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INTEGRATION OF BIOCHAR AND LEGUMES IN SUMMER GAP FOR ENHANCING PRODUCTIVITY OF WHEAT UNDER CEREAL BASED CROPPING SYSTEM

FAZAL JALAL[1], MUHAMMAD ARIF[1], KAWSAR ALI[2*], FAZAL MUNSIF[1], MUHAMMAD JAMAL KHAN[3] AND BUSHRA KHAN[4]

[1]*Department of Agronomy, The University of Agriculture Peshawar, Pakistan*
[2]*Department of Agriculture, Abdul Wali Khan University Mardan, Pakistan*
[3]*Department of Soil and Environmental Sciences, The University of Agriculture Peshawar, Pakistan*
[4]*Department of Environmental Sciences, University of Peshawar, Pakistan*
[*]*Corresponding author's email: kawsar@awkum.edu.pk*

Abstract

Biochar application is gaining popularity in agriculture system as prime technology in sustainable context. Field experiments were conducted 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, 60, 90 and 120 kg ha^{-1} to subsequent wheat crop. Biohcar application and plots previously sown with legumes improved thousand grain weight of wheat crop. Nitrogen application increased thousand spikes m^{-2}, 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.

Key words: Legumes, Biochar, Nitrogen, Yield and cropping system.

Introduction

Cereal based cropping systems are primarily followed in Pakistan because of higher productivity and profitability and for ensuring food security. These are highly nutrients exhaustive crops and require heavy doses of nutrients for optimum productivity (Timsina & Connor, 2001). Formerly fertilization with primary nutrients like N, P and K was considered vital for getting high yields of crops. However, the crop productivity decreased with the passage of time and currently higher doses of nutrients are required for achieving potential yields of the crops (Nambier, 1998; Yadav, 2000; Gill *et al*., 2008). This situation is further aggravated with worsening fertility of the soils and resulting emergence of multiple nutrient deficiencies including those of micronutrients. 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 *et al.,* 2008). It can enhance plant growth by improving soil chemical characteristics i.e. nutrient retention and availability and soil physical characteristics i.e., bulk density, water holding capacity, permeability and soil biological properties i.e. soil biota and soil microorganisms, all contributing to an increased crop productivity (Glaser *et al*., 2002; Yamato *et al*., 2006). In addition, biochar is highly recalcitrant to microbial decomposition and thus guarantees a long term benefit for soil fertility (Steiner *et al*., 2007).

Nitrogen fertilization plays an important role in improving soil fertility and increasing crop productivity (Habtegebrial *et al*., 2007). It increases grain yield (43-68%) and biomass (25-42%) in maize (Ogola *et al*., 2002). It contributes 18-34% increase in soil residual N (Yang *et al*., 2007). Sole residue incorporation or in combination with N fertilizer have positive effects on plant growth and production as well as on soil physiochemical properties (Khan *et al*., 2009). Synergistic effects of N with organic fertilizers (residue or FYM) accumulate more soil total N. It is also integral part of plant tissues and a plant is considered healthy, if its suitable amount is stored in its tissues. Thus fertilizer N has a positive and direct impact on plant growth (Malhi *et al*., 2006). Cultivation of legumes for seed, fodder or green manure helps in sustaining productivity of cereal based cropping systems and improves soil fertility through nutrient cycling (Herridge *et al*., 1995; Shah *et al*., 2003; Baijukya *et al*., 2005). In most parts of Pakistan, there is a hot summer period of 70–80 days available after the harvest of wheat till maize sowing from last week of April to mid-July which can be utilized by short duration legume crops for enhancing grain legumes production or fodder availability or green manuring. Retention of legume residues improves the N economy of the cropping system and enhances the crop productivity through the additional N and many other potential benefits (Chalk, 1998; Shah *et al*., 2003; Kirkegaard *et al*., 2008). Green manuring with annual leguminous crops like Sesbania is a widely known practice and found beneficial not only for realizing potential yields but also for N economy and improving soil fertility (Singh *et al*., 1991). Despite its usefulness, this practice is rarely followed by the farmers. Legumes such as mungbean (*Vigna radiata*) and cowpea (*Vigna unguiculata*) provide direct economic produce as well as stover which can be used as fodder or recycled to achieve a similar or somewhat lower effect as Sesbania green manuring (Roy & Ange, 1991; Kaytal, 1993; Shah *et al*., 2003; Ojiem *et al*., 2006). Likewise, mungbean as well as cowpea have direct value in human diet and potential to add N to the cropping system, especially when their residues with nodules are incorporated into the soil (Glasener *et al*., 2002; Shah *et al*., 2003; Timsina *et al*., 2006).

It is not only desirable but quite possible to reduce the reliance on synthetic N fertilizers and move towards greater use of legumes to supply N for crop production. In fact, legume-based systems are likely to be more sustainable than cereal-based or fertilizer based systems. 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, legumes and nitrogen on enhancing productivity, improving soil quality and getting sustainability in cereal based cropping system.

Materials and Methods

The experiments were conducted at the Research Farm of Agronomy department, the University of Agriculture Peshawar during s2011-2013. Wheat-maize-wheat cropping pattern was followed for the experiments. Before the test crop wheat, the summer legumes were adjusted in the summer gap (land available after wheat harvest till maize sowing) for grain, fodder and green manure purposes. Mungbean was used for grain purpose and cowpea was used for fodder purpose. Likewise, Sesbania was purely used for green manure purpose. A fallow was included in the experiment as control. Biochar was also included in the experiment with 0 and 50 t $ha^{-1.}$ Four N levels to the subsequent wheat crop were also included in the experiment. After the harvest of uniformly grown wheat crop, summer legumes i.e., cowpea (*Vigna unguiculata*, cv. Ebony), mungbean (*Vigna radiate*, cv. NIAB-2006) and Sesbania (Sebania aculeate, cv. Pashawari) with and without biochar was sown in the first week of May following recommended agronomic practices. 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 early 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}) in mid-July. After harvest of maize crop in the late October, the plots of the previous maize's experiment were utilized to accommodate four levels of N (0, 60, 90 and 120 kg ha^{-1}) specific to wheat crop. Higher levels of N were kept in plots previously allotted to high N levels. Nitrogen was applied to wheat crop in two splits; half each at sowing and boot stage and P was applied at the rate of 60 kg ha^{-1} at sowing. For legume's experiment randomized complete block design with three replications was used. A plot size of 5 m x 16 m was used from legumes' experiment. For maize's experiment, the plot of the previous legume's experiment was split into four plots to accommodate four levels of N. In this way, the subplot size became 5 m by 4 m. Likewise, for wheat experiment, the plots of the previous maize's experiment was utilized to accommodate four levels of N specific to wheat. 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).

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°C for 3-4 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}, 450 mg kg^{-1} Na, 2.24% Ca, and 0.92% Mg.

Nitrogen content: Soil, grain and stover/straw samples of all the crops as well as biomass of Sesbania were analyzed for N content following Kjeldahl method of Bremner & Mulvaney (1982). Soil samples collected (0-15 cm depth) from each treatment was also analyzed for determination of organic C (Walkley & Black, 1934). Data were recorded on number of spikes m^{-2}, number of grains $spike^{-1}$, thousand grain weight, biological yield and grain yield.

Procedure for data recording: Number of spike m^{-2} data was recorded by counting number of spikes in one meter row length at three randomly selected rows in each sub plot and was converted spike m^{-2}. For grains $spike^{-1}$ data, grains from five randomly selected spikes were obtained by hand threshing and were counted and converted into average number of grains $spikes^{-1}$. Data on thousand grain weight were recorded by counting two hundred grains at random from grain sample of each plot and were weighed with an electronic balance and then converted into thousand grain weight. For recording grain yield data, three central rows were harvested in each plot with the help of a sickle. Samples were sun dried, threshed and grains were weighed with the help of an electronic balance and data were converted into kg ha^{-1}. Three central rows were harvested at maturity from each plot, tied into bundles separately for wheat. The bundles were sun dried and weighed by spring balance for calculating biological yield. The data were converted into kg ha^{-1}.

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

Results and Discussion

Number of spikes m^{-2} was higher in second year as compared to first year of experiments (Table 1). Number of spikes m^{-2} enhanced with increase in nitrogen application rate. Higher number of spikes m^{-2} was recorded at N level of 90 to 120 kg ha^{-1}. Similarly, Jan & Khan (2000) reported that application of N fertilizer at vegetative stage increases the number of spikes per unit area in wheat. Likewise, Singh and Agarwal (2001) also reported that N application at the rate of 120 kg N ha^{-1} produced more number of spikes m^{-2}. Legumes and biochar application did not significantly affect number of grains $spike^{-1}$. However, nitrogen levels significantly affected number of grains $spike^{-1}$. Year as source of variation significantly affected number of grains $spike^{-1}$. All the interactions were not significant (Table 2). Higher number of grains $spike^{-1}$ was produced in second year as compared to first year of experiments. Number of grains $spike^{-1}$ improved with increasing level of nitrogen. Maximum number of grains $spike^{-1}$ was produced when the crop was applied N at the rate of 60, 90 and 120 kg N ha^{-1} as compared to minimum number of grains $spike^{-1}$ in control plots. These results agree with Wahab & Hussain (1997) who reported that nitrogen application increased number of grains $spike^{-1}$. Similarly, Banoori *et al*. (2005) reported that number of grains $spike^{-1}$ significantly enhanced with increasing level of N.

Table 1. Effect of biochar, legumes and nitrogen levels on number of spikes m^{-2}of wheat.

Biochar BC (ton ha^{-1})	Legumes (L)	Nitrogen N(kg ha^{-1}) 0	60	90	120	BC x L
0	Cowpea	263	290	398	361	328
0	Mungbean	270	321	356	336	321
0	Sesbania	249	343	296	351	310
0	Fallow	254	319	316	328	304
50	Cowpea	237	325	346	329	309
50	Mungbean	235	274	301	335	286
50	Sesbania	277	329	339	308	313
50	Fallow	252	308	372	335	317
			BC x N			Mean
0		259	318	342	344	316
50		250	309	340	327	306
			L x N			Mean
	Cowpea	250	308	372	345	319
	Mungbean	253	298	328	336	304
	Sesbania	263	336	318	329	312
	Fallow	253	313	344	332	310
		255 c	314 b	341 a	335ab	
	Year	Year 1	Year 2			
		300	322			
Main effects		**LSD$_{(0.05)}$**		**Interactions**	**Significance level**	
Year		*		BC x L	*	
Biochar BC)		Ns		BC x N	Ns	
Legumes (L)		Ns		L x N	Ns	
Nitrogen (N)		22.43		BC x L x N	Ns	

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

Table 2. Effect of biochar, legumes and nitrogen levels on grains spike^{-1} of wheat.

Biochar BC (ton ha^{-1})	Legumes (L)	Nitrogen N(kg ha^{-1}) 0	60	90	120	BC x L
0	Cowpea	44	48	48	50	47
0	Mungbean	44	49	52	51	49
0	Sesbania	45	52	55	54	51
0	Fallow	45	48	52	51	49
50	Cowpea	46	47	51	52	49
50	Mungbean	52	47	54	50	51
50	Sesbania	47	53	51	50	50
50	Fallow	44	50	47	51	48
			BC x N			Mean
0		45	49	52	51	49
50		48	49	51	51	50
			L x N			Mean
	Cowpea	45	47	49	51	48
	Mungbean	48	48	53	51	50
	Sesbania	46	52	53	52	51
	Fallow	45	49	50	51	49
		46	49	51	51	
	Year	Year 1	Year 2			
		47	51			
Main effects		**LSD$_{(0.05)}$**		**Interactions**	**Significance level**	
Year		*		BC x L	ns	
Biochar (BC)		Ns		L x N	ns	
Legumes (L)		Ns		BC x N	ns	
Nitrogen (N)		2.70		BC x L x N	ns	

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

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

Biochar BC (ton ha^{-1})	Legumes (L)	Nitrogen N(kg ha^{-1})				BC x L
		0	60	90	120	
0	Cowpea	46.6	49.5	48.4	47.5	48.0
0	Mungbean	47.7	47.0	47.2	47.8	47.5
0	Sesbania	50.2	51.9	46.8	46.7	48.9
0	Fallow	46.0	46.7	46.1	47.1	46.5
50	Cowpea	45.2	46.7	50.5	48.2	47.7
50	Mungbean	51.7	49.9	50.7	47.0	49.8
50	Sesbania	51.4	52.9	51.9	47.7	51.0
50	Fallow	46.6	48.1	47.8	50.1	48.2
			BC x N			Mean
0		47.6	48.8	47.1	47.3	47.7 b
50		48.7	49.4	50.2	48.3	49.1 a
			L x N			Mean
	Cowpea	45.9	48.1	49.4	47.9	47.8 b
	Mungbean	49.7	48.5	48.9	47.4	48.6ab
	Sesbania	50.8	52.4	49.3	47.2	49.9 a
	Fallow	46.3	47.4	47.0	48.6	47.3 b
		48.2ab	49.1 a	48.7ab	47.8 b	
	Year	Year 1	Year 2			
		44.0	52.9			
Main effects		**LSD$_{(0.05)}$**		**Interactions**	**Significance level**	
Year		*		BC x L	0.004	
Biochar (BC)		*		L x N	ns	
Legumes (L)		1.59		BC x N	ns	
Nitrogen (N)		1.31		BC x L x N	ns	

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

Thousand grain weight was significantly affected by legumes, biochar and nitrogen levels. All Interactions were not significant except BC x L (Table 3). Biochar application improved thousand grain weight of wheat. Application of biochar at the rate of 50 t ha^{-1} increased thousand grains weight as compared to no biochar application. The plots previously sown with Sesbania and mungbean produced heavier grains followed cowpea and fallow plots which were statistically at par with each other. Maximum thousand grain weight was recorded in plots when the crop was applied with N at the rate of 60 and 90 kg ha^{-1} which were statistically similar while minimum thousand grain weight was recorded in plots which received 120 kg N ha^{-1}. The BCxL interaction showed that plots having previously Sesbania incorporated with biochar produced higher thousand grain weight as compared to minimum in previously kept fallow plots without biochar. Many studies have shown that biochar is a useful resource to improve the physicochemical properties of soil, increase fertilizer-use efficiency and increase crop production (Chan *et al*., 2007, 2008; Deenik *et al*., 2011; Van Zwieten *et al*., 2010). Similarly, legumes improved grain weight in comparison with fallow. Nitrogen level of 0 to 90 kg ha^{-1} produced similar grain weight and further increase in N level decreased grain weight of wheat. Higher grain weight may be due to large accumulation of proteins and other reserved food in the seed because of high availability of nitrogen in soil from mixture of legumes and biochar and N source. Better utilization of freely available fertilizer nitrogen from treatment having legumes and nitrogen combination may have made plants more efficient in photosynthetic activity which led to higher grain weight. The results agree with Verma (1996) who reported that combination of nitrogen sources proved significantly better over control in terms of growth, grain weight, and other yield attributes. These results are also in line with Wahab & Hussain (1997) who reported that application of nitrogen fertilizer increased thousand grain weight of wheat. Similarly, Alam *et al*. (2005) reported increase in thousand grain weight of wheat through integrated use of organic and chemical fertilizers. Biological yield was significantly influenced by nitrogen application, however, legumes and biochar did not significantly affect biological yield of wheat. Year as source of variation was also non-significant. All interactions were not significant (Table 4). Application of N at the rate of 120 kg ha^{-1} produced higher biological yield followed by 90 kg ha^{-1} whereas lower biological yield was recorded in control plots. Biological yield consistently increased with increasing level of nitrogen from 0 to 120 kg ha^{-1}. The possible reason could be the better utilization of nutrients in plots having combination of higher doses of nitrogen fertilizer and legumes or biochar incorporation which enhanced the photosynthetic activity of the plants. These results agree with Singh & Agarwal (2001) and Abbas *et al*. (2006) who reported significant increases in wheat dry matter production with addition of nitrogen fertilizer. Similarly, Ramesh *et al*. (2002) reported that application of

100% recommended nitrogen improved dry matter accumulation of wheat instead of its seed yield. Grain yield was significantly influenced by nitrogen application, however, legumes and biochar did not significantly affect grain yield of wheat. Year as source of variation was also significant. All interactions were not significant for grain yield of wheat (Table 5). Higher grain yield was recorded in plots where the crop was treated at the rate of 120 kg N ha^{-1} which was at par with N level of 90 kg ha^{-1} followed by N level of 60 kg ha^{-1}. Lower grain yield was recorded in control plots. The grain yield usually depends upon various factors such as soil fertility status, water availability, crop management and environmental factors as well as plant genetic characteristics. Yield improvement due to N fertilizer may be due to enhanced availability and use of N, water and other related soil improvement benefits due to inorganic and organic N sources. The other probable reason could be better exploitation of nutrients in plots having combination of higher doses of nitrogen fertilizer in addition to legumes or biochar incorporation. Similarly, Singh & Agarwal (2001) reported higher grain yield with the highest level of nitrogen (120 kg N ha^{-1}). Likewise, Bakht *et al*. (2009) concluded that nitrogen application in addition to contribution of legumes in crop rotation significantly improve the N economy indicating higher crop productivity. Biochar and legumes significantly affected soil C after wheat harvest. Year as source of variation and nitrogen did not significantly affect soil C after wheat harvest. All other interactions were significant except BCxN for soil C after wheat harvest (Table 6).The plots previously sown with Sesbania , mungbean or cowpea resulted in higher soil C as compared to minimum soil C in fallow plots. The application of biochar enhanced soil C and it was higher in plots applied with 50 t ha^{-1}. The BCxL interaction showed that minimum soil C was recorded in previously fallow plots without biochar, however, plots previously sown with cowpea without biochar showed maximum soil C. In case of LxN interaction, maximum soil C was noted in control plots integrated with cowpea, while minimum soil C was recorded in Sesbania incorporated plots fertilized with 120 kg N ha^{-1}. The interaction of BCxN showed maximum soil C in plots fertilized with 60 kg N ha^{-1} treated with biochar. The LxBCxN interaction revealed that maximum soil C was recorded in plots fertilized with 60 kg N ha^{-1} where Sesbania was formerly mixed with biochar as compared to minimum soil C in summer fallow plots fertilized with 120 kg N ha^{-1} without biochar application. Biochar has been described as a possible means to improve soil fertility as well as other ecosystem services and increase soil store carbon (Lehmann & Joseph, 2009).The NxL interaction revealed that maximum soil C was recorded in plots fertilized with 60 kg N ha^{-1} where Sesbania was formerly mixed with biochar. Similar results are reported by Baijukya *et al*. (2005) who found that legumes in rotations increased soil carbon.

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

Biochar BC (ton ha^{-1})	Legumes (L)	Nitrogen N(kg ha^{-1})				BC x L
		0	60	90	120	
0	Cowpea	5738	7693	8823	10114	8092
0	Mungbean	6378	8066	9000	9684	8282
0	Sesbania	7745	8855	9089	9951	8910
0	Fallow	7244	8363	9499	9650	8689
50	Cowpea	6618	8527	9681	10333	8790
50	Mungbean	7289	8632	10367	10332	9155
50	Sesbania	6940	8431	9315	11000	8921
50	Fallow	5356	8613	8733	10113	8204
			BC x N			Mean
0		6777	8244	9103	9850	8493
50		6551	8551	9524	10444	8767
			L x N			Mean
	Cowpea	6178	8110	9252	10223	8441
	Mungbean	6834	8349	9684	10008	8719
	Sesbania	7343	8643	9202	10476	8916
	Fallow	6300	8488	9116	9881	8446
		6664 d	8398 c	9313 b	10147 a	
	Year	Year 1	Year 2			
		8698	8563			

Main effects	LSD$_{(0.05)}$	Interactions	Significance level
Year	ns	BC x L	ns
Biochar (BC)	ns	L x N	ns
Legumes (L)	ns	BC x N	ns
Nitrogen (N)	416.42	BC x L x N	ns

ns = Non significant

Means of the same category followed by different letters are significantly different from each other at 5% level of probability

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

Biochar BC (ton ha^{-1})	Legumes (L)	Nitrogen N(kg ha^{-1})				BC x L
		0	60	90	120	
0	Cowpea	2658	3212	3568	3737	3294
0	Mungbean	2435	3155	4176	3831	3399
0	Sesbania	2789	3646	3799	3797	3508
0	Fallow	2934	3475	3786	4193	3597
50	Cowpea	2381	3283	3795	4066	3381
50	Mungbean	2713	3164	4100	3667	3411
50	Sesbania	3114	3556	3632	4169	3618
50	Fallow	1924	3602	3412	3808	3187
			BC x N			Mean
0		2704	3372	3832	3889	3449
50		2533	3401	3735	3928	3399
			L x N			Mean
	Cowpea	2520	3247	3682	3901	3338
	Mungbean	2574	3160	4138	3749	3405
	Sesbania	2951	3601	3716	3983	3563
	Fallow	2429	3539	3599	4001	3392
		2618 c	3387 b	3783 a	3908 a	
	Year	Year 1	Year 2			
		3131	3718			
Main effects		**LSD$_{(0.05)}$**		**Interactions**	**Significance level**	
Year		*		BC x L	ns	
Biochar (BC)		Ns		L x N	ns	
Legumes (L)		Ns		BC x N	ns	
Nitrogen (N)		241.22		BC x L x N	ns	

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

Table 6. Effect of biochar, legumes and nitrogen levels on soil C (g kg^{-1}) after wheat harvest.

Biochar BC (ton ha^{-1})	Legumes (L)	Nitrogen N (kg ha^{-1})				BC x L
		0	60	90	120	
0	Cowpea	10.13	7.91	8.03	9.76	8.96
0	Mungbean	9.29	6.11	6.95	6.84	7.30
0	Sesbania	10.10	5.28	4.72	9.76	7.46
0	Fallow	8.91	5.84	6.26	3.95	6.24
50	Cowpea	8.45	7.91	5.91	6.41	7.17
50	Mungbean	8.82	8.51	8.05	6.77	8.04
50	Sesbania	6.40	12.86	8.17	7.36	8.70
50	Fallow	4.97	9.38	6.73	9.34	7.61
			BC x N			Mean
0		7.92	6.28	6.49	7.58	7.07 b
50		7.10	9.67	7.21	7.47	7.86 a
			L x N			Mean
	Cowpea	9.29	7.91	7.67	8.08	8.06 a
	Mungbean	9.05	7.31	7.50	6.81	7.67 a
	Sesbania	8.25	9.07	6.44	8.56	8.08 a
	Fallow	6.64	7.61	7.49	6.64	6.92 b
		8.38	7.98	7.85	7.52	
	Year	Year 1	Year 2			
		7.46	7.90			
Main effects		**LSD (0.05)**		**Interactions**	**Significance level**	
Year		Ns		BC x L	*	
Biochar (BC)		*		L x N	*	
Legumes (L)		0.74		BC x N	ns	
Nitrogen (N)		Ns		BC x L x N	*	

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

Table 7. Effect of biochar, legumes and nitrogen levels on soil N (g kg^{-1}) after wheat harvest.

Biochar BC (ton ha^{-1})	**Legumes (L)**	**Nitrogen N (kg ha^{-1})**				**BC x L**
		0	**60**	**90**	**120**	
0	Cowpea	0.42	1.13	0.85	0.92	0.83
0	Mungbean	0.88	1.37	1.14	1.32	1.18
0	Sesbania	1.13	0.71	0.77	0.92	0.88
0	Fallow	0.63	1.18	0.83	0.68	0.83
50	Cowpea	1.35	1.10	1.16	1.01	1.16
50	Mungbean	0.99	1.38	0.75	0.68	0.95
50	Sesbania	0.74	0.93	0.68	1.18	0.88
50	Fallow	1.16	1.22	1.14	0.93	1.11
			BC x N			Mean
0		0.76	1.10	0.89	0.96	0.93 b
50		1.06	1.15	0.93	0.95	1.02 a
			L x N			Mean
	Cowpea	0.89	0.96	1.00	1.11	0.99 ab
	Mungbean	0.93	1.00	0.94	1.37	1.06 a
	Sesbania	0.90	0.82	1.20	1.05	0.99 ab
	Fallow	0.72	0.80	0.94	0.98	0.86 c
		0.86 c	0.89 c	1.02 b	1.13 a	
	Year	Year 1	Year 2			
		0.94	1.01			

Main effects	**LSD (0.05)**	**Interactions**	**Significance level**
Year	*	BC x L	*
Biochar (BC)	*	L x N	*
Legumes (L)	0.074	BC x N	*
Nitrogen (N)	0.044	BC x L x N	*

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

Data concerning soil N after wheat harvest are reported in Table 7. Analysis of data indicated that legume, biochar and nitrogen fertilizer significantly affected soil N after wheat harvest. Year as source of variation also had significant effect on soil N. All interactions were also significant. The plots previously sown with legume increased soil N as compared to minimum in previously kept fallow plots. Application of biochar at the rate of 50 t ha^{-1} enhanced soil N after wheat harvest. Biochar has been shown by many researchers that it improves soil N, C and other physicochemical properties, fertilizer-use efficiency and crop production (Chan *et al*., 2007, 2008; Deenik *et al*., 2011; Van Zwieten *et al*., 2010). Higher soil N was recorded in plots fertilized with 120 kg N ha^{-1} as compared to minimum soil N in control plots. The interaction between BCxL showed that minimum soil N was measured in previously kept fallow plots and cowpea without biochar, however, previously sown sole mungbean plots showed maximum soil N. In case of LxN interaction, maximum soil N was noted in plots sown with mungbean and 120 kg N ha^{-1}, while minimum soil N was recorded in fallow plots without N application. The interaction of BCxN showed that maximum soil N was recorded in biochar plots fertilized with 60 kg N ha^{-1}. The interaction of LxBCxN revealed that maximum soil N was recorded in plots fertilized with 60 kg N ha^{-1} that were previously sown with mungbean as compared to minimum soil N in cowpea sown plots without biochar and N application. The higher soil N in legumes plots may be due to N fixation by legumes and mineralization of organic matter added to soil from their biomass. Savithri *et al.* (1991) reported a significant increase in the nutrients content of soil due to application of poultry manure.

Conclusions

It is concluded that legumes like cowpea, mungbean and Sesbania can be successfully adjusted in summer gap for getting fodder, grain or biomass for green manure, respectively. Legumes had pleasant effects on subsequent wheat crop in terms of improving yield traits and grain yield. It was discovered that wheat crop produced higher grain yield with 90 kg N ha^{-1} instead of 120 kg N ha^{-1} when sown after legumes.

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