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Full Length Article

The Effect of Different Planting Techniques on Productivity and Profitability of Barley-lentil Intercrops under Semi-arid Subtropical Climate

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Abstract

Sole cropping systems are depleting the soil resources with simultaneous decrease in productivity of field crops, especially cereals. In this scenario, intercropping cereals and legumes might be a pragmatic option to improve the system productivity and profitability. This two-year field study was conducted to test the productivity of barley-lentil intercropping system with different planting techniques. The experiment consisted of ten different treatments, i.e., i) lentil alone sown in 30 cm spaced single rows, ii) 3-rows of lentil on beds with 45 cm irrigation furrows, iii) 4-rows of lentil on beds with 60 cm irrigation furrows, iv) 6-rows of lentil on beds with 90 cm irrigation furrows, v) 8-rows of lentil on beds with 120 cm irrigation furrows, vi) 3-rows of lentil on beds with barley in 45 cm irrigation furrows, vii) 4-rows of lentil on beds with barley in 60 cm irrigation furrows, viii) 6-rows of lentil on beds with barley in 90 cm irrigation furrows, ix) 8-rows of lentil on beds with barley in 120 cm irrigation furrows and x) barley alone. The results indicated that all intercropping systems reduced the barley and lentil yield to a significant extent compared with monoculture of both crops. However, in barley production, the extra harvest obtained from lentil intercropping resulted in higher productivity than barley monoculture. Barley-lentil intercropping had 69-86% yield advantage on mono-cropped barley with the highest income of US$ 1432.24 ha^{-1}. In terms of aggressivity, relative crowding coefficient and competitive ratio, barley was dominant crop in all treatments. There was a progressive decrease in the amount of water used with increase in the size of strip from 3 to 8 rows with 45 to 120 cm irrigation furrows. The maximum water use efficiency (3.55-4.84 kg/cf^3) was recorded for 8-row strip system with 120 cm irrigation furrows as compared to all other planting geometries. In crux, 8-rows of lentil on beds with barley in 120 cm irrigation furrows proved the best intercropping system which provided the highest net income and benefit cost ratio, which could be used to maximize the productivity of barley-lentil intercropping system.

Keyword: Planting techniques; Productivity and profitability; Barley-lentil; Subtropical climate

Introduction

Limited input resources and their inefficient utilization is one of the most important constraints in low crop productivity (Aslam, 2016). Growing crops with low input requirements, water saving techniques and intercropping are the potential alternatives to maximize the crop productivity and profit margins (Brooker *et al*., 2014). Intercropping is raising two or more crops in the same field area (although not necessarily sowing or harvesting the crops at the same time) have been practiced worldwide (Li *et al*., 2013). Without increased inputs, or greater stability of yield with decreased inputs, intercropping could be one route to deliver sustainability by allowing genuine yield gains (Vandermeer, 2010; Zhang *et al*., 2010; Li *et al*., 2013). Moreover, intercropping may be a means to address some of the major problems which are associated with modern farming, including yield stagnations, pest and pathogen accumulation, soil degradation, and environmental deterioration, thereby helping to deliver sustainable and productive agriculture (Lithourgidis *et al*., 2011).

Intercropping of cereals and legumes was much common until 1960; however, farmers then started to replace legumes with inorganic nitrogen sources. Now-a-days, attention is shifting back towards intercropping cereals and legumes. The scientists have been exploring how different cereal-legume intercropping systems could help farmers to achieve more or comparable yields to conventional farming. Cereal-legume intercropping systems provide higher productivity per unit area, enhance soil fertility by fixing atmospheric nitrogen, reduce the infestation of insects, pests, diseases and weeds by increasing diverse crop foliage architectures and microclimate (Mpairwe *et al*., 2002; Kumar *et al*., 2005; Mucheru-Muna *et al*., 2010; Massawe *et al*.,

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2016). On the other hand, conventional mono-cropping system does not allow intercropping due to narrow single row arrangements. Therefore, planting geometry with different row arrangements can be an important factor for adjustment of narrow row crops, boosting yields by harvesting more solar radiation and efficient utilization of underground resources (Barros *et al*., 2004).

Similarly, different water requirement of crops can be a main hurdle in intercropping. Optimum planting geometry is an important factor in different intercropping systems for efficient utilization of available resources and harvesting more solar radiation than mono-cropping. Planting geometry depends on relative growth type and mechanism of yield enhancement, crop season and relative proportion of the component crops (Musa *et al*., 2010).

Raised bed technology saves 10-36% of water as compared to traditional flood irrigation system, thus it could be a viable approach to improve the water use efficiency of intercropping system (Akbar *et al.*, 2007). Crop requiring less water can be sown on upper beds and crop requiring more water can be sown in irrigation furrows. The raised bed planting system is gradually becoming popular among farmers as it allows light and frequent watering. Several studies have reported that bed planting improved crop yield, water and nutrient use efficiencies in different crops, including crops sown in drought prone areas (Lauren *et al.*, 2006; Hossain *et al.*, 2014, 2015).

Pulses (legume crops) can adjust in different cropping systems due to their short growth period and have ability to increase productivity because of their nitrogen fixation ability (Jeyabal and Kuppuswamy, 2001). Therefore, productivity of a cropping system can be increased by introducing legume into cereal cropping system (Maingi *et al*., 2001; Massawe *et al.*, 2016). In Pakistan, pulses are the most important source of vegetable protein and are known as poor man's meat. They are cultivated on 5% of the total cropped area. Because of their increasing demand in human and animal diet, existing food systems demand more area devoted to grain pulses. Due to competition with wheat, area under these crops cannot be increased. The only option is to grow them in association with cereals. Continuous growing of cereal crops in a conventional way affects soil functionality, fertility and enhance the incidence of insects, pests and diseases. The intercropping of legumes and cereals might be a viable option to improve the system productivity. Therefore, this two-year field study was designed to explore the productivity and bio-economics of barley-lentil intercropping systems under varying planting geometries of barley-lentil intercrops.

Materials and Methods

Experimental Site

This study was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (latitude 31.20°N, longitude 73.06°E, 184.5 m above sea level) for two consecutive years (2014-2015 and 2015-2016). The climate of the region is semi-arid with very hot and humid summers and dry cool winters. The average maximum and minimum temperatures in June are 40.5°C and 26.9°C, respectively. In January, the average minimum and maximum are 19.4°C and 4.1°C. The summer season starts in mid-April and continues till late October. May and June are the hottest months, while July, August and the first half of September can be oppressively humid, except for the rainy days. The coldest month is January, which is also a dry month with significant foggy days. The fog is particularly dense at night and in early morning hours in winter. The winter season starts in November and continues till early February. The average annual rainfall is only about 375 millimeters. Approximately half of the yearly rainfall is received in July and August during the monsoon season. The experimental years contrasted in terms of precipitation. In 2014-2015, the annual total precipitation was 147 mm and mostly received in the month of March, whereas the year 2015-2016 received low total annual precipitation of 116.5 mm (Table 1). The soil at the site was sandy clay loam soil of Lyallpur soil series. The plough layer (0.20 cm) consisted of total N (0.042%), total available phosphorous (6.94 ppm) and available potassium (139 ppm) with an initial soil pH of 7.89 (Table 2).

Experiment Materials and Design

Barley variety (Haier-93) and lentil variety (Masoor-89) was used during the experimental years. The whole field was fully ploughed (three times up to 20 cm) to ensure uniform soil conditions. The experiment was conducted in Randomized Complete Block Design (RCBD) with ten different barley-lentil combinations and planting geometries, *i.e*., i) lentil monoculture in even (30 cm) spaced single rows, ii) 3-rows strip of lentil monoculture with 45 cm irrigation furrows, iii) 4-rows strip of lentil monoculture with 60 cm irrigation furrows, iv) 6-rows strip of lentil monoculture with 90 cm irrigation furrows, v) 8-rows strip of lentil monoculture with 120 cm irrigation furrows, vi) 3-rows strip of lentil on beds with barley intercropped in 45 cm irrigation furrows, vii) 4-rows strip of lentil on beds with barley intercropped in 60 cm irrigation furrows, viii) 6-rows strip of lentil on beds with barley intercropped in 90 cm irrigation furrows, ix) 8-rows strip of lentil on beds with barley intercropped in 120 cm irrigation furrows, and x) barley monoculture in even 30 cm spaced single rows. Each plot had and area of 25.2 m^2 (3.6 m × 7.0 m), with 50 cm spacing between each plot. To establish the intercropping system, both crops were sown at the same time on October 10 and October 17 in 1^{st} and 2^{nd} year, respectively. Seed rate was kept 75 kg ha^{-1} and 35 kg ha^{-1} for barley and lentil, respectively for both crop seasons. Nitrogen and phosphorus were applied at the rate of 50 kg ha^{-1}. Half dose of nitrogen and whole phosphorus were applied as basal dose, while remaining half dose of nitrogen was applied with first irrigation to barley only. A measured quantity of irrigation water was applied every time only in furrows using

12-inches cut throat flume device, while flood irrigation was applied to flat sown treatments. During the whole period of experiment, the canal water was used for irrigation. In the beginning, water was applied to non-experimental plots to get a constant flow rate of irrigation water. When the level of water became constant in Ha and Hb wells of flume, experimental plots were irrigated. During irrigation, level of Ha and Hb wells was noted three times. Time required for watering every plot was noted by the stop watch. Four irrigations were applied during the crop season excluding "Rauni". Weeds were regularly controlled using a hand hoe, and pests and diseases were separately controlled timely with the idea of minimizing the pesticide application effects on the non-target crop. The both crops were harvested on April 10 and April 15 during 1st and 2nd year, respectively.

Data Collection

The crop was harvested manually, tied into bundles and placed in respective plots for sun drying. The sun-dried bundles were weighed for recording biological yield in each plot and then converted into t ha^{-1}. Sun dried bundles were threshed manually and grains of barley were separated from straw, cleaned and weighed by using an electric balance. The grain yield obtained from each sub plot was converted into t ha^{-1}. Harvest index calculated as the ratio of grain yield to the biological yield was expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\textit{Grain yield}}{\textit{Biological yield}} \times 100$$

Land equivalent ratio was calculated by the following formula of Willey (1979):

$$\text{LER} = \text{Lb} + \text{Ll} = \frac{\text{Ybl}}{\text{Ybb}} + \frac{\text{Ylb}}{\text{Yll}}$$

Where Lb and Ll are the respective yields of barley and lentil in the total intercropped area and Ybb and Yll are the monoculture yields of lentil and barley. An LER greater than 1.0 reveals an intercropping advantage and favors intercropping on crops growth and yield, while LER less than 1.0 indicates an intercropping disadvantage and the negative affections of intercropping on crops growth and yield. Area time equivalent ratio was calculated by the following formula of Hiebsch (1980):

$$\text{ATER} = (\text{Ryb} \times \text{tb})(\text{Ryl} \times \text{tl})/\text{T}$$

Where Ryb and Ryl are the relative yield of barley and lentil, while tb and tl are the duration (days) for barley and lentil and T indicates duration of whole intercropping system. By converting the yields of intercrops into grain yield of barley, barley grain yield equivalent was computed which was based on the existing market price of each intercrop (Anjeneyulu *et al.*, 1982). Aggressivity was calculated by the following formula of McGilchrist (1965):

$$\text{Abl} = \frac{\text{Ybl}}{\text{Ybb} \times \text{Zbl}} - \frac{\text{Ylb}}{\text{Yll} \times \text{Zlb}}$$

Where Abl is the aggressivity of barley relative to lentil in the intercropping system, Zbl and Zlb are the intercropping area proportions occupied by barley and lentil, respectively. If Abl is greater than 0, the competitive ability of barley exceeds that of lentil in intercropping, otherwise, lentil has greater competitiveness. The measure of relative dominance of one species over the other in an intercropping system is relative crowding coefficient (K). Relative crowding coefficient was calculated by the following formula of De Wit (1960):

$$\text{Kbl} = \frac{\text{Ybl}}{\text{Ybb} - \text{Ybl}} \times \text{Zlb}/\text{Zbl}$$

Where Kbl is a relative crowding coefficient for barley. All other abbreviations such as Ybb, Ybl, Zbl, Zlb have been described above in this section. Competitive ratio (CR) gives better measure of competitive ability of the crop and it also advantageous as an index over K and A (Willey *et al.,* 1980). Competitive ratio was calculated by the following formula proposed by Willey *et al.* (1980):

$$\text{CRb} = \text{Ybl}/\text{Ybb} \times \text{Zbl} \div \text{Ylb} \;/\; \text{Yll} \times \text{Zlb}$$

Where CRb is a competitive ratio value for barley crop. All the other abbreviations have been described above in this section.

Irrigation Water Use Efficiency

Irrigation water use efficiency (IWUE) is the ratio of total biomass produced to the volume of water used.

$$\text{IWUE} = \frac{\text{TDM}}{\text{Volume of water used}}$$

Where TDM is total dry matter yield (straw + grain).

Economic Analysis

The collected data for both year were economically examined by using standard methods devised by CIMMYT (1988). These methods involve partial budgeting, marginal analysis and sensitivity analysis. For each intercropping system, partial budget was assembled to assess the expenses incurred and net returns. In the analysis, prices of inputs prevailing in the present market during 2014-2015 and 2015-2016 were used to calculate the partial budget of different intercropping systems.

Statistical Analysis

The collected data was statistically analyzed in different steps. The normality in the dataset was tested first, and data showing non-normal distribution were normalized by appropriate transformation techniques. The differences between the years were tested by paired t test, which indicated significant difference among years. Therefore, the data of both years were analyzed and interpreted separately.

Table 1: Meteorological data during the experimental period

		Temperature (°C)						
		Maximum	Minimum	Mean	RH (%)	Rainfall (mm)	PE (mm/24 h)	SD (h)
2014	Oct	31.3	19.1	25.2	54.6	3.6	3.5	-
	Nov	26.3	11.5	18.9	61.7	10.0	1.8	7.6
	Dec	18.5	5.9	12.2	75.0	0.00	01..5	4.7
2015	Jan	16.6	6.9	11.7	75.3	12.2	1.1	5
	Feb	22.0	11.1	16.5	66.0	20.5	2.1	5.6
	Mar	24.5	13.6	19.1	64.0	67.9	13.05	4.9
	Apr	33.2	20.7	27.0	43.9	32.8	5.3	9.1
2015	Oct	32.2	19.1	25.4	52.9	14.5	4.0	-
	Nov	27.1	12.1	19.6	61.5	8.8	2.4	6.6
	Dec	21.8	7.2	14.5	62.6	0.00	1.9	7
2016	Jan	17.3	7.7	12.5	74.4	13.1	3.5	1.2
	Feb	23.3	9.3	16.3	58.1	7.8	2.3	8.5
	Mar	26.8	15.6	21.2	59.7	66.7	2.7	6.6
	Apr	34.3	19.2	27.2	47.4	5.6	6.1	8.3

RH = Relative humidity, PE= Pan Evaporation, SD = Sunshine duration, - =, no sunshine hours recorded due to clouds/fog

Table 2: Soil properties before the sowing of experiment during both experimental years

Soil properties	2014-15	2015-16
Sand (%)	62.11	60.91
Silt (%)	18.71	17.46
Clay (%)	19.21	21.64
pH	7.89	7.81
EC (dS m^{-1})	1.15	1.12
Soil organic matter (%)	0.76	0.76
Available N (%)	0.042	0.041
Available phosphorus (ppm)	6.94	6.84
Available potassium (ppm)	139	137

*Textural class was sandy clay loam during both years of study

Fishers Analysis of Variance (ANOVA) technique was used test the significance among treatments (Steel *et al.*, 1997). Least significant difference test at 5% probability was used as post-hoc where ANOVA indicated significant differences.

Results

Biological/grain Yield and Harvest Index of Barely

Sole barley produced significantly higher total biological yield, grain yield and harvest index as compared to barley sown in association with lentil during both crop years. Among intercropping treatments, 8-rows of lentil on beds with barley in 120 cm irrigation furrows recorded the highest biological yield, grain yield, while the highest harvest index was recorded from 4-rows of lentil on beds with barley in 60 cm irrigation furrows during 1st year. The highest harvest index during 2nd year was recorded from 6-rows of lentil on beds with barley in 90 cm irrigation furrows, which was statistically at par with 8-rows of lentil on beds with 120 cm irrigation furrows (Table 3).

Biological/grain Yield and Harvest Index of Lentil

The biological yield, grain yield and harvest index of lentil was significantly influenced by various intercropping systems in both years. Sole lentil produced significantly higher total biological yield, grain yield and harvest index as compared to lentil sown in association with barely during both crop years. Among the intercropping treatments, 8-rows of lentil on beds with barley in 120 cm irrigation furrows was best combination for biological yield, grain yield and harvest index for both crop seasons. The lowest biological yield, grain yield and harvest index were observed from 3-rows of lentil on beds with barley in 45 cm irrigation furrows during both years (Table 4).

Competitive Functions in Barley-lentil Intercropping Systems

Aggressivity (Aa): The highest aggressivity value (+0.97) was observed for 3-rows of lentil on beds with barley in 45 cm irrigation furrows for first year, which was followed by 6-rows of lentil on beds with barley in 90 cm irrigation furrows and 4-rows of lentil on beds with barley in 60 cm irrigation furrows, whereas the minimum (+0.21) aggressivity value was recorded for 8-rows of lentil on beds with barley in 120 cm irrigation furrows. During 2nd year 4-rows of lentil on beds with barley in 60 cm irrigation furrows recorded the highest aggressivity value (+1.14) followed by 3-rows of lentil on beds with barley in 45 cm irrigation furrows and 6-rows of lentil on beds with barley in 90 cm irrigation furrows, while the minimum was observed in 8-rows of lentil on beds with barley in 120 cm irrigation furrows.

Table 3: Influence of different planting techniques on biological and grain yields, and harvest index of barley

	Biological yield (t ha^{-1})		Grain yield (t ha^{-1})		Harvest index (%)	
Treatments	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
3-rows of lentil on beds with barley in 45 cm irrigation furrows	6.47 B	6.34 C	1.99 B	1.96 C	30.82 B	31.02 C
4-rows of lentil on beds with barley in 60 cm irrigation furrows	6.68 B	6.86 BC	2.10 B	2.17 BC	31.41 B	31.61 BC
6-rows of lentil on beds with barley in 90 cm irrigation furrows	6.65 B	6.58 BC	2.06 B	2.11 BC	31.05 B	32.03 BC
8-rows of lentil on beds with barley in 120 cm irrigation furrows	7.14 B	7.38 B	2.24 B	2.43 A	31.40 B	31.61 B
Barley alone at 30 cm spaced single rows (conventional system)	8.29 A	8.43 A	2.73 A	2.96 A	32.92 A	35.11 A
LSD ($p \leq 0.05$)	*0.96*	*0.93*	*0.36*	*0.35*	*1.42*	*1.36*

The treatments lacking barley were omitted

Table 4: Influence of different planting techniques on biological and grain yields, and harvest index of lentil

	Biological yield (t ha^{-1})		Grain yield (t ha^{-1})		Harvest index (%)	
Treatments	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Lentil alone at 30 cm spaced single rows (conventional system)	3.61 A	5.21 A	1.48 A	1.89 A	33.40 A	36.23 A
3-rows of lentil on beds with 45 cm irrigation furrows	3.55 A	4.68 B	1.32 BC	1.71 B	31.05 B	34.85 B
4-rows of lentil on beds with 60 cm irrigation furrows	3.57 A	4.26 B	1.33 B	1.49 C	30.26 BC	33.60 BCD
6-rows of lentil on beds with 90 cm irrigation furrows	3.46 A	4.28 B	1.29 BC	1.57 C	30.94 BC	33.85 BCD
8-rows of lentil on beds with 120 cm irrigation furrows	3.34 AB	4.58 B	1.28 BC	1.60 BC	31.23 B	39.95 BCD
3-rows of lentil on beds with barley in 45 cm irrigation furrows	2.58 C	2.76 E	0.70 F	1.02 E	29.35 C	31.30 E
4-rows of lentil on beds with barley in 60 cm irrigation furrows	2.95 BC	3.10 DE	0.82 F	1.25 D	30.94 BC	32.95 CD
6-rows of lentil on beds with barley in 90 cm irrigation furrows	3.32 AB	3.58 C	1.07 D	1.26 D	30.46 BC	32.74 D
8-rows of lentil on beds with barley in 120 cm irrigation furrows	3.36 AB	3.41 CD	1.24 C	1.52 E	30.58 BC	34.05 BC
LSD ($p \leq 0.05$)	*0.96*	*0.93*	*0.36*	*0.35*	*1.63*	*1.3*

The treatments lacking lentil were omitted

Relative Crowding Coefficient (RCC)

Barley had higher relative crowding coefficient than lentil which showed that barley utilized resources more competitively than lentil. Among component crops, barley proved highly dominant as it yielded higher values of relative crowding coefficient. The highest yield advantage was achieved by 8-rows of lentil on beds with barley in 120 cm irrigation furrows with the highest value of relative crowding coefficient during 2014-2015 (2.82) and 2015-2016 (3.93) (Table 5).

Competitive Ratio (CR)

Barley proved more competitive than lentil in terms of competitive ratio. In all geometric patterns, higher competitive ratio value was noted for barley than lentil. The highest value of competitive ratio during both years (22.97, 36.69) was noted in 8-rows of lentil on beds with barley in 120 cm irrigation furrows, while the lowest value was recorded for 3-rows of lentil on beds with barley in 45 cm irrigation furrows (Table 5).

Agronomic Advantages in Barley-lentil Intercropping Systems

Land equivalent ratio (LER): The total land equivalent ratio (combined LER of barley and intercrops) ranged between 1.25 and 1.69 during 1st year and 1.31 to 1.86 during 2nd year in different intercropping systems. This suggested a 0.25 to 69 and 31 to 86% yield advantage from different intercrops in respective years. The highest land equivalent ratio of 1.69-1.86 during both years was noted for 8-rows of lentil on beds with barley in 120 cm irrigation furrows, while the lowest was recorded for 3-rows of lentil on beds with barley in 45 cm irrigation furrows during both years. Land equivalent ratio was higher during 2nd year than 1st year (Table 6).

Area Time Equivalent Ratio

The lowest area time equivalent ratio (1.15-1.21) was noted for 3-rows of lentil on beds with barley in 45 cm irrigation furrows during both years, while the highest (1.53-1.71) was recorded for 8-rows of lentil on beds with barley in 120 cm irrigation furrows during both years of study. The intercropping advantages in area time equivalent ratio ranged between 15 to 53% during 1st year and 21to 71% during 2nd year (Table 6).

Barley Grain Yield Equivalent

The lowest grain yield equivalent (43.4-60.8) was noted in 3-rows of lentil on beds with barley in 45 cm irrigation furrows during both years, whereas the highest (108.3-123.5) was observed for 8-rows of lentil on beds with barley in 120 cm irrigation furrows during both years (Table 6).

Irrigation Water Use Efficiency

Different planting geometries markedly differed for irrigation water use efficiency during both years. The highest irrigation water use efficiency (3.55 kg cf^3) was recorded for 8-rows of lentil on beds with barley in 120 cm irrigation furrows,

Table 5: Competitive functions of barley as influenced by different planting techniques

	Aggressivity				Relative crowding coefficient						Competitive ratio			
Treatments	2014-15		2015-16		2014-15			2015-16			2014-15		2015-16	
	Barley	IC	Barley	IC	B	IC	Sys	B	IC	Sys	Barley	IC	Barley	IC
3-rows of lentil on beds with barley in 45 cm irrigation furrows	0.97	-0.97	1.07	-1.07	2.26	1.10	2.49	2.44	1.34	3.29	3.38	1.04	8.01	0.99
4-rows of lentil on beds with barley in 60 cm irrigation furrows	0.91	-0.91	1.14	-1.14	2.31	1.13	2.61	2.39	1.38	3.31	6.63	1.97	12.37	1.96
6-rows of lentil on beds with barley in 90 cm irrigation furrows	0.96	-0.96	0.72	-0.72	2.33	1.15	2.67	2.43	1.37	3.34	15.10	4.69	22.31	5.79
8-rows of lentil on beds with barley in 120 cm irrigation furrows	0.21	-0.21	0.42	-0.42	2.43	1.16	2.82	2.61	1.50	3.93	22.97	9.11	36.69	11.33

IC= Intercrop, B= Barley, Sys= System, The treatments where barley had no competition with lentil were omitted

Table 6: Agronomic advantages of barley as influenced by different planting techniques

	Land equivalent ratio		Area time equivalent ratio		Barley grain yield equivalent	
Treatments	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
3-rows of lentil on beds with barley in 45 cm irrigation furrows	1.25	1.31	1.15	1.21	43.4	60.8
4-rows of lentil on beds with barley in 60 cm irrigation furrows	1.37	1.43	1.27	1.33	58.1	77.5
6-rows of lentil on beds with barley in 90 cm irrigation furrows	1.42	1.65	1.32	1.55	84.7	85.1
8-rows of lentil on beds with barley in 120 cm irrigation furrows	1.69	1.86	1.53	1.71	108.3	123.5

The treatments where barley had no competition with lentil were omitted

Table 7: Water related attributes as influenced by different planting techniques

Treatments	Total water applied (cubic ft. per ha)	Irrigation water use efficiency	Percent saving water	Additional area (ha) that can be brought under cultivation by saved irrigation water	Additional yield of barley (t ha^{-1}) that can be obtained by saved irrigation water
Lentil alone at 30 cm spaced single rows (conventional system)	711383	1.18	-	-	-
3-rows of lentil on beds with 45 cm irrigation furrows	505417	1.54	28.8	0.29	1.79
4-rows of lentil on beds with 60 cm irrigation furrows	489807	1.57	31.3	0.31	1.95
6-rows of lentil on beds with 90 cm irrigation furrows	450476	1.65	36.2	0.36	2.25
8-rows of lentil on beds with 120 cm irrigation furrows	587800	1.32	17.4	0.17	1.08
3-rows of lentil on beds with barley in 45 cm irrigation furrows	561205	2.29	20.8	0.21	1.30
4-rows of lentil on beds with barley in 60 cm irrigation furrows	540752	2.59	24.0	0.24	1.49
6-rows of lentil on beds with barley in 90 cm irrigation furrows	506677	3.14	28.8	0.29	1.79
8-rows of lentil on beds with barley in 120 cm irrigation furrows	586939	3.55	17.2	0.17	1.07
Barley alone at 30 cm spaced single rows (conventional system)	757212	2.34	-6.1	-0.06	-0.38

which was followed by 6-rows of lentil on beds with barley in 90 cm irrigation furrows (3.14 kg cf^3) against 1.18 kg cf^3 (lentil), and 2.34 kg cf^3 (barely) for conventional system of flat irrigation (Table 7).

Water Saving under Different Planting Techniques

Raised bed planting geometry caused substantial saving of irrigation water over flat irrigation system. The quantity of water applied per hectare to the raised bed system and flat irrigation system varied to considerable extent and amounted from 711383 to 757212 ft^3 ha^{-1}, respectively during 2014-15. The highest amount of water, i.e., 711383 and 757212 ft^3 ha^{-1} was applied to the conventional sown lentil (lentil alone at 30 cm spaced single rows) and barely (barley alone at 30 cm spaced single rows), respectively (Table 7).

A progressive increase in the amount of water saved was observed with variable bed size and irrigation furrow size over conventional flat irrigation system during both years of study. In lentil mono-cropping system, the highest water saving (36.2%) was recorded for 6-rows of lentil on beds with 90 cm irrigation furrows. Among lentil-barely intercropping systems, the highest water saving (28.8%) was noted for 6-rows of lentil on beds with barley in 90 cm irrigation furrows (Table 7).

Potential Increase from Irrigation Savings

On the basis of additional area that can be brought under barley cultivation by the saved irrigation water and grain yield that can be contributed by this area, it was recorded that besides compensating the reduced yield in the respective treatments, saved water increased the potential total yield over the flat irrigation system to a remarkable extent (Table 7). The water saved through intercropping systems and water use techniques can irrigate additional 0.17 to 0.21 hectares of land under cultivation. Moreover, this saving in water may produce 1.07 to 2.25 t ha^{-1} of additional barely yields (Table 7).

Economic Analysis

The economic analysis showed that gross benefit of barley +

Table 8: Economic analysis as influenced by different planting techniques

Treatments	Gross benefit ($ ha^{-1})	Variable cost ($ ha^{-1})	Fixed cost ($ ha^{-1})	Total cost ($ ha^{-1})	Net income (($ ha^{-1}))	BCR
Lentil alone at 30 cm spaced single rows (conventional system)	1853.50	259.36	853.95	1113.31	750.18	1.66
3-rows of lentil on beds with 45 cm irrigation furrows	1666.50	238.11	853.95	1082.07	584.44	1.54
4-rows of lentil on beds with 60 cm irrigation furrows	1551.00	215.21	853.95	1069.16	481.85	1.45
6-rows of lentil on beds with 90 cm irrigation furrows	1573.00	221.11	853.95	1071.44	501.56	1.47
8-rows of lentil on beds with 120 cm irrigation furrows	1584.00	225.25	858.89	1077.63	506.37	1.47
3-rows of lentil on beds with barley in 45 cm irrigation furrows	1913.00	271.18	862.01	1133.19	779.81	1.69
4-rows of lentil on beds with barley in 60 cm irrigation furrows	2177.90	299.95	862.01	1159.27	1018.64	1.88
6-rows of lentil on beds with barley in 90 cm irrigation furrows	2296.70	317.70	862.01	1177.52	1119.19	1.95
8-rows of lentil on beds with barley in 120 cm irrigation furrows	2648.80	354.38	862.01	1216.39	1432.41	2.18
Barley alone at 30 cm spaced single rows (conventional system)	1358.40	159.74	856.45	1016.19	342.21	1.34

lentil sown in different intercropping systems ranged from $ 1358.40 to $ 2648.80 ha^{-1}. Among different intercropping systems, the highest gross benefit of $ 2648.80 ha^{-1} was noted for 8-rows of lentil on beds with barley in 120 cm irrigation furrows followed by 6-rows of lentil on beds with barley in 90 cm irrigation furrows with a gross benefit of $ 2296.70 ha^{-1}. The highest total cost ($ 1216.39 ha^{-1}) was also noted for 8-rows of lentil on beds with barley in 120 cm irrigation furrows. The highest net benefits were recorded for 8-rows of lentil on beds with barley in 120 cm irrigation furrows with highest benefit cost ratio (2.18) among all intercropping systems, while the lowest net benefits were noted in barley alone with the lowest (1.34) benefit cost ratio (Table 8).

Discussion

The final yield of a crop is a function of the combined effect of genetic, agronomic and environmental conditions. Barley and lentil crops grown in mono-cropping system produced significantly higher total biological yield and final grain yield as compared to barley-lentil intercropping during both crop years. Barley and lentil yields were reduced by different intercropping systems established with various planting geometries. The reduction in barley and lentil yields might be attributed to long term association of both component crops. Harvest index significantly differed for both crops among various treatments during both years. The difference in harvest index values was might be due to variable plant-plant competition due to variable planting geometries. Harvest index values were highest during 2nd year due to more ideal environmental conditions. This clearly indicated that physiological ability of barley to utilize the dry matter towards economic yield is significantly affected by various intercropping systems. In current study, sole crops used applied inputs more efficiently due to competition free environment in the absence of component crop. Several previous studies have reported that intercropping decreased the yield of field crops than sole crops (Mandal *et al.*, 1986; Subramanian and Rao, 1988; Lal *et al.*, 1998; Katiyar and Katiyar, 2002; Raghuwanshi *et al*., 2002).

In terms of competitiveness, different intercrops didn't compete equally for both crop years. Barley was dominant and more competitive crop than lentil throughout this study. Barley utilized resources more competitively than lentil as barley appeared dominant in all intercropping systems. Barley captured resources (light, water and nutrients) more efficiently than lentil as Lentil is a short statured crop and its low competitive ability could be attributed to the shading effect of barley. The difference in LER value might be due to more favorable growth conditions during 2nd year than 1st year. Similar findings were also reported by Mandal *et al*. (1986) in case of wheat + chickpea and wheat + sarson intercropping systems. Similarly, Rai (1988) also found that LER of all legumes intercrops showed yield advantage in case of buffel grass intercropped with annual grain legume crops.

Barley grain yield equivalent is an important principle to determine the advantages of intercropping over sole cropping. Barley grain yield equivalent values were higher for 2nd year than 1st year due to more feasible environmental conditions during 2nd year. The variation in grain yield equivalent among different treatments might be due to competition within treatments due to different planting geometries.

Raised bed planting technique caused substantial saving of irrigation water over flat irrigation system. This water saving might be attributed to the reason that in all intercropped treatments, a measured quantity of irrigation water was applied only to irrigation furrows keeping in view the water requirement of crop sown. The crop sown on upper beds gets water through seepage. There was progressive increase in the amount of water saved and yield with increasing bed and irrigation furrow size over conventional flat irrigation system. The water saving is directly related with the increasing bed size, which decreased the amount of irrigation water applied in the furrows. The irrigation water saving was 36%, 40% on wide beds, 34%, 31% on medium beds and 7% to 8% on narrows beds, for wheat and maize crops respectively, when compared with flat basins (Akbar *et al*., 2016).

The feasibility and profitability of an intercropping system is reflected through economic returns (Khan *et al*., 2012). Barley-lentil intercropping system was economically better than their sole stands in terms of net field benefits with low cost of production. Net field benefits in intercropping systems were higher than sole stands because barley intercropped with lentil with raised bed planting technique utilized resources more efficiently and losses caused by intercropped were compensated by component crop. The cost of production was less than sole crop expenditures as values of benefit cost ratio were higher in intercropped treatments than sole crop stands.

In another study, the highest net returns were obtained when sorghum was intercropped with groundnut, soybean and pigeonpea with 3:3 row ratios than sole crops (Angadi *et al*., 2004). In another study, intercropping of sorghum and soybean in different row arrangements gave highest net returns than the sole crops (Kadam *et al*., 2005). Significantly higher net field benefits of different intercropping systems in cotton, rice and wheat has also been reported by Saeed *et al*. (1990, 1999), Khan (2000).

Conclusion

The intercropping of 8-rows of lentil on beds with barley in 120 cm irrigation furrows performed better and appeared most promising system in terms of profitability and irrigation water use efficiency. This system could be used to improve the productivity and profitability of both crops through intercropping.

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