Ethiop. J. Agric. Sci. 31(2) 45-59 (2021)

Productivity and Land Use Efficiency of Wheat-Lentil Intercropping under Two Tillage Practices

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ከጊዜ ወደ ጊዜ እየጨመረ የመጣውን ህዝብ ለመመገብ በአንድ የእርሻ ማሳ ላይ ምርታማነትን ማሳደግ በጣም አስፈለጊ ነው፡፡ ስለሆነም ሰብልን አሰባጥሮ መዝራት ምርትን ለማሳደግ ተስፋ ሰጪ ሥርዓት ተደርጎ ይወሰዳል በተጨማሪም ምርታማነትን እና የመሬት አጠቃቀምን ውጤታማ ያደርጋል፡፡ የስንዴ እና ምስር የተለያዩ የሰብል ስብጥር በስንዴ እና በምስር ምርታማነት እና የመሬት አጠቃቀም ውጤታማነት በሁለት የእርሻ አስተራረስ ዘዴ ለመገምገም በምንጃር ወረዳ እ.ኤ.አ. ከ 2015-2017 ባለው የሰብል ምርት ወቅት የመስክ ጥናት ተካሂዷል፡፡ ምርምሩ የተካሄደዉ እስፕሊት ፕሎት በተባለ ዲዛይን ሲሆን እያንዳንዱ ትሪትመንት ሶስት ጊዜ ተደጋግሟል፡፡ ትሪትመንቶቹ ያካተቱት ሁለት የአስተራረስ ዘዴ (ባህላዊ እና ዝቅተኛ) በዋና ፕሎት ላይ ሲዉሉ አምስት የስንዴ እና ምስር ስብጥር አዘራር ዘዴ(1፡0፤1፡1፤2፡1፤1፡2 እና 0፡1) ደግሞ በንዑስ ፕሎት ላይ በማድረግ ነዉ፡፡ የሙከራዉ ዉጤት እንዳሳየዉ በስንዴ እና ምስር የእድገት መለኪያዎች ላይ ጉልህ ተፅኖ አልነበረዉም፡፡ የአስተራረስ ዘዴዎችም በስንዴ ምርታማነት ላይ የጎላ ተፅኖ አልነበረዉም ነገር ግን በምስር ምርታማነት ላይ የጎላ ተፅኖ ነበረዉ፡፡ ከፍተኛ የምስር ምርት (1546 ኪ.ግ/ሄ.ክ) የተገኘዉ ከዝቅተኛ የአስተራረስ ዘዴ ሲነፃፀር የባሕላዊ አስተራረስ ዘዴ የተሸለ ምርት አስገኝቷል፡፡ በስብጥር አዘራር ዘዴ በሁለቱም ሰብሎች ላይ የጎላ ተፅኖ ነበረዉ፡፡ ከፍተኛ የስንዴ ምርት (2932 እና 2982 ኪ.ግ/ሄ.ር) የተገኘዉ ስንዴ ብቻውን ሲዘራ (1፡0) እና 2፡1 ስንዴ እና ምስር ስብጥር ነዉ፡፡ ይሁን እንጂ አሰባጥሮ መዝራት የምስር ምርት እንደሚቀንሰው ጥናቶ ያሳያል፡፡ ከስብጥር አዘራር ዘዴ መካከል 2፡1 ስንዴ-ምስር ስብጥር ከፍተኛ የመሬት አጠቃቀም፤የመሬትና የጊዜ አጠቃቀም እንዲሁም የገንዘብ ጥቅም አስገኝቷል፡፡ ስለሆነም 2፡1 ስንዴ-ምስር ስብጥር ለስንዴ እና ምስር በስብጥር የማምረት ዘዴ ምቹ መሆኑን ጥናቱ አረጋግጧል፡፡

Abstract

To feed the ever-increasing population, increase productivity per unit area is one of the most attractive strategies. Intercropping is considered a promising system for increasing crop productivity and land-use efficiency. A field study was conducted to evaluate the effect of different crop combinations of wheat-lentil on the productivity of wheat (Triticum aestivum L.) and lentil (Lens culinaris) and land use efficiency under two tillage practices in Minjar district during 2015-2017 cropping seasons. The experiment was carried out using split-plot design with three replications. The treatments consisted of two tillage practices (conventional and minimum tillage) assigned as the main plot and five wheat-lentil intercropping combinations (1:0, 1:1, 2:1, 1:2 and 0:1) assigned as the subplot. The tillage practices and intercropping had significant effect on growth parameters of wheat and lentil. Minimum tillage increased growth parameters for wheat, but reduced growth parameters for lentil. The yield of wheat was non-significantly affected by tillage practices, but the yield of lentil was significantly affected by tillage systems. A higher yield of lentil (1546 kgha^{-1}) was obtained in conventional tillage as compared to minimum tillage practices. Intercropping combination had a significant effect on both growth and yield parameters of both crops. The highest yield of wheat (2932 and 2982 kgha^{-1}) was recorded in sole wheat (1:0) and 2:1 wheat-lentil combination, while the highest *yield of lentil (1575 kgha^{-1}) was obtained in sole lentil (0:1). Among intercropping combinations, 2:1 wheat-lentil gave the highest LER, ATER, and MAI values. Therefore, 2:1 wheat-lentil intercropping combinations were found suitable for higher productivity and production of component crops and the intercropping system of wheat-lentil in any of the combinations found to be more profitable and productive compared to sole wheat and lentil.*

Keywords: intercropping, lentil, tillage, wheat, yield

Introduction

The demand for food has been increasing while the availability of land has been diminishing due to the rising of population pressure. Thus, the only way to raise agricultural production is to increase yield per unit area (Seran et al. 2010; Khan et al. 2014). Crop production can be intensified through intercropping (Martin-Guay et al. 2018). Intercropping is a system management of crops which involves growing of two or more different crop species at the same time in separate row combination on the same piece of land (Maitra, 2018). Intercropping offers potential benefits relative to monocropping by increasing yield and profit per unit area/time through the efficient use of resources, such as nutrients, water and light (Nasri et al. 2014). Intercropping is favored to monocropping as a result of a higher yield due to better utilization of resources, and this is particularly when legumes are planted with cereals (Sachan and Uttam, 1992), that improves soil fertility due to nitrogen fixation (Manna *et al.* 2003).

Hence, it is imperative to look for such intercropping systems/patterns, which have the potential of raising minor crops such as pulses in association with major food crops like wheat in Ethiopia. Incorporation of grain legume in cereal-based cropping system aims at increased productivity and profitability to achieve food and nutritional security and sustainability (Snapp et al. 2010). In addition to legume is a source of high-quality food and feed, they have a high potential for conservation agriculture and also contributes to climate change by reducing greenhouse gases emission (Stagnari et al. 2017). Lentil is a cool-season food legume playing a significant role in human and animal nutrition as well as soil fertility maintenance. Though cereal-legumes intercropping have many advantages, wheat-based farming systems have been predominantly by mono-cropped. Productivity and long-term maintenance of wheat-lentil mixtures depend on the crop combination in intercropping systems. Thus, determining the ideal crop combination is a very important research topic.

Conservation agriculture (CA) is a set of principles for sustained high crop yields and environmental protection. It requires minimal soil disturbance, permanent soil cover with crop residue and crops plus cropping system (Farooq and Siddique 2014).

The introduction of conservation agriculture in Ethiopia by SG 2000 dated back in 2005 GC (Tsegaye *et al*. 2017), since then several studies have been conducted by different research centers in the country. Those studies, however, focused only on the productivity of the test crops under sole crop conditions. Recent studies on the integrated approaches of intercropping under conservation agriculture-focused only on maize based intercropping with few pulse crops on selected agro-ecologies. However, there is a lack of information about its feasibility on wheat and lentil intercropping system. Therefore, the objective of this study was to evaluate the effect of different crop combinations on the productivity of wheat and lentil under two tillage practices.

Materials and Methods

Characterization of the study site

Field experiment was conducted at Minjar, North Shewa zone of Amhara National Regional State, Ethiopia. It is located at a latitude of 9° 09' 60.00" N and longitude of 39° 19' 60.00" E at an altitude of 1040 m.a.s.l. Total annual rainfall in the year 2015, 2016 and 2017 were approximately 722.6 , 903.4 and 802.6 mm, respectively (Figure 1). The average minimum and maximum temperatures of 2015, 2016 and 2017 are 15.4 and 27.6 ^{0}c, 15.2 and 29.0 ^{0}c and 15.9 and 28.4 ^{0}c, respectively. The soil type is slightly Vertisol.

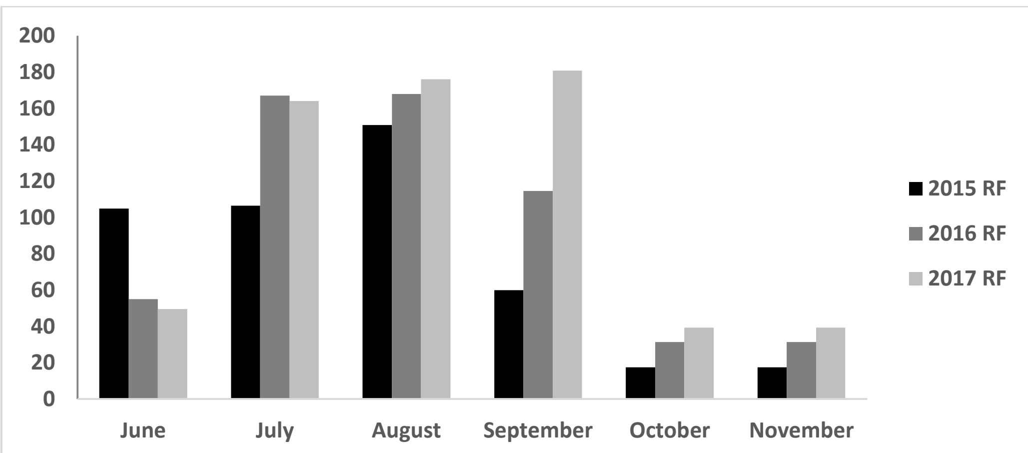

Figure. 1. Total rainfall for the cropping season (June to November, 2015, 2016 and 2017) at Minjar

Experimental design, treatments and crop management

The experiment was laid out using split-plot design with three replications. The treatments consisted of two tillage practices (conventional and minimum tillage) assigned as the main plot and wheat-lentil intercropping combinations assigned as sub-plot treatments. The intercropping treatments of wheat-lentil 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 4 m x 4m = 16 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 (4 times plow), the tillage was practiced according to farmer practice. The first plowing was started in mid-April. For minimum tillage treatments, primary tillage was completely avoided and secondary tillage was restricted to seedbed preparation in the row zone only and post-emergence herbicide recommended for the area was applied before planting. Wheat variety Ude and lentil variety Denkaka were used. For both sole and intercropped wheat and lentil, the planting date was on July 15 and July 12 and July 15 in 2015, 2016 and 2017, respectively. The seeds of both crops were sown with hand drilling in 20 cm rows spacing. For Wheat, N fertilizer at a recommended rate of 69 kg ha^{-1} and P fertilizer at a recommended rate of 46 kg ha^{-1} 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 were applied at tillering stage as a top dressing. For lentil, the recommended rate of 18 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} in the form of DAP was applied to both sole and intercropped lentil at planting. 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.

Data collection

Data such as plant height, number of tillers per plant, spike length, grain yield, dry biomass and harvest index were collected for wheat. For lentil, data such as plant height, number of branches per plant, number of pods per plant, seeds per pod, seed yield, dry biomass and harvest index were determined.

Competition indices

Land equivalent ratio (LER) was used to quantify the efficiency of the intercropping treatments and calculated according to Willey and Osiru (1972).

$$LER = (Y\mathrm{ab} / Y\mathrm{aa}) + (Y\mathrm{ba} / Y\mathrm{bb})$$

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 advantage of intercropping over monoculture.

Area time equivalent ratio (ATER) - ATER which takes growth periods of the individual intercrops into consideration, is more suitable to compare sole and intercropping in this experiment since the growth period (life cycle) of wheat and lentil were different. The land occupancy period of wheat was 110 days while that of lentil was 90 days. Area time equivalent ratio was calculated by the formula given by (Hiebsch and McCollum 1987):

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

Where Lw and Ll are relative yields of partial LER's for wheat and lentil component crops,

While tw and tl are durations (days) for wheat and lentil crops,

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

Monetary advantage index (MAI) - The economic advantage of the intercropping system was measured by Monetary Advantage Index (MAI). MAI was calculated as described by Ghosh et al. (2004):

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

The price of a grain of wheat (20 Birrkg^{-1}) and lentil (40 Birrkg^{-1}) produced were valued based on the average dominant prices during 2016 and 2017 from local market in the study area.

Statistical Analysis

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

Results and Discussions

Effect of tillage and intercropping on wheat

The effect of tillage practices and wheat-lentil intercropping combination on growth parameters of wheat are presented in Table 1. The main effect of tillage practices and intercropping had a significant ($P<0.05$) effect on plant height and the number of tillers per plant of wheat, but spike length was significantly (P<0.05) affected by only tillage practices. The interaction effect of tillage practices and intercropping was non-significant (P>0.05) for all growth parameters of wheat.

The tallest (76.63 cm) plant height, highest (4.05) number of tillers per plant and largest (5.96 cm) spick length of wheat were obtained from minimum tillage as compared to conventional tillage. The activities of minimum soil disturbances improved organic matter and enhanced soil matter that improved soil fertility (Johnson et al. 2006), which results in better crop performance. This result is in agreement with Gezahegn et al. (2019) who reported the highest growth parameters of tef in minimum tillage than conventional tillage. In contrary, Dong et al. (2009) found that the number of wheat tillers produced with minimum tillage was significantly lower than that of conventional tillage.

The highest plant height (78.25 cm) and highest number of tillers per plant (4.40) of wheat were obtained when wheat was planted in 2:1 wheat-lentil combination, which was not significantly different (p>0.05) from 1:2 wheat-lentil combinations. In contrast, the lowest plant height (73.46) and lowers number of tillers per plant (3.6) were obtained in sole wheat and 1:1 wheat-lentil intercropping, respectively. The improvement in growth of wheat in lentil intercropping may be due to a better environment, nutrient availability, interception, absorption and utilization of solar radiation. Besides, competition for light under intercropping increased the plant height of the commponent crop compared to sole cropping as plants are known to become etiolated under increasing shade (Scott, 2012). Similarly, Das et al. (2012) reported the highest growth at intercropped wheat with lentil than sole wheat. Singh et al. (2019) also reported that the plant height of wheat was significantly better in 2:1 row ratio of wheat + lentil intercropped than other crop combinations.

Table 1. Effect of tillage practices and wheat-lentil intercropping combination on plant height, number of tillers per plant and spike length of wheat

Tillage practices (T)	Plant height (cm)	number of tillers number of tillers	spike length (cm)
Conventional tillage (4 times)	74.70b	3.65b	5.80b
Minimum Tillage (one time)	76.63a	4.05a	5.96a
LSD(5%)	1.75	0.34	0.14
CV (%)	2.17	6.54	2.50
Intercropping combination (I)			
Wheat+Lentil (1:1)	74.60bc	3.60c	5.82
Wheat+Lentil (2:1)	78.25a	4.40a	5.89
Wheat+Lentil (1:2)	76.35ab	4.27ab	5.98
Sole wheat (1:0)	73.46c	3.93bc	5.83
LSD (5%)	2.47	0.34	Ns
T x I	ns	ns	ns
CV(%)	3.95	8.22	4.16

Means with the same letter in columns are not significantly different at 5% level of significance

The effect of tillage practices and wheat-lentil intercropping combination on yield and yield components of wheat are presented in Table 2. The main effect of tillage practices had non-significant (P>0.05) effect on thousands of seed weight, dry biomass yield, grain yield and harvest index, but had a significant (P<0.05) effect on grain per spike. Similarly, Ruiz et al. (2019) reported a non-significant effect of the conservation tillage system on yield and yield component of durum and bread wheat under mono cropping. Pittelkow et al. (2015) also reported that conservation tillage practices did not increase the grain yield of cereals in moist regions due to the impact of conservation tillage on yield varies among climatic zones. However, higher (49.2) grain per spike of wheat was obtained in minimum tillage as compared to conventional tillage. The high grain per spike was attributed to the better growth performance of wheat in minimum tillage.

All yield and yield components of wheat were significantly (P<0.05) affected by the main effect of intercropping except grain per spike, but non-significant difference observed due to the interaction of tillage practices and intercropping. Thousands grain weight (50.83 gm) of wheat was higher in 2:1 wheat-lentil intercropping combination than other intercropping combinations and sole wheat. The highest thousand-grain weight in 2:l wheat-lentil combination might be due to greater competition exerted by the dominant wheat crop for light, space and nutrients than lentil.

Table 2. Effect of tillage practices and wheat-lentil intercropping combination on yield and yield components of wheat

Tillage practices	Thousand seed weight (g)	Grain per spike	Dry biomass (kgha^{-1})	Grain yield (kgha^{-1})	Harvest index (%)
Conventional tillage (4 times)	46.25	40.08b	8223.6	2608.3	0.317
Minimum Tillage (one time)	49.58	49.02a	8508.3	2644.4	0.311
LSD (5%)	ns	2.96	Ns	ns	ns
CV (%)	5.95	9.68	8.23	8.87	6.34
Intercropping combination					
Wheat+Lentil (1:1)	47.17b	44.93	7986.1b	2317.9b	0.290b
Wheat+Lentil (2:1)	50.83a	44.50	8861.1a	2931.9a	0.331a
Wheat+Lentil (1:2)	46.50b	47.23	7447.2b	2273.6b	0.305b
Sole wheat	47.17b	41.53	9169.4a	2981.9a	0.325a
LSD (5%)	3.25	ns	698.51	221.49	0.3
T x I	ns	ns	Ns	ns	ns
CV(%)	7.59	11.29	10.10	10.20	8.5

Means with the same letter in columns are not significantly different at 5% level of significance, ns= non-significant

The highest (2932 and 2982 kg ha^{-1}) and (8861 and 9169 kg ha^{-1}) grain and biological yield of wheat were obtained in 2:1 wheat-lentil intercropping and sole wheat, respectively. This means the presence of lentil in 2:1 wheat-lentil combination didn't affect wheat grain and biomass yield. In contrast, intercropping ratio of 1:1 and 1:2 gave lower yield than sole wheat. Similarly, Banik (1996) reported intercropping wheat-lentil (1:1) reduced the yield of wheat crops compared with respective pure stands. Among the intercropping combinations, grain and biological yield of wheat showed significantly increased with each wider row ratio of wheat and lentil. This is because the yields are directly related to plant population of wheat under different row ratios. This might be due to greater competition exerted by the dominant wheat crop for resources over lentil. The greater canopy of wheat also helped to intercept a greater part of light. This result is in agreement with Kaushik et al. (2016) who reported the highest grain yield of wheat in the highest wheat ratio. Chapagain and Riseman (2014) also reported that wheat yield was higher in 2:1 wheat/bean arrangement than 1:1 arrangement.

Effect of tillage and intercropping on lentil

Effect of tillage practices and wheat-lentil intercropping combination on plant height, numbers of branches per plant, numbers of pods per plant and numbers of seed per plant of lentil are presented in Table 3. The main effect of tillage had a significant ($P<0.05$) effect on lentil plant height only, but not on numbers of branches per plant, numbers of pods per plant and numbers of seed per plant of lentil. However, the main effect of intercoping had a significant ($P<0.05$) effect on numbers of branches per plant, numbers of pods per plant and numbers of seed per plant, but not on numbers of seed per pod. Interaction effect of tillage and intercropping combination was not significant ($P>0.05$) on the above parameters.

Conventional tillage gave higher (48.61 cm) plant height of lentil than minimum tillage. Tilled soil allows seedlings to emerge from deeper in the soil compared from one plow (Frank et al., 2007), this might result in better growth of the crops. In addition, the soil of the study area is Vertisol, which has hold excess water during the main rainy season (June-August) and lentil is highly susceptible to waterlogging. This might also affect the growth of the crop. Regassa et al. (2006) stated that lentil is planted on well-prepared, weed-free and friable soil fields.

Table 3. Effect of tillage practices and wheat-lentil intercropping combination on plant height, numbers of branches per plant, numbers of pods per plant and numbers of seed per plant of lentil

Tillage practices	Plant height (cm)	numbers of branches per plant	Number of pods per plant	Number of seed per pod
Conventional tillage (4 times)	48.61a	3.05a	54.28	1.85
Minimum Tillage (one time)	43.77b	2.78b	50.81	1.80
LSD (5%)	4.22	ns	ns	ns
CV (%)	10.76	5.01	18.90	6.96
Intercropping combination				
Wheat+Lentil (1:1)	46.29ab	2.83ab	50.0b	1.77
Wheat+Lentil (2:1)	48.29a	2.75b	48.2b	1.87
Wheat+Lentil (1:2)	46.49ab	2.88ab	53.9ab	1.85
Sol lentil	43.69b	3.10a	58.0a	1.83
LSD (0.05)	4.22	0.3	5.8	ns
T x I	ns	ns	ns	ns
CV (%)	12.36	6.57	21.14	8.63

Means with the same letter in columns are not significantly different at 5% level of significance, Ns= non-significant

The tallest (48.29 cm) plant height of lentil was recorded in 2:1 wheat-lentil, which was not significantly ($P>0.05$) different from other intercropping combinations. In contrary, the shortest (43.69cm) lentil was observed in sole lentil. Competition for light under intercropping increased the plant height of lentil compared to sole lentil. According to Scott (2012), plants in intercropping are known to become etiolated under increasing shade. Likewise, Yağmur and Kaydan (2006) reported that the plant height of lentil was higher in mixing and row intercropping treatments due to the competing of two different crops. Almaz et al. (2017) also reported shorter soybean plants in monocrop as compared to intercropped.

The maximum (3.10) and (58) numbers of branches per plant and pods per plant of lentil were observed in sole lentil, which was not significantly different ($p>0.05$) from 1:2 wheat-lentil combinations. In contrast, the minimum (2.75) and (48.2) numbers of branches per plant and pods per plant of lentil were observed in intercropping of lentil in 2:1 wheat-lentil combination. The increased competition between plants for growth factors in intercropping system contributed to the decrease in the number of effective branches per plant. Similarly, the reduction of a number of pods per plant was attributed to the inhibition of initiation of pods due to strong interspecific competition between wheat and lentil for the growth factor. Similarly, Yağmur and Kaydan (2006) reported a lower number of pod numbers in mixing and row cropping systems with barley.

Effect of tillage practices and wheat-lentil intercropping combination on yield and yield component of lentil are presented in Table 4. Biomass and seed yield of lentil were significantly (P<0.05) affected by the main effect of tillage practices and intercropping combination, but thousands seed weight and harvest index of lentil were not significantly (P>0.05) affected by tillage practices and intercropping combination. The interaction effect of tillage practices and intercropping combination was no significant (P>0.05) difference in all yield and yield components.

Table 4. Effect of tillage practices and wheat-lentil intercropping combination on yield and yield components of lentil

Tillage practices	Thousand seed weight (g)	Dry biomass Yield (kgha^{-1})	Seed yield (kgha^{-1})	Harvest index (%)
Conventional tillage (4 times)	31.25	2368.1a	1545.6a	57
Minimum Tillage (one time)	29.04	2161.0 b	1285.1b	64
LSD (5%)	ns	327	188.8	ns
CV (%)	9.35	14.98	14.56	6.40
Intercropping combination (I)				
Wheat+Lentil (1:1)	31.00	2080.2bc	1309.0b	0.66
Wheat+Lentil (2:1)	29.67	1831.1c	1201.4b	0.66
Wheat+Lentil (1:2)	29.92	2383.5ab	1376.0ab	0.55
Sol lentil	30.00	2763.3a	1574.8 a	0.57
LSD (5%)	NS	463	208.86	NS
T x I	NS	Ns	Ns	NS
CV(%)	11.08	17.23	16.83	8.8

Means with the same letter in columns are not significantly different at 5% level of significance; NS= non-significant

Both dry biomass (2368kg ha^{-1}) and seed yield (1546kg ha^{-1}) of lentil were higher under conventional tillage as compared to minimum tillage (Table 4). This might be due to a well tilled field/conventional tillage resulted in rapid seed germination, good emergence, improved seedling growth thereby improved biomass and seed yield. Also, Kiliç et al. (2015) revealed that conservation tillage (minimum tillage) has tended to be less productive than conventional plowing probably due to lack of weed control in the conservation tillage systems.

The highest (2763 and 1575 kg ha^{-1}) dry biomass and seed yield () of lentil were obtained from sole lentil, which was not significantly different (p>0.05) from 1:2 wheat-lentil intercropping (Table 4). In contrast, the lowest (1831 and 1201 kg ha^{-1}) dry biomass and seed yield of lentil were observed in 2:1 wheat-lentil intercropping combination. This was probably due to a higher degree of interspecific competition between the intercrops. In wheat-lentil intercropping, the wheat crop has developed properly with an adequate canopy and can strongly hinder the effective growth of lentil due to shade effect and radiation interception. The intensity and quality of the intercepted light by the canopy are the most significant determinants of yield and yield components (Thole, 2007). In addition, the reduction of lentil 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 lentil was highly correlated with yield components, hence any reduction in yield components can also reduce yield. This result is in agreement with Çiftçi and Ulker (2005) who reported the highest grain yield of lentil from sole lentil crops as compared to wheat-lentil and barley/lentil intercropping. Similarly, Ahlawat et al. (1995) found a reduction in grain yield of lentil in wheat lentil intercropping under irrigated environment.

Competition indices

The value of partial and total land equivalent ratio (LER), area time equivalent ratio (ATER) and monetary advantage index (MAI) of the wheat-lentil intercropping system as influenced by intercropping combination are presented in Table 5. The partial LER of wheat and lentil were less than 1 under all intercropping combinations. The partial LER of wheat was higher than lentil under 1:1 and 2:1 wheat-lentil intercropping. However, the partial LER of lentil was higher in 1:2 wheat-lentil intercropping combination. A high percentage of wheat-lentil in intercropping gave higher partial LER. Similar results were reported by Yağmur and Kaydan (2006) and Ciftci and Ulker (2005).

The total LER in all intercropping combinations was greater than 1. Among intercropping combinations, 1:2 wheat-lentil intercropping gave the greater (1.75) LER (Table 5). The greater LER (>1) indicating the yield advantage of wheat-lentil intercropping system over sole cropping. The better utilization of growth resources by component crops in intercropping systems contributed to the higher LER. The more efficient utilization of resources was attributed to the morphological and physiological differences among intercrop components. The same result was reported by Çiftçi and Ulker (2005).

The highest (1.08) ATER was recorded in a 2:1 wheat-lentil intercropping combination. Only 2:1 wheat-lentil intercropping combination gave ATER greater than 1 (Table 5). This could be due to the reason that 2:1 wheat-lentil intercropping combinations planted in the same inter and intra row spacing gave compatible more efficient total resource exploitation and greater overall production than sole crops and the remaining intercropping combination. In contrast, 1:1 and 1:2 wheat-lentil intercropping combination showed values less than 1.00 indicating the disadvantage of intercropping over sole cropping. In all wheat-lentil intercropping combinations, the ATER values were lesser than LER values indicating the overestimation of resource utilization probably due to the wide variations in the maturity periods of the crops of which wheat stayed longer on the land and had enough time to compensate for the lentil competition.

In all wheat-lentil intercropping combinations MAI values were positive, indicating the economic advantage of wheat-lentil intercropping over sole cropping (Table 5). The highest (45591 EB ha^{-1}) MAI was recorded in 2:1 wheat-lentil intercropping combination and the lowest (37347 EB ha^{-1}) was recorded in 1:1 wheat-lentil intercropping combination. MAI was mainly influenced by the market price of produce and economic yield harvested. Banik et al. (2006) reported that higher seed yield and net income under planting pattern with differed row ratios of wheat-chickpea may be explained in higher total productivity under intercropping with relatively less input investment.

Table 5: The effect of intercropping combination on competition indices

Treatment	Partial Land Equivalent Ratio		Land Equivalent Ratio	Area time equivalent ratio	Monetary advantage Index EBha^{-1}
	Wheat	Lentil			
Wheat+Lentil (1:1)	0.78	0.77	1.55	0.86	37347
Wheat+Lentil (2:1)	0.98	0.76	1.75	1.08	45591
Wheat+Lentil (1:2)	0.76	0.87	1.64	0.84	39083

Conclusion

The tillage practices and intercropping combinations had a significant effect on growth parameters of wheat and lentil. Minimum tillage increased growth parameters for wheat, but reduced growth parameters for lentil. The yield of the yield of lentil was significantly affected by tillage. A higher yield of lentil was observed in conventional tillage than minimum tillage. Intercropping combination had a significant effect on both growth and yield parameters of both crops. The highest yield of wheat was observed in 2:1 wheat-lentil combination, while the highest lentil yield was observed in sole lentil. Based on competitive indices, wheat-lentil intercropping was found to be more profitable and productive compared to sole cropping. A 2:1 wheat-lentil gave the highest LER, ATER, and MAI value. Therefore, 2:1 wheat-lentil intercropping combinations were found suitable for higher productivity and production of crops and the intercropping system of wheat-lentil in any of the combinations found to be more profitable and productive compared to sole wheat and lentil. Further should be required to see the effect of CA on soil productivities in the study area.

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