cornelis, W. M., Araya, T., Wildermeersch, J., Mloza-Banda, M. K., Waweru, G., Obia, A.,... & Boever, D. (2013). Building resilience against drought: the soil-water perspective. *Desertification and Land degradation: Processes and Mitigation*, 1-15.

[16] Kassie, B. T., Hengsdijk, H., Rötter, R., Kahiluoto, H., Asseng, S., & Van Ittersum, M. (2013). Adapting to climate variability and change: experiences from cereal-based farming in the Central Rift and Kobo Valleys, Ethiopia. *Environmental Management*, *52* (5), 1115-1131.

[17] Desta, B. T., Gezahegn, A. M., & Tesema, S. E. (2020). Planting Time Effects on the Productivity of Tef [Eragrostis tef (Zucc.) Varieties in Ethiopia. *American Journal of Life Sciences*, *8* (3), 34-40.

[18] Willey, R., & Osiru, D. (1972). Studies on mixtures of maize and beans (*Phaseolus vulgaris*) with particular reference to plant population. *Journal of Agricultural Science, 79* (03), 517-529.

[19] Hiebsch, C., & McCollum, R. (1987). Area-time equivalency ratio: a method for evaluating the productivity of intercrops. *Agronomy Journal, 79* (1), 15-22.

[20] Ghosh, P., Bandyopadhyay, K., Manna, M., Mandal, K., Misra, A., & Hati, K. (2004). Comparative effectiveness of cattle manure, poultry manure, phosphocompost and fertilizer-NPK on three cropping systems in vertisols of semi-arid tropics. II. Dry matter yield, nodulation, relative chlorophyll content and enzyme activity. *Bioresource Technology, 95* (1), 85-93.

[21] Ghaffarzadeh, M. (1979). Economic and biological benefits of intercropping Berseem clover with oat in corn-soybean-oat rotations. *Journal of Production Agriculture*, 10, 314-319.

[22] Gezahegn, A. M., Desta, B. T., Takele, A., & Eshetu, S. (2019). Productivity of tef [Eragrostis tef] under conservation tillage practices in central Ethiopia. *Cogent Food & Agriculture*, *5* (1), 1707038.

[23] Das, A. K., Khaliq, Q. A., & Haider, M. L. (2012). Efficiency of wheat-haricot bean and wheat-chickpea intercropping systems at different planting configurations. *International Journal of Sustainable Crop Production*, 7 (1), 25-33.

[24] Singh, A., Kumar, R., & Kaur, M (2019). Effect of haricot bean intercropping on growth, yield and quality of wheat (Triticum aestivum). Journal of pharmacology and Photochemistry, 4, 152-156.

[25] Wue, J., Cai, L. Q., Luo, Z. Z., Li, L. L., & Zhang, R. Z. (2014). Effects of conservation tillage on soil physical properties of rainfed field of the Loess Plateau in Central of Gansu. *J. Soil Water Conserv*, *28*, 112-117.

[26] Peng, Z. K., Li, L. L., Xie, J. H., Kang, C. R., Essel, E., Wang, J. B., & Shen, J. C. (2018). Effects of conservational tillage on water characteristics in dryland farm of central Gansu, Northwest China. *Ying yong sheng tai xue bao=The journal of applied ecology*, *29* (12), 4022-4028.

[27] Cai, L. Q., Luo, Z. Z., Zhang, R. Z., Huang, G. B., Li, L. L., & Xie, J. H. (2012). Effect of different tillage methods on soil water retention and infiltration capability of rainfed field. *J. Desert Res*, *32*, 1362-1368.

[28] Shao, Y., Xie, Y., Wang, C., Yue, J., Yao, Y., Li, X.,... & Guo, T. (2016). Effects of different soil conservation tillage approaches on soil nutrients, water use and wheat-maize yield in rainfed dry-land regions of North China. *European Journal of Agronomy*, *81*, 37-45.

[29] Pittelkow, C. M., Liang, X., Linquist, B. A., Van Groenigen, K. J., Lee, J., Lundy, M. E.,... & Van Kessel, C. (2015). Productivity limits and potentials of the principles of conservation agriculture. Nature, 517 (7534), 365-368.

[30] Chapagain, T., & Riseman, A. (2014). Intercropping wheat and beans: effects on agronomic performance and land productivity. *Crop Science*, 54 (5), 2285-2293.

[31] Yahuza, I. (2011). Wheat/faba bean intercropping system in perspective. *Journal of Biodiversity and Environmental Sciences (JBES)*, *1* (6), 69-92.

[32] Scott, L. C. (2012). Basic environmental photobiology. *Wahington State university, US.*

[33] Temesgen, J., Kufa, T., & Wondimu, Z. (2015). Effect of Plant Density of Hybrid Maize and Common Bean Varieties on the Productivity of Intercropping System at Jimma, South West Ethiopia. *Global Journal of Life Science and Biological Research*, 1 (1), 7-17.

[34] Almaz, M. G., Halim, R. A., & Martini, M. Y. (2017). Effect of Combined Application of Poultry Manure and Inorganic Fertiliser on Yield and Yield Components of Maize Intercropped with Soybean. *Pertanika Journal of Tropical Agricultural Science*, *40* (1).

[35] Alemayehu, D., Shumi, D., & Afeta, T. (2018). Effect of variety and time of intercropping of common bean (Phaseolus vulgaris L.) with maize (Zea mays L.) on yield components and yields of associated crops and productivity of the system at mid-land of Guji, Southern Ethiopia. *Adv. Crop Sci. Tech*, *6*, 324.

[36] Getahun, A., & Abady, S. (2016). Effect of Maize (Zea may L.) on Bean (Phaseolus vulgaris L.) yield and its components in Maize-Bean intercropping. *International Journal of Science and Research*, *5*, 126-133.

[37] Çiftçi, V., Toğay, N., Toğay, Y., & Doğan, Y. (2006). The effects of intercropping sowing systems with dry bean and maize on yield and some yield components. *Journal of Agronomy*, *5* (1), 5.

[38] Nassary, E. K., Baijukya, F., & Ndakidemi, P. A. (2020). Productivity of intercropping with maize and common bean over five cropping seasons on smallholder farms of Tanzania. *European Journal of Agronomy*, *113*, 125964.

[39] Liu, B., Liu X. B., Wang, C., Jin, J., Harbert, S. J., and Hashemi, M. (2010). Response of soybean yield and yield components to light enrichment and planting density. International Journal of Plant Production, 4 (1): 1-10.

[40] Abera, R., Worku, W., & Beyene, S. (2017). Performance variation among improved common bean (Phaseolus vulgaris L.) genotypes under sole and intercropping with maize (Zea mays L.). *African Journal of Agricultural Research*, *12* (6), 397-405.

[41] Worku W (2008). Evaluation of common bean (Phaseolus vulgaris L.) genotype of diverse growth habit under sole and intercropping with maize (Zea mays L.) in southern Ethiopia. *Journal of Agronomy,* 7 (4): 306-313.

[42] Sahota, T. S., & Malhi, S. S. (2012). Intercropping barley with pea for agronomic and economic considerations in northern Ontario. *Agric. Sci*. 3: 889–895.

[43] Willey, R. (1979). Intercropping-its importance and research needs: Part 1. Competition and yield advantages. In *Field crop abstracts* (Vol. 32, pp. 1-10).

[44] Aasim, M., Umer, E. M., & Karim, A. (2008). Yield and competition indices of intercropping cotton (Gossypium hirsutum L.) using different planting patterns. *Tarim Bilimleri Dergisi*, *14* (4), 326-333.

[45] Tamado, T., & Eshetu, M. (2000). Evaluation of sorghum, maize and common bean cropping systems in East Hararghe, Eastern Ethiopia. *Ethiopian Journal of Agricultural Sciences*, *17* (1-2), 33-45.

[46] Banik, P., Midya, A., Sarkar, B. K., & Ghose, S. S. (2006). Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. *European Journal of Agronomy*, *24* (4), 325-332.

[47] Bhatt, B. K., Dixit, S. K., & Darji, V. B. (2010). Monetary evaluation of sesame based intercropping systems. *Indian Journal of Agricultural Research*, *44* (2), 146-149.