Research Article

Integration of Biochar and Legumes in Summer Gap for Enhancing Productivity of Cereal Based Cropping System

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Abstract | Biochar can improve soil quality, increase crop production and sequester C in agricultural systems. Two years field experiments were conducted on corn crop at the research farm of the University of Agriculture Peshawar, during 2011-2013. Wheat-maize-wheat cropping pattern was followed with the adjustment of legumes in summer gap (land available after wheat harvest till maize sowing). Legumes i.e. mungbean, cowpea and sesbania with a fallow were adjusted in the summer gap with and without biochar application. Biochar was applied at the rate of 0 and 50 t ha^{-1} with four N levels of 0, 90, 120, 150 kg ha^{-1} to subsequent maize crop. Biochar significantly enhanced plant height and grain yield. The plots previously sown with legumes produced taller plants and high number of grains ear^{-1}. Nitrogen application increased plant height, number of grains ear^{-1}, thousand grains weight, grain and biological yield. It is concluded that integration of biochar and legumes could be a useful strategy for enhancing the overall farm profitability and productivity of cereal-based systems by providing increased yields from this additional 'summer gap' crop.

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Introduction

In Pakistan cereal based cropping systems are predominantly followed due to higher farm income and ensuring food security. These crops require high amount of nutrient due to their exhaustive nature (Timsina et al., 2006). For obtaining higher yield of crops, fertilization with primary nutrients like N, P and K is considered vital. However, the crop productivity decreases with the passage of time and currently higher doses of nutrients are required for achieving high yields of the crops (Gill et al., 2008). This situation is further aggravated with worsening fertility of the soils and causes several nutrient deficiencies including those of micronutrients. For sustainable crop production, the practice of organic matter buildup is important as organic matter is life of soil and improves soil structure and texture (Behera et al., 2007). Crop residue incorporation is a useful practice for improving microbial activity and stabilizing organic matter content of soil (Palm et al., 2001). Legumes which have unique quality to fix atmospheric nitrogen increase soil fertility are almost eliminated from cropping system due to low economic yield and other socioeconomic constraints (Ojiem et al., 2007).

Biochar is a fine grained charcoal high in organic carbon and largely resistant to decomposition. It is produced from pyrolysis of plants and other organic waste feed stocks. Biochar application has received a growing interest as a sustainable technology to improve highly weathered or degraded soils (Lehmann and Rondon, 2006). It can enhance plant growth by improving soil chemical characteristics, physical characteristics and biological properties all contributing to an increased crop productivity (Yamato et al., 2006). Crop yield are usually increased when biochar are applied along with chemical fertilizers (Steiner et al., 2007). Crop yield and soil fertility are increased with application of nitrogen fertilizers (Ogola et al., 2002). Nitrogen fertilizer in combination with crop residue has positive effects on plant growth and production as well as on soil fertility (Khan et al., 2009). Increase in soil total nitrogen was observed due to beneficial effect of N with organic fertilizers (residue or FYM) (Malhi et al., 2006).

Currently the use of living materials as nourishments for crop production has received attention for sustainable crop yield (Tejada et al., 2009). Agrarian are involved to establish an agricultural system, which can reduce cost of production and conserve the natural resources. Therefore, interest in organic manuring has re-emerged due to significance of green manure and high fertilizer prices. Long-term soil productivity can be achieved through the application of organic manures that maintain along with meeting timely requirement of nutrients. Urea and organic material show a pleasant effect for plant as source of nitrogen (Bocchi and Tano, 1994).

There are few studies quantifying the relative contribution of biochar and legumes in summer gap towards N economy, productivity, profitability and soil fertility in cereal based cropping system. Hence, a comprehensive study was undertaken to study the direct and residual effects of biochar and legumes on enhancing productivity, improving soil quality and getting sustainability in cereal based cropping system.

Material and Methods

The current study was conducted at NDF, the University of Agriculture Peshawar during 2011-2013. Wheat-maize-wheat cropping pattern was followed for the experiments. The summer legumes were adjusted in the summer gap (land available after wheat harvest till maize sowing from last week of April to mid July) for grain, fodder and green manure purposes. Mungbean (cv. NIAB-2006) was used for grain purpose and cowpea (cv. Ebony) was used for fodder purpose. Likewise, sesbania (Sebania aculeate, cv. Peshawari) was purely used for green manure purpose. A fallow was included in the experiment as control. Biochar was also applied at the rate of 0 and 50 t ha^{-1}. Four N levels to the subsequent maize crop were also included in the experiment. Summer legumes (mungbean, cowpea and sesbania with and without biochar) were grown on 03 May after the harvest of uniformly grown wheat crop. The seeds of mungbean, cowpea and sesbania were treated with proper inoculums to ensure maximum nodulation. The biomass of sesbania was incorporated into the field with a disc harrow in first weak of July.

After land preparation, each plot of the previous legumes' experiment was split into four sub plots to accommodate four levels of N to maize crop. Maize was sown with four levels of N fertilizer (0, 90, 120 and 150 kg ha^{-1}) on 15-July. Nitrogen was applied to maize through urea in two equal splits, half each at sowing and 30 days of growth. Similarly, the recommended rate of phosphorus fertilizer was applied at the rate of 90 kg ha^{-1} to maize at sowing. A plot size of 5 m x 16 m was used for legumes' experiment. For maize's experiment, the plot of the previous legume's experiment was split into four sub plots to accommodate four levels of N. In this way, the subplot size became 5 m by 4 m. The biomass of sesbania was weighed before incorporation. The same experiments were repeated on the same plots without disturbing the demarcation of each sub plot for two years (2011-2012 and 2012-2013).

Treatments for legumes' experiment were as follow:

T1= Mungbean (grain purpose) + 0 t ha^{-1} Biochar, T2= Mungbean (grain purpose) + 50 t ha^{-1} Biochar, T3= Cowpea (fodder purpose) + 0 t ha^{-1}, T4= Cowpea (fodder purpose) + 50 t ha^{-1}, T5= Sesbania (green manure) + 0 t ha^{-1} Biochar, T6= Sesbania (green manure) + 50 t ha^{-1} Biochar, T7 = Fallow + 0 t ha^{-1} Biochar, T8 = Fallow + 50 t ha^{-1} Biochar

The biochar used in these experiments was produced using a traditional 'on-farm' method common for small-scale production of charcoal in Pakistan. Acacia (Acacia spp.) wood was pyrolysed at 300-500 oC for 24 h, and pulverized to form a coarse powder. The pH (6.84 ±0.02) and EC (3040 ±101 µS cm^{-1}) were determined in 1:1 w/v biochar-to-distilled water samples with standard electrodes. Similarly, it had 40% C, 2.25% N, 0.14% P, 2052 mg kg^{-1} K, 450 mg kg^{-1} Na, 2.24% Ca, and 0.92% Mg.

Treatments for maize experiment were as follow:
Nitrogen levels for maize

0 , 90, 120, 150 kg ha^{-1}

Data were recorded on the following parameters of maize crop:

Plant height (cm), grains ear^{-1}, thousand grain weight (g), grain yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%).

Statistical analysis

The data were analyzed according to ANOVA technique appropriate for Randomized Complete Block (RCB) design with split plot arrangement for maize experiment using Statistix 8.1 software. The treatment means were compared at $P<0.05$ level of probability using LSD test (Jan et al., 2009).

Meteorological data

The mean monthly temperature and rainfall data from May 2011 to April 2013 during the growing season of both years at experimental site are shown in figure 1.

Results and Discusion

Plant height (cm)

Data concerning plant height of maize are reported in table 1. Statistical analysis of the data indicated that year as a source of variation did not significantly affect plant height of maize. However, biochar and legumes significantly affected plant height of maize. Similarly, plant height was also significantly affected by nitrogen levels. All interactions were not significant for plant height of maize. The application of biochar increased plant height of maize. Biochar application at the rate of 50 t ha^{-1} produced taller plants as compared to no biochar application. Likewise, plots previously sown with legumes produced taller plants as compared to plots previously kept fallow. In similar way, plant height increased with increasing level of nitrogen. Taller plants were recorded in plots treated with 150 or 120 kg N ha^{-1} followed by N level of 90 kg ha^{-1}. These results are in agreement with the findings of Verheijen et al. (2004) who reported that biochar application to soils enhances plant growth. Our results agree with Lopez et al. (2007) reported that increase in nitrogen application improved plant height of maize. These results are also in line with Chan et al. (2007) who reported that combined use of biochar and fertilizers enhanced plant height.

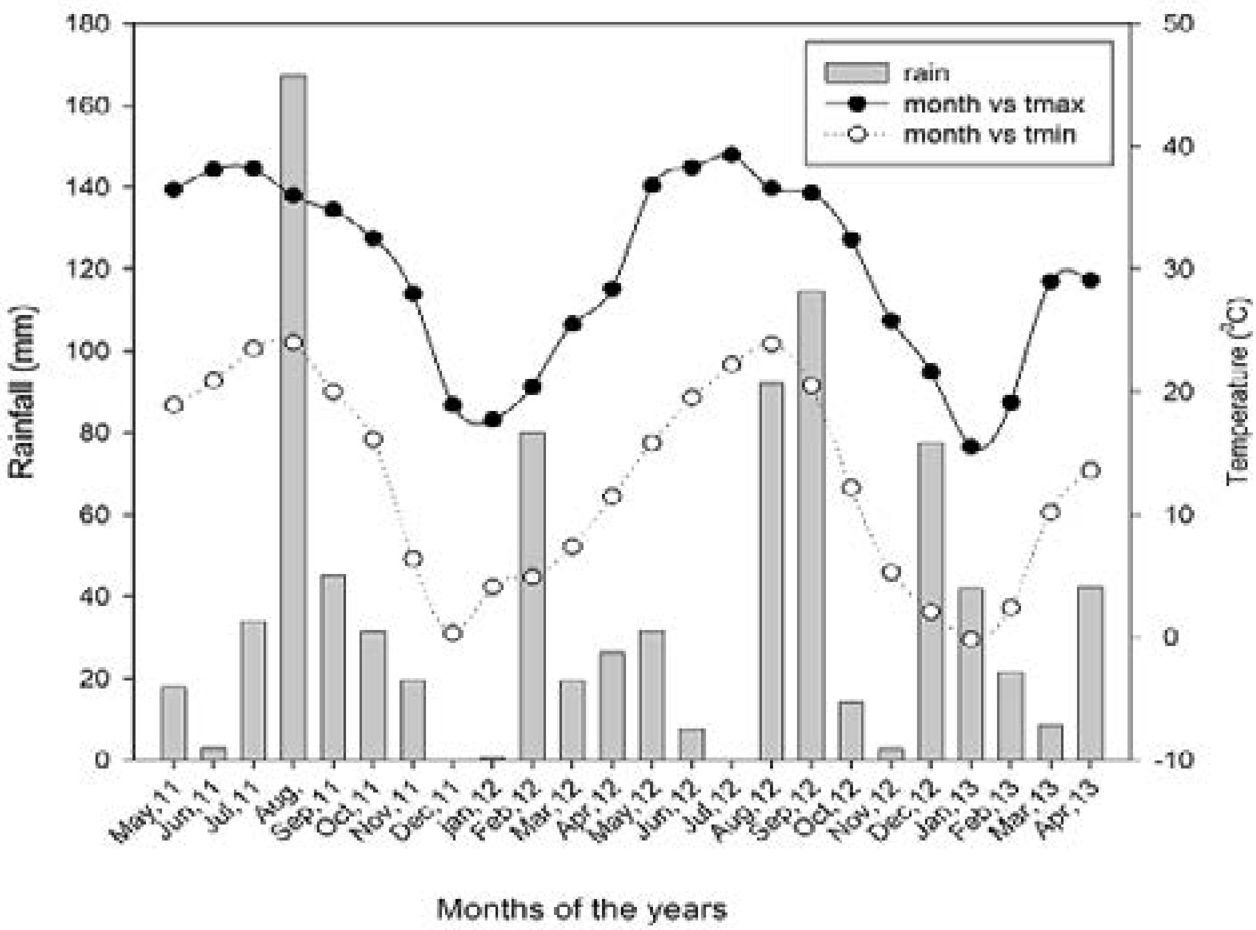

Figure 1. *Mean monthly temperature and rainfall data from May 2011 to April 2013.*

Table 1. *Effect of biochar, legumes and nitrogen levels on plant height (cm) of maize.*

		Nitrogen (kg ha^{-1})				
Biochar (BC) ton ha^{-1}	**Legumes (L)**	**0**	**90**	**120**	**150**	**BC x L**
0	Cowpea	193	203	214	205	204
0	Mungbean	188	196	208	197	197
0	Sesbania	173	194	207	209	196
0	Fallow	174	186	191	195	187
50	Cowpea	203	201	210	217	208
50	Mungbean	189	207	211	220	207
50	Sesbania	197	209	212	219	209
50	Fallow	174	195	204	206	195
			BC x N			**Mean**
0		182	195	205	201	196 b
50		191	203	209	215	205 a
			L x N			**Mean**
	Cowpea	198	202	212	211	206 a
	Mungbean	189	201	210	208	202 a
	Sesbania	185	201	209	214	202 a
	Fallow	174	191	197	200	191 b
		187 c	199 b	207 a	208 a	
	Year	**2011-2012**		**2012-2013**		
		199		202		
Main effects		LSD$_{(0.05)}$		Interactions	Significance level	
Year		Ns		BC x L	ns	
Biochar (BC)		*		BC x N	ns	
Legumes(L)		5.53		L x N	ns	
Nitrogen (N)		4.92		BC x L x N	ns	

Means the same category followed by different letters are significantly different from each other at 5% level of probability.
** = Significant at 5% level of probability, ns = Non significant*

Number of grains ear^{-1}

Data regarding number of grains ear^{-1} of maize are presented in table 2. Biochar application did not significantly affect number of grains ear^{-1} however; legumes and nitrogen levels significantly affected number of grains ear^{-1}. Year as source of variation also had significant effect on number of grains ear^{-1}. The interactions between BC x N and L x N for number of grains ear^{-1} were significant. All other interactions were non-significant. Legumes enhanced number of grains ear^{-1} in maize crop. The plots previously sown with sesbania gave more numbers of grains ear^{-1} as compared to cowpea, mungbean and fallow. Maximum number of grains ear^{-1} was produced when the crop was given nitrogen fertilizer at the rate of 120 kg N ha^{-1} followed by 150 kg N ha^{-1} whereas minimum number of grain ear^{-1} was recorded in control plots. The interaction between BCxL showed that previously fallow plots without biochar gave minimum number of grains ear^{-1} however; the incorporation of sesbania with and without biochar gave maximum number of grains ear^{-1}. In case of LxN interaction, higher number of grains ear^{-1} was counted in plots fertilized with 120 kg N ha^{-1} where formerly sesbania was incorporated as compared to minimum number of grains ear^{-1} in fallow plots without N application. Plots previously sown with sesbania improved grains ear^{-1} in comparison with other legumes and fallow. Legumes produced heavier grains of maize as compared to fallow treatment. Similar results are reported

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Table 2. *Effect of biochar, legumes and nitrogen levels on grains ear^{-1} of maize.*

		Nitrogen (kg ha^{-1})				
Biochar (BC) ton ha^{-1}	**Legumes (L)**	**0**	**90**	**120**	**150**	**BCxL**
0	Cowpea	436	444	469	421	443
0	Mungbean	431	433	461	477	450
0	Sesbania	453	475	548	502	494
0	Fallow	426	435	464	433	440
50	Cowpea	415	453	474	426	442
50	Mungbean	434	448	479	544	476
50	Sesbania	460	466	548	507	495
50	Fallow	408	450	501	534	473
			BC x N			**Mean**
0		436	447	486	458	457
50		429	454	500	503	472
			L x N			**Mean**
	Cowpea	426	449	471	424	442 b
	Mungbean	433	441	470	511	463 b
	Sesbania	456	471	548	504	495 a
	Fallow	417	442	482	483	456 b
		433 c	451 c	493 a	481 b	
	Year	**2011-2012**	**2012-2013**			
		445 b	484 a			
Main effects		LSD$_{(0.05)}$		Interactions	Significance level	
Year		*		BC x L	ns	
Biochar (BC)		ns		BC x N	*	
Legumes(L)		26.93		L x N	*	
Nitrogen (N)		19.56		BC x L x N	ns	

Means the same categories followed by different letters are significantly different from each other at 5% level of probability.
** = Significant at 5% level of probability, ns = Non significant*

by Humphreys (1994) who found that forage legumes improved soil fertility, yield and its related parameters. In similar manner, Ahmad (2000) reported that nitrogen application enhanced yield and yield components in wheat. Abiye and Saleem (1995) reported that nitrogen fixing legumes may suggest an attractive sound means of reducing inputs and increasing profitable outputs of the crop. Ali et al. (1999) reported that total N fixed by legumes increased the dry matter and yield related attribute of maize. Hayat et al. (2008) reported that legumes in rotation with cereals gave higher dry matter and yield production in maize.

Thousand grain weight (g)

Data on thousand grain weight of maize are given in table 3. Analysis of data revealed that legumes and nitrogen significantly affected thousand grains weight however, the effect of biochar was not significant. Year as source of variation also significantly affected thousand grains weight. All interactions were not significant for thousand grains weight of maize. Legumes cultivation as a preceding crop had pleasant effects on thousand grains weight of maize. Plots previously sown with mungbean, cowpea or sesbania produced heavier grains as compared to fallow plots. Likewise, nitrogen application improved thousand grains weight as compared to control plots. Higher thousand grains weight was recorded in plots where the cropwas given nitrogen fertilizer at the rate of 120 kg ha^{-1} followed by 150 and 90 kg ha^{-1} as compared to minimum thousand grains weight in control plots. The increased thousand grains weight in fertilized plots may be due the accessibility of nitrogen at grain filling stage which may have resulted in higher thousand

Table 3. *Effect of biochar, legumes and nitrogen levels on thousand grain weight (g) of maize.*

		Nitrogen (kg ha^{-1})				
Biochar (BC) ton ha^{-1}	**Legumes (L)**	**0**	**90**	**120**	**150**	**BC x L**
0	Cowpea	233	240	257	230	240
0	Mungbean	239	240	262	230	243
0	Sesbania	213	231	244	233	230
0	Fallow	195	215	246	234	222
50	Cowpea	226	235	262	259	245
50	Mungbean	247	236	254	251	247
50	Sesbania	235	243	261	237	244
50	Fallow	202	227	234	232	224
			BCxN			**Mean**
0		220	231	252	232	234
50		227	235	253	245	240
			LxN			**Mean**
	Cowpea	229	237	259	244	242 a
	Mungbean	243	238	258	240	245 a
	Sesbania	224	237	252	235	237 a
	Fallow	198	221	240	233	223 b
		224 c	233 b	252 a	238 b	
	Year	**2011-2012**	**2012-2013**			
		214 b	260 a			
Main effects		$LSD_{(0.05)}$		Interactions	Significance level	
Year		*		BC x L	ns	
Biochar (BC)		ns		BC x N	ns	
Legumes (L)		12.02		L x N	ns	
Nitrogen(N)		9.51		ns	ns	

Means the same categories followed by different letters are significantly different from each other at 5% level of probability.
** = Significant at 5% level of probability, ns = Non significant*

grains weight. Ahmad (2000) reported that thousand grains weight and grain yield in maize increased with increase in nitrogen application. These results are also in line with Chan et al. (2007) who reported that the combination of biochar and nitrogen increased plant yield.

Grain yield (kg ha^{-1})

Data concerning grain yield of maize are reported in table 4. Statistical analysis of the data showed that legumes, biochar and nitrogen levels significantly affected grain yield of maize. Year as source of variation also had significant effect on grain yield of maize. All interactions were found non-significant except BCxL. Legumes as preceding crop improved grain yield of maize. The plots previously sown with cowpea, mungbean or sesbania produced higher grain yield as compared to fallow which resulted in minimum grain yield. Biochar application also enhanced grain yield and its application at the rate of 50 t ha^{-1} produced higher grain yield as compared to no biochar treatment. Likewise, nitrogen application constantly increased grain yield from 0 to 120 kg ha^{-1} but thereafter was no significant increase in grain yield of maize. Maximum grain yield was recorded in plots treated with fertilizer N at the rate of 120 kg ha^{-1} as compared to minimum grain yield in control plots. The interaction between BCxL showed that maize plots having previously cowpea plus biochar gave higher grain yield as compared to minimum grain yield in

Table 4. *Effect of biochar, legumes and nitrogen levels on grain yield (kg ha^{-1}) of maize.*

		Nitrogen (kg ha^{-1})				
Biochar (BC) ton ha^{-1}	**Legumes(L)**	**0**	**90**	**120**	**150**	**BC xL**
0	Cowpea	1904	2439	3135	3032	2628
0	Mungbean	2123	2511	3038	3173	2711
0	Sesbania	2054	2258	3041	2839	2548
0	Fallow	2000	2249	3147	3194	2647
50	Cowpea	2658	2397	3833	3663	3138
50	Mungbean	2710	2669	3159	3065	2901
50	Sesbania	2495	2708	3397	3073	2918
50	Fallow	1977	2400	2639	2650	2416
			BC x N			**Mean**
0		2021	2364	3090	3060	2634 b
50		2460	2544	3257	3113	2843 a
			L x N			**Mean**
	Cowpea	2281	2418	3484	3348	2883 a
	Mungbean	2417	2590	3099	3119	2806 a
	Sesbania	2275	2483	3219	2956	2733 a
	Fallow	1988	2324	2893	2922	2532 b
		2240 c	2454 b	3174 a	3086 a	
	Year	**2011-2012**	**2012-2013**			
		2375 b	3102 a			
Main effects		**$LSD_{(0.05)}$**		**Interactions**	**Significance level**	
Year		*		BC x L	*	
Biochar (BC)		*		L x N	ns	
Legumes (L)		191.17		BC x N	ns	
Nitrogen (N)		160.64		BC x L x N	ns	

Means of the same category followed by different letters are significantly different from each other at 5% level of probability.
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previously fallow plots with biochar. Aslam and Mehmood (2003) reported that improved organic matter and physical characteristics of soil increase soil fertility and can play an important role in the growth and yield of cereal crops. Verheijen et al. (2004) reported that biochar application improves soil functions such as soil physical and biological properties resulting in higher grain yield. Asai et al. (2009) reported that application of biochar resulted in higher grain yields. The increase in grain yield may be due to sufficient nitrogen availability in soil. These results are in agreement with Ogola et al. (2002) who observed an increase of 43-68% in grain yield due to nitrogen application. Shafi et al. (2007) reported that nitrogen application significantly enhances the crop production in the course of additional nitrogen. This may be due to previously sufficient nutrients available in soil resulting maximum biological yield. The adequate availability of nitrogen in soil made the crop prolific resulting in maximum biological yield. Steiner et al. (2008) reported that the N recovery in biomass was significantly higher when the soil contained additional fertilizers. Danga et al. (2009) reported that grain legumes grown in turning round with annual cereal crops contribute to the total pool of nitrogen in the soil and improve the yield of cereals.

Biological yield (kg ha^{-1})

Data on biological yield of maize are presented in table 5. Year as a source of variation significantly affected biological yield of maize. The application of biochar did not significantly increase biological yield. Legumes and nitrogen levels significantly affected biological yield. The BCxL and LxN interactions were significant, while rest of interactions were not significant. Legumes as preceding crop improved biological yield of maize. The plots previously sown with cowpea, sesbania or mungbean produced higher bi-

Table 5. *Effect of biochar, legumes and nitrogen levels on biological yield (kg ha^{-1}) of maize.*

		Nitrogen (kg ha^{-1})				
Biochar (BC) ton ha^{-1}	Legumes (L)	0	90	120	150	BC x L
0	Cowpea	5193	6134	7378	8127	6708
0	Mungbean	5080	6153	7766	7295	6574
0	Sesbania	5512	6399	8060	7767	6935
0	Fallow	4742	5457	6642	7294	6034
50	Cowpea	6453	7305	9344	10480	8396
50	Mungbean	5953	6610	8878	8644	7521
50	Sesbania	6204	6828	8192	8206	7358
50	Fallow	5045	5994	6470	6814	6081
			BCxN			Mean
0		5193	6134	7378	8127	6708 a
50		5080	6153	7766	7295	6574 b
			L x N			Mean
	Cowpea	5823	6720	8361	9303	7552 a
	Mungbean	5516	6382	8322	7969	7047 a
	Sesbania	5858	6614	8126	7987	7146 a
	Fallow	4893	5725	6556	7054	6057 b
		5523 c	6360 b	7841 a	8078 a	
	Year	2011-2012	2012-2013			
		6278 b	7623 a			
Main effects		$LSD_{(0.05)}$		Interactions	Significance level	
Year		*		BC x L	*	
Biochar(BC)		*		L x N	*	
Legumes(L)		600.17		BC x N	ns	
Nitrogen (N)		351.25		BC x L x N	ns	

Means of the same category followed by different letters are significantly different from each other at 5% level of probability.
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ological yield as compared to previously fallow plots. Likewise, biological yield consistently improved with increasing nitrogen levels till 120 kg ha^{-1} but there was no significant increase with further increase in nitrogen level. Higher biological yield was recorded in plots when the crop was given nitrogen fertilizer at the rate of 150 kg ha^{-1} as compared to minimum biological yield in control plots. The in teraction between BCxL showed that plots having previously cowpea plus biochar gave maximum biological yield as compared to minimum biological yield in fallow plots without biochar application. In case of LxN interaction, maximum biological yield was noted in plots fertilized with 150 kg N ha^{-1} where cowpea was previously sown in comparison with minimum biological yield in fallow plots without N application. Plots previously sown with legumes enhanced biological yields of maize as compared to fallow treatment. Aslam and Mehmood (2003) reported that improved organic matter and physical characteristics of soil increase soil fertility and can play an important role in the growth and yield of maize crops. Akbar et al. (2002) reported that growth parameters including biological yield increased with increasing nitrogen rates.

Harvest Index (%)

Data regarding harvest index are presented in table 6. Year as source of variation did not significantly affect harvest index. Likewise, legumes and biochar did not significantly affect harvest index of maize. Similarly,

Table 6. *Effect of biochar, legumes and nitrogen levels on harvest index (%) of maize.*

		Nitrogen (kg ha^{-1})				
Biochar (BC) ton ha^{-1}	**Legumes (L)**	**0**	**90**	**120**	**150**	**BC x L**
0	Cowpea	34	37	44	38	38
0	Mungbean	40	41	40	43	41
0	Sesbania	34	36	38	36	36
0	Fallow	39	41	47	44	43
50	Cowpea	39	33	41	37	38
50	Mungbean	43	40	36	36	39
50	Sesbania	40	40	42	39	40
50	Fallow	37	40	40	39	39
			BC x N			**Mean**
0		37	39	42	40	40
50		40	38	40	38	39
			L x N			**Mean**
	Cowpea	37	35	43	38	38
	Mungbean	42	41	38	39	40
	Sesbania	37	38	40	37	38
	Fallow	38	41	44	41	41
		38	39	41	39	
	Year	**2011-2012**	**2012-2013**			
		38	41			
Main effects		**LSD$_{(0.05)}$**		**Interactions**	**Significance level**	
Year		ns		BC x L	*	
Biochar(BC)		ns		L x N	*	
Legumes(L)		ns		BC x N	*	
Nitrogen (N)		ns		BC x L x N	ns	

* = *Significant at 5% level of probability, ns = Non significant*

nitrogen levels also did not significantly affect harvest index of maize. All interactions except BCxLxN significantly affected harvest index of maize crop. Legumes x biochar interaction showed that maize plots having previously mungbean gave maximum harvest index without biochar inclusion. Legumes x nitrogen interaction showed that maximum harvest index was noted in fallow plots fertilized with 120 kg N ha^{-1}. The BCxN interaction indicated that maximum harvest index was recorded in plots fertilized with 120 kg N ha^{-1} without biochar incorporation. Maximum harvest index of maize by legumes was probably due to release of macro in addition to micro nutrients from the organic source favorably affected growth yield and yield components which ultimately increased grain yield and harvest index. These results are in line with Rao and Shaktawat (2002) who reported that residual effect of combinations of profitable nitrogenous and organic fertilizer resulted in maximum harvest indexes. The LxN interaction indicated that maximum harvest index was noted in fallow crop fertilized with 120 kg N ha^{-1} without biochar application. This might be due to high nitrogen levels which positively interacted with light as well as environmental factors to enhance photosynthesis, producing more harvest index. Soni and Sikarwar (1991) observed the residual effect of applied varying fertilizer levels on subsequent wheat crops showing positive effect on yield of wheat.

Conclusion and Discussion

Legumes had pleasant effects on subsequent crop maize in term of improving grain yield and soil properties (N and organic matter). Biochar application significantly increased grain yield of maize. Higher grain and biological yields of maize were obtained with 120 kg N ha^{-1} in place of its recommended dose of 150 kg N ha^{-1} when sown after legumes. Similarly, plots previously sown with either cowpea or mungbean resulted in higher grain yield of maize.

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