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Comparison of Barley-based Intercropping System for Productivity and Net Economic Return

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Abstract

Increasing population and decreasing on farm resources are threating the future food security. In this scenario, the cropping systems which can meet the increasing demand of food, feed and forage are needed. Intercropping is an eco-friendly option for sustaining and increasing the productivity of farmlands as it control weeds, improve soil health and increase the net returns per unit area. In this two-year study, we compared the relative performance and profitability of barley-based intercropping systems. Winter crops viz. chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* Medik), egyptian clover (*Trifolium alexandrinum* L.), linseed (*Linum usitatissimum* L.), fennel (*Foeniculum vulgare* Mill), garden cress (*Lepidium sativum* L.) and garlic (*Allium sativum* L.) were intercropped with barely (*Hordeum vulgare* L.). All the intercrops decreased the grain yield of barley over sole cropping. In this regard, minimum reduction in grain yield of barely was observed when it was intercropped with lentil (8.74%), while maximum reduction (17.85%) was recorded when barley was intercropped with fennel. However, barley appeared to be dominant crop as was indicated by its higher values of relative crowding coefficient, competitive ratio and positive sign of aggressivity. All intercrops gave more economic returns than sole cropping of barley; however, on the basis of land equivalent ratio, maximum yield advantage was recorded in barley + lentil intercropping system, while on the basis of net profits, maximum net economic return was recorded in barley + garlic intercropping. These results suggested that farmers in central Punjab Pakistan, may adopt barley + garlic intercropping system.

Keywords: Barley; Competitive function; Grain yield; Intercropping; Land equivalent ratio; Net profitability

Introduction

Increasing population pressure and decreasing resources accomplished with decrease in the rate of food production are threat to the future food security. To address these interlinked challenges, there is a need to redefine the present cropping systems to develop an economic-based cropping systems for sustainable production to meet the increasing demand of food, feed and forage. Among various options to sustain the yields in various cropping systems; intercropping is an eco-friendly and efficient method, which can help in increasing crop production mainly at small holdings of Pakistan as it satisfied the diversified demands of the farmers (Imran *et al.,* 2011; Khan *et al.,* 2012). Intercropping involves the best utilization of natural resources and has the potential to increase the productivity on small farms as it provides security against potential losses of monoculture (Ghosh, 2004). Intercropping increases the yield benefits per unit area than individual cropping. Intercropping also increase the system efficiency and net economic return (Yildirim and Guvence, 2005), by checking destruction caused by diseases, pests and weeds (Sekamatte *et al.,* 2003) and more effective usage of light, temperature and water with good combination of miscellaneous rooting system, height, canopy and nutrient requirement with respect to sole crop (Lithourgidis *et al.,* 2011). Higher yield is obtained through intercropping by enhancing the diversity in cropping system but the existing conventional planting method does not permit convenient intercropping because of narrow row spacing of single row planting system. Optimum planting geometry is an important factor for higher production by efficient utilization of underground resources and also harvesting as much as the solar radiation and in turn better assimilation. There are different planting arrangements for different intercropping systems, which depend upon the relative growth characteristics of the component crops and the mechanism of yield enhancement. Such arrangements may be influenced by season and the relative proportion of the component crops (Musa *et al*., 2010). In this scenario, there is dire need to introduce new plantation techniques having least effect on main crop yield and also facilitate intercropping. Uniform adjustment of the crop spacing in the field is the most important factor for yield and quality of a crop (Barros *et al.,* 2004).

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In Pakistan, most of the farmers have small land holdings (< 2 ha). Low production of barley is principally due to less area under cultivation and competition with wheat, which is the staple food of the country. The other reasons of low production of barley includes poor agronomic practices, lack of high yielding varieties, inadequate pest and disease management, shortage of good quality seeds, uneven plant distribution, marketing problem and low adoption of developed technologies (Badar *et al.,* 2002; Qureshi and Memon, 2008; Okoko *et al.,* 2008). Existing food supply systems demands more area to be grown under grains, pulses, oilseeds and medicinal plants because of their ever increasing usage in the daily human diet. Area under these crops, however, can not be increased due to competition with wheat. The only option is to grow them in association with winter cereals to increase the production of oilseeds, pulses and medicinal plants. Generally, farmers are not practicing intercropping of barley with other winter crops for their diversified needs. Thus, there is need to develop the best sustainable intercropping system to increase the production of barley and other winter crops simultaneously. This study was therefore, conducted to compare the yield advantages of different barley-based intercropping systems and to assess the compatibility/ feasibility of some winter intercrops in barley under the existing agro-climatic conditions of Faisalabad, Pakistan.

Materials and Methods

Experimental Site and Design

This two-years study was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad, during winter seasons of 2009-2010 and 2010-2011. Before sowing, the soil samples were taken from 0-15 cm and 15-30 cm depth for physico-chemical analysis. The soil of experimental site was sandy clay loam, having pH 7.85, electrical conductivity 1.14 dS m^{-1}, organic matter 0.76%, total nitrogen 0.041%, available phosphorus 6.90 ppm and exchangeable potassium 137 ppm. The experiment was laid out in randomized complete block design with three replications having net plot size of 3.2 m × 7.0 m. The intercropping systems comprised of barley alone, barley + chickpea, barley + lentil, barley + egyptian clover, barley + linseed, barley + fennel, barley + garden cress and barley + garlic. The weather data during the experimental period are given in Table 1.

Crop Husbandry

Uniform seedbed was prepared for all component crops in all experimental units. For seedbed preparation, pre-soaking irrigation of four acre inches was applied, and after the arrival of soil at workable soil moisture, the seedbed was prepared by cultivating three times with the help of tractor mounted cultivator. Barley and its associated crops were sown on November 04, 2009 and November 06, 2010 with single row hand drill in both years. Pure stand of all crops was also maintained in this experiment. Fertilizer was applied as the requirement of main crop (barley) at the rate of 100:75:75 kg NPK ha^{-1} in the form of urea, di-ammonium phosphate and sulphate of potash. The whole phosphorus, potassium and half of nitrogen was applied at sowing, while remaining half dose of nitrogen was applied at first irrigation. At tillering, first irrigation was applied while remaining two irrigations were applied according to crop need and climatic conditions. The barley was harvested at maturity on 8^{th} and 6^{th} April, while chickpea on 5^{th} and 2^{nd} April, lentil on 2^{nd} and 1^{st} April, linseed on 6^{th} and 4^{th} April, fennel on 17^{th} and 19^{th} April, garden cress on 5^{th} and 2^{nd} April and garlic on 28^{th} and 29^{th} March of 2010 and 2011 than threshed manually after sun drying. All other agronomic operations were kept normal and uniform for all the treatments.

Observations

Observations on relevant parameters were recorded at harvest by using standard procedures. Total number of spike bearing tillers of barley per unit area was counted by using quadrate before harvesting of crop. Number of grains per spike was recorded from ten randomly selected spikes from each plot of the respective treatment. Three lots of thousand grains were counted with the help of seed counter from the yield obtained from each plot and then weighed to record the thousand grain weight. All crops (sole, mixtures) were harvested manually; sundried and biological yield was measured in kilogram per plot by using hand held weighing balance and then was converted to kg/ha. Ratio between economic yield and biological yield represents the harvest index.

Competition Functions

The competitive functions of different component crops in barley-based intercropping system were recorded (means of both years are given in Table 5 in terms of aggressivity (A), relative crowding coefficient (K) and competitive ratio (CR) which were determined by using the following formulae:

Aggressivity value was derived from the following formula proposed by McGilchrist (1965).

$$Aab = \frac{Yab}{Yaa \times Zab} - \frac{Yba}{Ybb \times Zba}$$

Where, Aab = Aggressivity value for the component crop "a".

Yaa pure stand yield of crop "a".
Yab intercrop yield of crop "a".
Ybb pure stand yield of crop "b".
Yba intercrop yield of crop "b".

Zab are sown proportions of crop "a" in an intercropping system.

Zba are sown proportions of crop "b" in an intercropping system.

Relative crowding coefficient (K) was calculated by the following formula, which was proposed by Dewit (1960):

$$Kab = \frac{Yab}{Yaa - Yab} \times \frac{Zba}{Zab}$$

Kab = Relative crowding coefficient for the component crop "a".

Competitive ratio (CR) was calculated by the formula proposed by Willey *et al.* (1980).

$$CRa = \frac{Yab}{Yaa \times Zab} \div \frac{Yba}{Ybb \times Zba}$$

CRa = Competitive ratio value for the component crop "a". All the other abbreviations have been described above in this section.

Land Equivalent Ratio (LER)

Land equivalent ratio (LER) for each crop was computed by using the following formulae described by Willey (1979) as:

$$LER = La + Lb = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

La and Lb are the LERs for the individual crops.

Yaa = Pure stand yield of crop "a" Ybb = Pure stand yield of crop "b".

Yab = Intercrop yield of crop "a" intercropped with crop "b".

Yab = Intercrop yield of crop "b" intercropped with crop "a".

Statistical Analysis

Data were analyzed statistically by using appropriate technique (Steel *et al.*, 1996) using computer software MSTAT-C and treatments were compared by applying least significance difference test at $p \leq 0.05$.

Results

Grain yield and yield components of barley were significantly influenced by different intercropping systems excluding number of grains per spike of barley (Table 2). During both years the number of tillers was affected significantly and all associated cultures reduced the total number of tillers of barley significantly than sole cropping (Table 2). During first year (2009-2010), minimum number of fertile tillers was observed in barley + chickpea and barley + linseed. In second year (2010-2011), lower number of fertile tillers was noted in barley + fennel, which was at par with barley+linseed intercropping system. Intercropping systems significantly affected 1000-grain weight of barley (Table 2). During first year (2009-2010), the sole cropping of barley produced the highest 1000-grain weight as against the minimum when barley was intercropped with fennel, which was at par with barley + garden cress intercropping systems. Grain weight of barley was slightly higher in 2010-2011 than 2009-2010 (Table 2).

During both years of study, the intercropping systems had significant effect on barley grain yield (Table 3). Although among all the intercropping systems, the sole crop of barley produced higher grain yield than intercropped barely, however the maximum reduction in barley grain yield was observed in barley + fennel intercropping system. The maximum grain yield of barley was obtained in sole crop which was followed by barley + lentil intercropping system while the minimum grain yield was obtained in barley + fennel intercropping system (Table 3).

Barley produced 10.06% higher biological yield (BYH) during 2009-2010 than 2010-2011. The intercropping systems had significant effect on BYH of barley (Table 3). During both years sole crop of barley gave the higher biological yield as compared to other intercropping systems. During 2009-2010, the maximum biological yield was recorded in sole barley as against the minimum in barley + garden cress intercropping system (Table 3). During both years, sole barley showed higher harvest index. Similarly, the barley intercropped with chickpea and lentil gave significantly higher harvest index than other intercropping systems under study (Table 4).

Aggressivity (A) value was the minimum for barley + garlic which indicates the most competitive crop with barley,while the lentil, chickpea and egyptian clover showed less competition with barley (Table 5). In case of relative crowding coefficient (K), the supreme yield advantage was recorded from barley + lentil intercropping system as it showed the maximum value of 'K’. The greater value of competitive ratio (CR) shows the crop is more competitive than the crop which has low value of competitive ratio. The barley + egyptian clover intercropping system showed maximum compitition with barley rather than other intercrops. On the basis of land equivalent ratio (LER), the maximum yield advantage was recorded in barley + lentil intercropping system (Table 6).

The gross benefit of barley sown in different intercropping systems fluctuated from Rs. 10,4273 to 26,0788 ha^{-1}. Among different intercropping systems the highest gross benefit was observed in barley + garlic intercropping system followed by barley + lentil and barley + egyptian clover intercropping system. However, the net field benefits achieved were highest in the intercropping systems of barley + garlic followed by barley + lentil, barley + egyptian clover, barley + linseed, barley + chickpea, barley + fennel and barley + garden cress, respectively (Table 7).

Table 1: Meteorological data for the growing period 2009-2010 and 2010-2011

Month	Temperature (°C)			Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum	Mean		
2009-2010					
Sep. 2009	36.3	24.4	30.3	61.02	20.6
Oct. 2009	32.7	17.1	24.9	50.90	17.5
Nov. 2009	25.7	10.8	18.2	54.67	00.7
Dec. 2009	22.1	07.0	14.5	64.42	00.0
Jan. 2010	16.2	06.0	11.1	72.32	00.8
Feb. 2010	22.0	09.5	15.7	62.68	11.9
Mar. 2010	30.4	16.5	23.5	50.55	08.8
Apr. 2010	38.4	21.4	29.9	36.80	01.3
May 2010	40.7	25.4	33.1	31.44	11.2
2010-2011					
Sep. 2010	33.9	23.3	28.6	56.77	36.0
Oct. 2010	32.9	19.7	26.3	49.58	00.0
Nov. 2010	27.1	10.5	18.8	52.27	00.0
Dec. 2010	20.8	05.9	13.3	60.53	01.0
Jan. 2011	15.9	04.3	10.1	53.42	00.0
Feb. 2011	20.2	08.7	14.4	42.96	15.1
Mar. 2011	26.4	13.1	19.8	49.84	06.8
Apr. 2011	32.0	17.2	24.8	36.95	20.9
May 2011	40.6	24.9	32.8	32.98	14.6

Source: Agricultural Meteorology Cell, Department of Crop Physiology, University of Agriculture, Faisalabad

Table 2: Yield and yield components of barley in different intercropping systems

Intercropping systems	Productive tillers (m^{-2})	No. of grains per spike (g)	1000-grain weight (g)	Productive tillers (m^{-2})	No. of grains per spike (g)	1000-grain weight (g)
	2009-2010			2010-2011		
Barley alone	604.67 a	51.03	36.49 a	486.00 a	49.37	39.55 a
Barley + Chickpea	477.33 c	50.48	34.95 bc	440.00 b	50.10	38.60 abc
Barley + Lentil	508.67 bc	51.13	35.63 b	455.33 ab	49.80	39.04 ab
Barley + Egyptian clover	540.00 b	50.97	34.90 bc	379.67 c	49.30	38.20 bc
Barley + Linseed	477.67 c	51.18	35.43 b	401.33 c	49.33	37.83 cd
Barley + Fennel	533.67 b	51.09	34.37 c	382.67 c	49.10	37.13 d
Barley + Garden cress	526.00 bc	51.13	34.37 c	394.00 c	48.73	37.19 d
Barley + Garlic	542.33 b	50.93	35.28 b	470.67 ab	50.07	38.84 ab
LSD (0.05)	55.271	-	0.7820	31.518	-	1.0007

Any two means not sharing a letter differ significantly at 5% level of probability (0.05)

Table 3: Yield and yield components of barley in different intercropping systems

Intercropping systems	Biological yield (kg ha^{-1})	Barley grain yield (kg ha^{-1})	Harvest index (%)	Biological yield (kg ha^{-1})	Barley grain yield (kg ha^{-1})	Harvest index (%)
	2009-2010			2010-2011		
Barley alone	13091 a	3975 a	30.40 a	11773 a	3727 a	31.65 a
Barley + Chickpea	12474 c	3675 bc	29.51 b	11150 c	3504 c	31.43 a
Barley + Lentil	12643 b	3726 b	29.52 b	11233 b	3556 b	31.65 a
Barley + Egyptian clover	12014 e	3564 de	29.71 b	10825 e	3309 f	30.57 bc
Barley + Linseed	12229 d	3621 cd	29.67 b	10974 d	3391 e	30.90 b
Barley + Fennel	11809 f	3496 f	29.66 b	10440 g	3197 h	30.61 bc
Barley + Garden cress	11929 e	3530 ef	29.65 b	10615 f	3225 g	30.37 c
Barley + Garlic	12257 d	3643 c	29.79 b	11046 d	3462 d	31.33 a
LSD (0.05)	105.97	58.464	0.4641	81.898	27.123	0.3392

Any two means not sharing a letter differ significantly at 5% level of probability (0.05)

Discussion

Different cropping systems significantly affected the yield components of barley. The higher grain yield of sole barley could be recognized to higher yield components *viz.* number of productive tillers and number of grains/spike compared with other intercropping combinations (Naeem *et al.,* 2013). While, in intercropping systems lower yield of barley might be due to competition for crucial growth resources, interspecific competition between barley and intercrops, allelopathic effects of intercrops on each other resulting in lower 1000-grain weight and seed yield (Rao, 1991; Bhatti *et al.*, 2006). In several other studies, Mandal *et al.* (1985) and Nazir *et al.* (1988) recorded significant reduction in plant population density per unit area of wheat crop with different intercropping systems, and similar trend was

Table 4: Yield of intercrops sown in barley-based intercropping system

Intercropping system	Sole crop seed yield (kg ha^{-1})		Sole crop biological yield (kg ha^{-1})		Intercropped seed yield (kg ha^{-1})		Intercropped biological yield (kg ha^{-1})	
	2009-2010	2010-2011	2009-2010	2010-2011	2009-2010	2010-2011	2009-2010	2010-2011
Chickpea	588.05 a	546.63 a	1807.93 a	1783.03 a	471.70 b	432.26 b	1498.35 b	1428.96 b
Lentil	784.62 a	721.69 a	2164.68 a	2094.46 a	650.99 b	610.50 b	1846.95 b	1811.66 b
Egyptian clover	-----------	-----------	50375.24 a	48312.06 a	----------	-----------	28259.69 b	27126.95 b
Linseed	740.47 a	738.11 a	2542.2 a	2501.60 a	428.55 b	403.74 b	1679.73 b	1672.22 b
Fennel	551.50 a	509.29 a	1943.87 a	1907.44 a	330.52 b	313.43 b	1422.62 b	1400.09 b
Garden cress	638.62 a	620.40 a	3010.75 a	2979.32 a	376.25 b	375.12 b	2462.05 b	2218.00 b
Garlic	4756.31a	4513.58 a	5264.44 a	5120.05 a	3028.49 b	3017.15 b	3301.11 b	3327.71b

Any two means not sharing a letter differ significantly at 5% level of probability (0.05)

Table 5: Competitive functions of barley-based intercropping system

Intercropping system	Aggressivity (A)		Competitive ratio (CR)		Relative Crowding Coefficient (K)		
	Barley	Intercrop	Barley	Intercrop	Barley	Intercrop	System
Barley + Chickpea	0.04	-0.04	1.15	0.87	13.736	3.780	51.917
Barley + Lentil	0.04	-0.04	1.13	0.89	17.324	3.848	66.662
Barley + Egyptian clover	0.08	-0.08	1.08	0.93	8.291	1.307	10.834
Barley + Linseed	0.06	-0.06	1.62	0.62	10.162	2.100	21.340
Barley + Fennel	0.07	-0.07	1.43	0.70	6.628	1.526	10.115
Barley + Garden cress	0.07	-0.07	1.47	0.68	7.139	1.506	10.754
Barley + Garlic	0.03	-0.03	1.41	0.71	11.887	3.764	44.740

Table 6: Land equivalent ratio (LER) of barley based intercropping systems

Intercropping systems	Barley	Intercrops	System
Barley + Chickpea	0.93	0.81	1.75
Barley + Lentil	0.95	0.84	1.78
Barley + Egyptian clover	0.89	0.83	1.72
Barley + Linseed	0.91	0.56	1.47
Barley + Fennel	0.87	0.61	1.48
Barley + Garden cress	0.88	0.60	1.47
Barley + Garlic	0.92	0.65	1.57

observed in different intercrops in this study, which might be due to more competition among the component crops for food and nutrients required for their growth and development. In another study, Malik *et al.* (1992) reported that the 1000-seed weight of sesame was significantly affected by row spacing. Significant reduction in biological yield in all intercropping systems was recognized due to competition between barley and associated cultures for plant growth factors. Such reduction in BYH was studied by Nazir *et al*. (2000) in wheat-based intercropping systems and Wahla *et al*. (2009) in barley-based intercropping systems due to less number of fertile tillers. The reduction in harvest index of barley due to intercropping might be intensive antagonism between the component crops for space, nutrient, moisture and light at grain formation, which probably lowered the ability of barley to supply the assimilates to grain development (Singh and Gupta, 1994).

The zero value of aggressivity indicates that the components crops are equally competitive, if the numerical value the crops are same, then the dominant species are signed positive and the recessive specie are signed with negitive. This study narrated that value of aggressivity for barley was positive which indicated that it was dominant and negative sign for component crops showed that they were recessive. Actually the component crops strongly influence the aggressiveness, inclusion of legume the best option to improve it (Sarkar *et al.,* 2001; Bhatti *et al.*, 2006). The higher value of 'K' represents that the component crop was dominant and with the lower value of 'K' the component crop was dominated. It is evident from the competitive ratio value that except Egyptian clover the other crops like lentil, chickpea, linseed, fennel, garden cress and garlic are the most appropriate crops for intercropping in barley. Higher LER in intercropping systems recognized the best utilization of natural resources (land, light) and other inputs (fertilizer and water), (Sarkar and Chakraborty, 2000; Sarkar *et al.,* 2001).

The efficiency of any production system is evaluated on the basis of its economic analysis. The highest total variable cost was noted in intercropping systems of barley + garlic followed by barley + egyptian clover and barley + chickpea intercropping systems, respectively. The variations in net benefits among various intercropping systems may be related to the existing market prices of the various crops grown as intercrops, which vary from crop to crop and even between the various varieties of the same crop.

Table 7: Partial budget of pooled results (2009-2010 and 2010-2011) of different barely based intercropping systems

Parameters	Barley alone	Barley + Chickpea	Barley + Lentil	Barley + Egyptian clover	Barley + Linseed	Barley + Fennel	Barley + Garden cress	Barley + Garlic	Remarks
Grain yield	3851	3590	3641	3437	3506	3346	3378	3552	kg ha^{-1}
Adjusted yield	2696	2513	2549	2406	2454	2342	2364	2487	Less than 30% from actual yield
Value	94350	87947	89200	84194	85897	81981	82757	87028	Rs. ha^{-1}
Value of straw	9924	9381	9448	9109	9237	8875	9007	9241	Rs. ha^{-1}
Value of Intercrop	-	18188	44778	29043	21996	21724	19811	164519	Rs. ha^{-1}
Gross benefits	104273	115516	143426	122346	117130	112600	111575	260788	Rs. ha^{-1}
Cost that vary (Barley)	10150	10150	10150	10150	10150	10150	10150	10150	Rs. ha^{-1}
Cost that vary (Intercrops)	-	8700	7275	8900	7000	6480	6800	73600	Rs. ha^{-1}
Total expenditure	10150	18850	17425	19050	17150	16630	16950	83750	Rs.ha^{-1}
Net benefits	94123	96666	126001	103296	99980	95970	94625	177038	Rs. ha^{-1}

Following prices per kg of crops was used at the time of experiment
Barley = Rs. 35 per kg; Chickpea = Rs. 58 per kg; Lentil = Rs. 140 per kg; Egyptian clover fodder = Rs. 1.50 per kg; Linseed = Rs. 75 per kg; Fennel = Rs. 95 per kg; Garden cress (haloon) = Rs. 75 per kg and Garlic = 45 per kg and barely straw = 1.63 per kg

In conclusion, intercropping in barley is better than sole crop and the intercropping systems of barley + garlic gave the highest net return followed by barley + lentil and barley + egyptian clover. Farmer may adopt barley + garlic intercropping system or barley + lentil intercropping system for enhanced productivity and to fulfil domestic spices requirement and pulse production in the country.

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