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Effect of biochar based enriched manures on growth parameters and yield of wheat at different levels of fertilizers

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Abstract
Field experiments were carried out at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) India during *rabi* 2013-14 and 2014-15 to evaluate the effect of biochar based enriched manures on growth parameters and yield of wheat at different levels of fertilizers. The treatments consisted seven levels of biochar based enriched manures (BM) and three levels of recommended doses of fertilizers (RDF). The experiment was replicated thrice in a factorial randomized block design (FRBD). The results showed that, the application of biochar based enriched manures and fertilizers significantly increased the plant height, chlorophyll content and grain yield of wheat. Among the biochar based manures treatment BM_6 (Biochar 10q ha^{-1} + Carpet waste 5 q ha^{-1} + PGPR) gave the highest significant result over the control. Among the levels of recommended dose of fertilizer (RDF), application of 100% RDF (RDF_{100}) gave significantly higher improvement in growth parameters and yield over 50% RDF (RDF_{50}) and control (RDF_0). The interaction effect of biochar based manures and fertilizer levels ($RDF_{100} \times BM_6$) were also showed a beneficial effect on grain yield of wheat.

Keywords: Biochar, Fertilizers, PGPR, grain yield and wheat

Introduction

Generation of organic waste is expected to continue increasing, which has become a global issue. If not properly handled, the large volume of organic waste may deteriorate air, water, and soil quality, resulting in significant impacts to food, energy, and water supplies. Among the different agro-wastes, 116 million tonnes of rice husk is produced annually by more than 75 countries (FAO 2002) [14]. Rice husk constitutes a valuable resource, but due to lack of proper residue management practices its potential is often underutilised leading to negative environmental consequences. Except for limited use in power generation, rice husk waste causes serious environmental problems. Burning rice husk waste on open fields is thought to be one of the major contributors to greenhouse gas emissions. Recycling of this agro-waste for nutrient management in soil may be considered as an alternative option to burning (Munda *et al.,* 2016) [30]. Some large rice mills at Mirzapur and Chandauli district of Uttar Pradesh have already perfected this approach. Using rice husks to produce energy and biochar simultaneously, these mills reduce their fossil fuel bill and carbon emissions, and produce the biochar as a by-product, which can be used as a soil amendment.

Biochar is a highly stable organic material, produced through pyrolysis of woody materials, agricultural wastes, green waste and animal manures is reported to have pronounced effects on soil physico-chemical (Cross and Sohi, 2011) [9] and biological properties (Lehmann *et al.,* 2011) [24]. Significant increases in plant growth and a reduction in greenhouse gas emissions from soil has been reported (Chan *et al*., 2007) [7]. Biochar was recently investigated as a bulking agent in waste composting. This material has a great potential for composting due to its chemical, physical and structural properties (Krolczyk *et al*., 2014) [21]. It can function as an amendment, a bulking agent or both; particularly for composting mixtures with high moisture and low C/N ratio (Steiner *et al*., 2011; Malinska *et al*., 2014) [37, 27].

Carpet waste is another waste product which is the by-product of the highly develop carpet industries of Sant Ravidas Nagar (Bhadohi) district of Uttar Pradesh. There is a clear need to identify an alternative use for protein-rich product and its by-products (Zheljazkov, 2005) [41]. Carpet waste contains about 12% of nitrogen and can be used as an organic manure in the soil after proper Composting. Plat *et al.* (1984) [32] suggested the utilization of wool waste in composted form, as feedstock's and nitrogen sources for plants, and Tiwari *et al.* (1989) [40] reported a marked response in chickpea and wheat growth using differently amended soils with wool waste composts. Enrichment of compost in terms of increasing the nutrient content of final compost product have been studied (Gaind *et al*., 2006) [15]. Microbial enrichment technique with bio-inoculants to composting material had been shown to improve the quality of compost (Dey *et al*., 2002) [11]

Fertilizers constitute an integral part of improved crop production technology (Saifullah *et al*., 2002) [33]. The proper amount of fertilizer application is considered a key to the bumper crop production (Tariq *et al*., 2007) [39]. Nitrogen (N) is major factor limiting yield of wheat (Andrews *et al*., 2004) [3]. Optimum N management to wheat is important for maximum yield, optimum water utilization and minimum contamination to environment (Corbeels *et al*., 1999) [8]. Phosphorus is essential for enhancing seed maturity and seed development (Ziadi *et al*., 2008) [42]. Both P and K application favoured tillering of wheat and reduced lodging in wheat (Liakas *et al*., 2001) [25], improved photosynthetic activity and transport to the ripening grains.

Materials and Methods

The present investigation conducted at Agricultural Research Farm, Banaras Hindu University, Varanasi during rabi 2013–14 and 2014-15. Varanasi is situated at an altitude of 80.71 meters above mean sea level and located between $25^0 14'$ and $25^0 23'$N latitude and $82^0 56'$ and $83^0 30'$E longitude and falls in a semi-arid to sub humid climate. The soil belongs to Inceptisol, had sandy loam texture, bulk density 1.41 Mg m^{-3}, pH (1:2.5) 7.92; electrical conductivity 0.19 dS m^{-1} organic carbon 0.44%, available nitrogen 158.2 kg ha^{-1}, available phosphorus 21.0 kg ha^{-1} and available potassium 170.5 kg ha^{-1}. A total of 21 treatment combinations comprising of seven levels of Biochar based manures (BM_0 = No manure, BM_1=Biochar @10 qha^{-1}, BM_2=Biochar @10 q ha^{-1}+PGPR, BM_3=Biochar @10 q ha^{-1}+ Carpet waste @ 2.5 q ha^{-1}, BM_4=Biochar @10 q ha^{-1} + Carpet waste @ 2.5 q ha^{-1}+PGPR, BM_5=Biochar @10 q ha^{-1} + Carpet waste @ 5 q ha^{-1} and BM_6 =Biochar @10 q ha^{-1} + Carpet waste @ 5 q ha^{-1}+PGPR (@ = Organic materials used for composting on the basis of area to be applied) and three levels of recommended doses of fertilizer RDF_0 = Control, RDF_{50} = 50% of RDF, RDF_{100} = 100% of RDF (100% RDF= N, P_2O_5 and K_2O i.e. 120, 60, and 60 kg ha^{-1}) with 3 replications under Randomized block design in Factorial experiment. Biochar based manures were applied in experimental field as per treatments. The doses of N, P and K were applied through urea, di-ammonium phosphate (DAP) and by muriate of potash (MOP). Half of the N and full dose of P and K was applied at the time of sowing of crop and remaining N fertilizer was applied in two equal portions after first and second irrigation. All improved packages of practices were followed to raise the crop. Chlorophyll content (SPAD value) of the plants was measured by the use of chlorophyll meter at 30 and 60 days after sowing. Plant height (cm) of the wheat was recorded at 30, 60, 90 days after sowing (DAS) and at harvest stage. Grain yields were recorded after harvesting of crop and the data were statistically analysed.

Preparation of biochar based enriched manures

Six pits were dig out of appropriate size (4'x3'x1.5') for the preparation of six types of biochar based enriched manures (BM).The known quantity of rice husk biochar (RHB) and carpet waste (CW) was filled in pits on the basis of area to be applied. After 15 days of initiating the composting process, turning of the compost was done and microbial consortium was applied in the respective manure pits along with cowdung slurry. PGPR consortium applied was the mixture of different beneficial microbes *Azotobacter croococcum*, *Bacillus subtilis*, *Pseudomonas fluorescens*, *Paenibacillus polymyxa*, and *Trichoderma harzianum* in equal proportion. PGPR Consortium was thoroughly mixed to ensure complete and uniform contact with decomposing material. PGPR consortium was added after 15 days of initial composting to protect the microbes from direct exposure to excess heat generated from the materials. The pits were covered by polythene sheet and allowed to decompose. The mixture was turned over fortnight interval and also proper moisture was maintained. Biochar based enriched manure of each pit were divided in equal parts on weight basis for execution of the treatments in the plots.

Results and Discussion

Plant height

The plant height is one of the important characteristics, which indicates the nutrient absorption capacity as well as health of the plants. It is evident that the plant height significantly varied with varying fertility levels and levels of biochar based enriched manures at all the growth stages of wheat.

Perusal of data revealed that plant height of wheat influenced significantly due to different levels of fertilizers causing it to vary in the range of 20.07 to 31.46 cm and 21.29 to 32.65 cm at 30 DAS, 57.06 to 68.36 cm and 58.16 to 69.54 cm at 60 DAS, 76.58 to 95.03 cm, 78.04 to 96.33 cm at 90 DAS and 79.77 to 97.74 cm and 81.88 to 99.83 cm at harvesting stage during 2013-14 and 2014-15, respectively (Table 1). The highest plant height of wheat was obtained with the application of 100% doses of fertilizers (RDF_{100}), while the lowest was recorded with Control (RDF_0) at all the stages in both the years. The plant height due to application of (RDF_{100}) and (RDF_{50}) increased by 56.77 and 30.89% at 30 DAS; 19.81 and 10.94% at 60 DAS; 24.09 and 12.63% at 90 DAS; and 22.53 and 12.08% at harvesting in *rabi* 2013-14 whereas; 53.40 and 29.11% at 30 DAS; 19.55 and 10.88% at 60 DAS; 23.43 and 12.17% at 90 DAS; and 21.93 and 11.79% at harvesting in *rabi* 2014-15 over control (RDF_0) respectively. This increase in plant height due to increase in fertilizer doses was might be due to an increase in nutrient availability and therefore, significant increase in vegetative growth of plants was obtained. Similar results were also reported by Singh *et al*. (2007) [36]; Garg (2007) [16]; Shivakumar and Ahlawat (2008) [35] and Lavakush *et al.* (2014) [22].

Perusal of data revealed that plant height of wheat also influenced due to different levels of biochar based manures causing it to vary in the range of 23.36 to 28.79 cm and 24.58 to 29.78 cm at 30 DAS; 60.36 to 65.47 cm and 61.44 to 66.73 cm at 60 DAS; 81.91 to 89.77 cm and 83.11 to 90.95 cm at 90 DAS; and 84.89 to 92.62 cm and 87.04 to 94.74 cm at harvesting stage during 2013-14 and 2014-15, respectively (Table 1). The highest plant height of wheat was obtained with the treatment of BM_6, while the lowest was recorded with control (BM_0) at all the stages in both the years. The plant height due to application of (BM_6) increased by 23.26 and 21.14% at 30 DAS; 8.48 and 8.62% at 60 DAS; 9.60 and 9.43% at 90 DAS; and 9.10 and 8.84% at harvesting in *rabi* 2013-14 and *rabi* 2014-15 respectively, over control (RDF_0).

However, the interaction effect of fertilizer levels and biochar based manures on plant height of wheat was found to be non significant at all the stages and in both the years (Table 1).

Chlorophyll content (SPAD Value)

Chlorophyll content, an indicator of photosynthetic activity, is related to the N concentration in green plants and serves as a measure of the response of crops to N fertilizer application and soil nutrient status (Minotta and Pinzauti, 1996) [29].

Perusal of data revealed that chlorophyll content (SPAD value) of wheat influenced significantly due to different levels of fertilizers causing it to vary in the range of 26.57 to 34.83 and 26.57 to 34.77 at 30 DAS, 32.78 to 41.18 and 34.08 to 42.92 at 60 DAS, during *rabi* 2013-14 and 2014-15, respectively (Table 2). The chlorophyll content (SPAD value) increased with increasing fertilizer level from 0 (RDF_0), to 100% (RDF_{100}). The maximum chlorophyll content (SPAD value) of wheat was obtained with the application of 100% RDF (RDF_{100}), while the lowest was recorded with control (RDF_0) at all the stages in both the years. The chlorophyll content (SPAD value) due to application of (RDF_{100}) and (RDF_{50}) increased by 31.07 and 20.09% at 30 DAS; 25.61 and 16.72% at 60 DAS; in *rabi* 2013-14 whereas; 30.87 and 19.92% at 30 DAS; 25.61 and 16.17% at 60 DAS; in *rabi* 2014-15 over control (RDF_0) respectively. These results are in agreement with the findings of Sharma (1995) [34] who reported that, leaf chlorophyll content was higher when optimum doses of NPK was applied to the plants leading to the uptake of Mg which is the central molecule of chlorophyll. Also these findings are in accordance with that of Sutpal and Saimbhi (2003) [38] who reported N and P supply increased the uptake of Mg leading to the formation of more photosynthetic structures including chlorophyll.

Perusal of data revealed that chlorophyll content (SPAD value) of wheat also influenced due to different levels of biochar based manures causing it to vary in the range of 29.02 to 33.40 and 28.99 to 33.58 at 30 DAS; 35.19 to 39.97 and 36.97 to 40.97 at 60 DAS; during 2013-14 and 2014-15, respectively (Table 2). The maximum chlorophyll content (SPAD value) of wheat was obtained with the treatment of BM_6, while the lowest was recorded with control (BM_0) at all the stages in both the years. The maximum chlorophyll content (SPAD value) due to application of (BM_6) increased by 15.09 and 15.85% at 30 DAS and 13.60 and 10.83% at 60 DAS; in *rabi* 2013-14 and *rabi* 2014-15 respectively, over control (RDF_0). The increase in chlorophyll content may be attributed to adequate supply of nitrogen by carpet waste and PGPR. Mensah (2013) [28] reported highest Leaf chlorophyll content in plants treated with biochar, bio fertilizer and inorganic fertilizers. Diatta (2016) [13] also reported that biochar application to soils significantly increased pearl millet aboveground biomass and leaf chlorophyll the first year after application, however no significant differences were observed in the second year between biochar treatments and control plots.

However, the interaction effect of fertilizer levels and biochar manures was found to be non significant in the respect of SPAD value at both the stages and in both the years (Table 2).

Grain yield

Results revealed that the grain yield significantly increased with increasing the levels of fertilizers causing it to vary in the range of 25.29 to 48.62 q ha^{-1} in *rabi* 2013-14 and 26.76 to 50.11 q ha^{-1} in *rabi* 2014-15, respectively (Table 2). The maximum grain yield of wheat was obtained with the application of 100% doses of fertilizers (RDF_{100}), while the lowest was recorded with control (RDF_0) in both the years. The grain yield due to application of (RDF_{100}) and (RDF_{50}) increased by 57.34 and 92.22% in *rabi* 2013-14 and 54.36 and 87.24% in *rabi* 2014-15 over control (RDF_0), respectively. It is well documented that yield of crop depends on a number of factors including root growth, nutrient uptake, photosynthesis, etc. for which fertilizer play a vital role. The increase in grain and straw yield was might be due to number of reasons. Enhanced rate of nutrient supply, particularly N, P and K led to increase the leaf area index (LAI) in plants (Azeez, 2009) [5]. Increasing photosynthetic rate with fertilization can be also attributed to increasing amount of chlorophyll pigments, since N is one of the major components of chlorophyll (Kizilkaya, 2008 and Diacono *et al*., 2013) [20, 12]. However, more LAI and chlorophyll increased the interception of solar radiation by plants that results in higher photosynthesis rate and its translocation and accumulation in grain and straw. Consequently, plants became able to produce more yield components grain and straw. The results of the present investigation were in tune with the finding of the Patidar and Mali (2003) [31]; Abraham and Lal (2004) [1] and Dadhich *et al*., (2011) [10] who have reported an increased grain and straw yield of wheat with increasing levels of fertilizer.

Perusal of data revealed that grain yield of wheat also influenced due to different levels of biochar based manures causing it to vary in the range of 33.58 to 42.38 q ha^{-1} in *rabi* 2013-14 and 34.99 to 43.89 q ha^{-1} and in *rabi* 2014-15, respectively (Table 2). The maximum grain yield of wheat was obtained with the treatment of BM_6, while the lowest was recorded with control (BM_0) in both the years. The grain yield due to application of biochar based manure (BM_6) increased by 26.21% in *rabi* 2013-14 and 25.44% in *rabi* 2014-15 over control (RDF_0), respectively. Plant growth and yield increases with biochar additions have been, in most cases, attributed to the optimization of the availability of plant nutrients (Gaskin *et al*., 2010; Glaser *et al*., 2002; Lehmann *et al*., 2003) [17, 18, 23] increases in soil microbial biomass and activity (Biederman and Harpole, 2013) [6]. Likewise, wood biochar addition increased wheat yield by up to 30%, with no differences in grain N content, and sustained yield for two consecutive seasons without biochar addition in the second year. Major *et al*. (2010) [26] reported that maize grain yield did not increase significantly in the first year following addition of 20 t ha^{-1} biochar (biomass-derived black carbon), but increased by 28, 30 and 140% over the control for the three consecutive years.

However, the interaction effect of fertilizer levels and biochar based manures on grain yield of wheat was found to be statistically significant on grain yield in both the years (Table 2). The grain yield of wheat influenced due to different levels of fertilizers and biochar based manures causing it to vary in the range of 20.95 to 51.47q ha^{-1} in *rabi* 2013-14 and 22.28 to 53.05 q ha^{-1} and in *rabi* 2014-15, respectively. The maximum grain yield of wheat was obtained with the combination of $RDF_{100} \times BM_6$, while the lowest was recorded with control ($RDF_0 \times BM_0$) in both the years. The grain yield due to the treatment of $RDF_{100} \times BM_6$, increased by 145.6% in *rabi* 2013-14 and 138.1% in *rabi* 2014-15 over control (RDF_0 x BM_0), respectively. Results concur with the findings of Alburquerque *et al*. (2013) [2] where they reported significant biochar × mineral fertilization interaction as the highest grain production was obtained when biochars were combined with the complete mineral fertilization, demonstrating the beneficial effect of biochar on wheat yield.

Table 1: Effect of RDF and biochar based carpet waste and PGPR enriched manure on plant height of wheat during *rabi* season of 2013- 14 and 2014-15.

Treatments	Plant height (cm)							
	30 DAS		60 DAS		90 DAS		Harvesting	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Factor - I RDF								
RDF_0	20.07	21.29	57.06	58.16	76.58	78.04	79.77	81.88
RDF_{50}	26.27	27.48	63.30	64.49	86.26	87.54	89.41	91.53
RDF_{100}	31.46	32.65	68.36	69.54	95.03	96.33	97.74	99.83
SEm±	0.21	0.21	0.30	0.31	0.38	0.39	0.35	0.40
CD (P = 0.05)	0.60	0.59	0.87	0.90	1.08	1.12	1.01	1.15
Factor – II BBM								
BM_0	23.36	24.58	60.36	61.44	81.91	83.11	84.89	87.04
BM_1	23.99	25.21	60.99	62.14	83.16	84.74	86.05	88.14
BM_2	24.60	25.81	61.62	62.78	83.97	85.33	86.85	88.95
BM_3	25.87	27.09	62.89	63.98	85.98	87.34	88.91	91.01
BM_4	27.25	28.52	64.26	65.48	88.06	89.46	91.44	93.52
BM_5	27.68	28.99	64.75	65.89	88.84	90.21	92.06	94.16
BM_6	28.79	29.78	65.47	66.73	89.77	90.95	92.62	94.74
SEm±	0.32	0.32	0.47	0.48	0.58	0.60	0.54	0.61
CD (P = 0.05)	0.92	0.90	1.33	1.37	1.65	1.71	1.55	1.75
RDF × B	NS	NS	NS	NS	NS	NS	NS	NS

RDF_0, RDF_{50}, RDF_{100} = 0, 50, & 100% RDF, respectively; BM_0 = No biochar enriched manure (control), BM_1= Biochar 10q ha^{-1}, BM_2 = Biochar 10q ha^{-1} + PGPR, BM_3 = Biochar 10q ha^{-1}+ Carpet waste 2.5 q ha^{-1}, BM_4 = Biochar 10q ha^{-1} + Carpet waste 2.5 q ha^{-1} + PGPR, BM_5 = Biochar 10q ha^{-1}+ Carpet waste 5 q ha^{-1} & BM_6 = Biochar 10q ha^{-1} + Carpet waste 5 q ha^{-1} + PGPR, respectively.

Table 2: Effect of RDF and biochar based carpet waste and PGPR enriched manure on chlorophyll content (SPAD value) and grain yield of wheat during *rabi* season of 2013-14 and 2014-15.

Treatments	Chlorophyll content (SPAD Value)				Grain yield (q ha^{-1})	
	30 DAS		60 DAS			
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Factor - I RDF						
RDF_0	26.57	26.57	32.78	34.08	25.29	26.76
RDF_{50}	31.91	31.86	38.09	39.75	39.80	41.31
RDF_{100}	34.83	34.77	41.18	42.92	48.62	50.11
SEm±	0.23	0.24	0.23	0.26	0.30	0.27
CD (P = 0.05)	0.66	0.68	0.67	0.74	0.86	0.65
Factor – II BBM						
BM_0	29.02	28.99	35.19	36.97	33.58	34.99
BM_1	29.55	29.55	35.72	37.46	33.95	35.43
BM_2	29.82	29.77	36.02	37.79	35.20	36.72
BM_3	30.87	30.87	37.06	38.48	37.49	39.02
BM_4	32.20	32.20	38.62	40.25	41.06	42.56
BM_5	32.87	32.50	38.88	40.52	41.66	43.13
BM_6	33.40	33.58	39.97	40.97	42.38	43.89
SEm±	0.35	0.36	0.36	0.39	0.46	0.35
CD (P = 0.05)	1.01	1.04	1.02	1.13	1.32	0.99
RDF × B	NS	NS	NS	NS	S	S

RDF_0, RDF_{50}, RDF_{100} = 0, 50, & 100% RDF, respectively; BM_0 = No biochar enriched manure (control), BM_1= Biochar 10q ha^{-1}, BM_2 = Biochar 10q ha^{-1} + PGPR, BM_3 = Biochar 10q ha^{-1}+ Carpet waste 2.5 q ha^{-1}, BM_4 = Biochar 10q ha^{-1} + Carpet waste 2.5 q ha^{-1} + PGPR, BM_5 = Biochar 10q ha^{-1}+ Carpet waste 5 q ha^{-1} & BM_6 = Biochar 10q ha^{-1} + Carpet waste 5 q ha^{-1} + PGPR, respectively.

Conclusions

On the basis of results it can be concluded that the addition of biochar based manures alone had a positive effect on plant height, chlorophyll content and overall yield of wheat crop but clearly lower than compared to the fertilizers. The application of biochar based manures composted with carpet waste and microbial enriched with PGPR consortium in two different ratios had significantly better response on plant height, chlorophyll content and grain yield of wheat In addition, there was a significant interaction between biochar based manures and fertilizer levels because the highest grain yield was obtained when biochar based manures were combined with the complete mineral fertilization showing the beneficial effect of biochar on wheat yield.

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