Journal of Pharmacognosy and Phytochemistry 2019; 8(1): 138-143

Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(1): 138-143
Received: 01-11-2018
Accepted: 03-12-2018

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Effect of biochar based enriched manures on yield attributes of wheat at varying NPK levels in Indo-Gangetic plains of Eastern Uttar Pradesh

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Abstract
Biochar as a bulking agent for composting has been proposed as a novel approach to prepare good quality compost due to large surface area and porosity, thus high ion exchange and adsorption capacity. Field experiments were carried out at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) during rabi 2013-14 and 2014-15 to evaluate the effect of biochar based enriched manures on plant growth parameters and yield of wheat at different NPK levels. The experiment was replicated thrice in a factorial randomized block design (FRBD). The results showed that, the application of biochar based enriched manures along with fertilizers significantly increased the number of tillers m^{-1} row length, number of grains $spike^{-1}$, test weight (g) and grain yield of wheat. Among the enriched manures levels, application of biochar composted with carpet waste in ratio of 2:1 along with enriched with PGPR consortium gave significantly highest result over the control. Among the levels of recommended dose of fertilizer, application of 100% RDF (RDF_{100}) recorded significantly higher improvement in yield 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, enriched manure, yield attribute, 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 FAO 2002). Continuous application of fertilizers in indiscriminate manner with decreasing trends of manure application since inception of green revolution has shown bad impression on soil health. Consequently, most of soils particularly in agro-climatic zone of Indo-Gangetic plains are showing decreasing trend of organic carbon and deficiency of many major secondary and micro nutrients. Due to low content of organic carbon in soil, the nutrient use efficiency of major nutrient is declining and therefore yields of most of the major crops are not increasing even after application of higher doses of fertilizers. Under such circumstances, organic material highly resistant to microbial decomposition must be incorporated along with easily decomposable organic manure so that organic carbon could be gained at high rate in the soil (Rondon *et. al.*, 2007). Realising the above problems, some researchers have previously tried to use the more resistant organic matter such as biochar in combination to organic manure in the soil.

Biochar was recently investigated as a highly stable and bulky organic material, produced through pyrolysis of woody materials, agricultural wastes, green waste and animal manures and have 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 (Malinska *et al*., 2014) [24] and have pronounced effects on soil physico-chemical (Cross and Sohi, 2011) and biological properties (Lehmann *et al*., 2011). Carpet waste is another waste protein-rich product (Zheljazkov, 2005) [36] and can be used as organic manure in the soil after proper Composting (Plat *et al.*, 1984) [27]. The enrichment of composting material with mineral nutrients not only enhances the rate of decomposition but also improves the nutrient status of the compost. In the recent past some studies have been conducted to improve the decomposition rate during composting by adding fertilizers (Enwezer, 1976) [12], and inoculation with organisms (Wani and Shinde, 1976) [35].

Wheat (*Triticum aestivum* L.) is the second most important food crop of India. The combined and balanced used of biochar based enriched manure and NPK fertilizers at proper time plays an important role in wheat production. Keeping these facts in view, an experiment was conducted to assess the effect of biochar based enriched manures on yield attributes and yield of wheat at different levels of fertilizers.

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 25014' and 25023'N latitude and 82056' and 83030'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, P2O5 and K2O 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

Number of tillers m^{-1} row length

The number of tillers m^{-1} row length influenced by different levels of fertilizers and biochar based manures are presented in table 1. From the data, it is evident that there was a significant increase in number of tillers m^{-1} row length with the application of fertilizers and biochar based manures in both the years.

The results pertaining to the effect of RDF levels, revealed that the increasing doses of fertilizer application increased the total number of tillers at the all the stages i.e. 30, 60 and 90 DAS and at harvesting stage. After 30 DAS, the number of tillers m^{-1} row length decreases up to 90 DAS in both the years (Table 1). Application of 100% RDF (RDF_{100}) produced the maximum number of tillers, 67.16 and 68.88 at 30 DAS, 104.20 and 101.94 at 60 DAS, 95.21 and 97.41 at 90 DAS, and 81.23 and 83.60 at harvesting stage during 2013-14 and 2014-15, respectively. The minimum number of tillers m^{-1} row length of wheat was recorded with control (RDF_0). The maximum number of tillers due to application of 100% NPK increased by 32.82 and 31.01% at 30 DAS, 19.79 and 20.36% at 60 DAS, 22.06 and 21.36% at 90 DAS and 26.92 and 25.99 at harvesting stage over the control during 2013- 14 and 2014-15, respectively. The increase in number of tillers was might be due to increased rate of fertilizer, which, led to greater stimulation of vegetative growth. All fertility levels significantly affected vegetative and reproductive growth of the plants depending upon the availability of needed nutrition which leads to proportional increase in tillers. Singh *et al*. (2007) [30] suggest that ineffective tillers died with the time of growth and only effective tillers are remained. Therefore, decrease in number of tillers was observed at harvesting stage. Perusal of data revealed that number of tillers m^{-1} row length of wheat also influenced due to different levels of biochar based manures. The lowest number of tillers due to no manure treatment was 55.35, 57.36 at 30 DAS, 92.69, 90.40 at 60 DAS, 83.66, 85.75 at 90 DAS and 69.65, 72.00 at harvesting stage during respective years of 2013-14 and 2014-15 (Table 1). The maximum number of tillers due to application biochar composted with carpet waste in 2:1 ratio and enriched with PGPR consortium (BM_6), were 62.50, 64.50 at 30 DAS, 99.56, 97.28 at 60 DAS, 90.57, 92.90 at 90 DAS, and 76.54, 78.89 at harvesting stage which was statistically at par with number of tillers due to application biochar composted with carpet waste in 2:1 ratio (BM_5). In comparison to treatment BM_0, treatment BM_6 increased tillers by 12.93 and 12.45% at 30 DAS, 7.41 and 7.61% at 60 DAS, 8.26 and 8.35% at 90 DAS and 9.89 and 9.58 at harvesting stage in respective years of 2013-14 and 2014-15. Significant increase in number of tillers m^{-1} row length was might be due to the availability of essential elements to the wheat crop in sufficient amount by biochar and carpet waste in manures because biochar as a component of compost can have synergistic benefits and increase microbial activity and reduce nutrient losses during composting, undergoing composting with carpet waste helps to charge the biochar with nutrients. Singhal *et al.* (2017) [31] reported significant increase in yield of rice due to beneficial effect of FYM, carpet waste and PGPR application.

However, the interaction effect of fertilizers × biochar based manures on number of tillers m^{-1} row length of wheat was found to be non-significant at all stages and in both the years (Table 1).

Number of grains spike^{-1}

It is evident that the number of grains spike^{-1} recorded at maturity of wheat significantly influenced with different fertility levels and biochar based enriched manures have been presented in table 2. Number of grains spike^{-1} significantly increased by different fertility levels and biochar based enriched manures over control during both the years.

The maximum number of grains spike^{-1} observed with the application of 100% RDF. The number of grains spike^{-1} due to treatment of RDF_{50} and RDF_{100} increased by 21.16 and 37.16% in rabi 2013-14 and by 21.17 and 37.14% in rabi 2014-15, respectively over control (RDF_0) (Table 2). These results are in agreement with Singh *et al.*, 2008 [29].

Among the treatments of biochar based enriched manures, treatment BM_6 (biochar composted with carpet waste in ratio of 2:1 and enriched with PGPR consortium) recorded the maximum number of grains per spike (39.50 and 39.74) which was significantly superior over BM_0 (control) but statistically at par with treatment BM_5 (biochar composted with carpet waste in ratio of 2:1) and BM_4 (biochar composted with carpet waste in ratio of 4:1 and enriched with PGPR consortium) (Table 2). Biochar based manures BM_1, BM_2, BM_3, BM_4, BM_5, and BM_6 increases the grains per spike to the extent of 1.42 1.33, 4,94, 10.05, 11.24 and 11.94% in first year and 1.18, 1.56, 5.04, 10.64, 11.36, and 11.95% in second year, respectively. These results are in agreement with Thavanesan and Seran (2018) [33] who reported that the application of rice straw and husk biochar in soil, increased the numbers of tillers, number of filled grains per panicle, grain weight per panicle and hundred grain weight of rice. Similar results were also reported by Chen *et al.* (2016) [9] who found that biochar increased grains per panicle through promoting rice grain filling under temperate climate conditions.

The interaction effect of fertilizer levels and biochar based manures on number of grains spike^{-1} of wheat was found to be statistically significant in both the years (Table 2). The grains per spike of wheat influenced due to different levels of fertilizers and biochar based manures causing it to vary in the range of 29.75 to 44.66 in rabi 2013-14 and 30.04 to 45.14 in rabi 2014-15, respectively. The maximum grains per spike of wheat were 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 50.11% in rabi 2013-14 and 50.26% in rabi 2014-15, respectively over control ($RDF_0 \times BM_0$). Ahmad *et al.* (2016) [2] who reported positive effect of biochar application on yield and agronomic yield attributes of wheat and found that biochar was more efficient when supplemented with recommended dose of chemical fertilizer and micronutrients. These results confirmed the results of this study, which reveals that biochar yields highest impact when used along with recommended dose of N, P, K and micronutrients (Arif *et al.*, 2012) [5].

Test weight (g)

It is evident that the test weight recorded at maturity of wheat significantly influenced with different fertility levels and biochar based enriched manures have been presented in table 2. Test weight was significantly increased by different fertility levels and biochar based enriched manures over control during both the years.

Results pertaining to the effect of RDF levels on test weight of wheat have been presented in table 2. The test weight of grain increased significantly with increasing levels of the fertilizer application (RDF). The values 33.56, 40.17 and 45.16g in 2013-14 and 33.78, 40.49 and 45.48g in 2014-15, respectively obtained with 0, 50 and 100% RDF. The doses of 50 and 100% NPK were able to increase the test weight over control by 19.70 and 34.56% during 2013-14 and 19.85 and 34.63% during 2014-15, respectively. Similar results have been also reported by Tetarwal *et al.* (2011) [32] and Kachroo and Razan (2006) [19], they reported that this increase was owing to higher amount of fertilizer, which increased the nutritional acquisition and hence forth resulted in more nutrient uptake and increased the meristematic activity of the plant.

Among the treatments of biochar based enriched manures, significantly higher values of test weight of wheat 41.90 and 42.02g were recorded with treatment BM_6 (biochar composted with carpet waste in ratio of 2:1 and enriched with PGPR consortium) when compared with their control (37.34 and 37.64g) in year 2013-14 and year 2014-15 respectively (Table 2). Biochar based manures BM_1, BM_2, BM_3, BM_4, BM_5 and BM_6 increases the test weight to the extent of 1.12, 1.38, 5.10, 10.58, 11.47 and 12.23% in first year and 1.18, 1.36, 5.15, 10.65 11.09 and 11.61% in second year, respectively. Iqbal (2017) [16] reported that yield parameters of wheat like spike length, thousand grain weight, grain yield and straw yield were higher with application of rice straw biochar only compared to control. These results agreement with Inyang *et al.* (2010) [15] who reported that increasing biochar application significantly increased the 1000 grains weight.

The interaction effect of fertilizer levels and biochar based manures on test weight of wheat was found to be statistically significant in both the years (Table 2). The test weight of wheat influenced due to different levels of fertilizers and biochar based manures causing it to vary in the range of 31.84 to 47.13g in rabi 2013-14 and 32.07 to 47.37g in rabi 2014-15, respectively. The maximum test weight 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 test weight due to the treatment of $RDF_{100} \times BM_6$, increased by 48.02% in rabi 2013-14 and 47.70% in rabi 2014-15 over control ($RDF_0 \times BM_0$), respectively. Ahmad *et al.* (2016) [2] also reported positive effect of biochar application on yield and agronomic yield attributes of wheat and found that biochar was more efficient when supplemented with recommended dose of chemical fertilizer and micronutrients. These results confirmed the results of this study, which reveals that biochar yields highest impact when used along with recommended dose of N, P, K and micronutrients (Arif *et al.*, 2012) [5].

Grain yield (q ha^{-1})

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) [7]. 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, 11]. 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) [26]; 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. 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) [13, 14, 22] increases in soil microbial biomass and activity (Biederman and Harpole, 2013) [8] 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) [23] 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 ($RDF_0 \times BM_0$), respectively. Results concur with the findings of Alburquerque *et al*. (2013) [3] 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.

Conclusions

On the basis of results it can be concluded that the addition of fertilizers and biochar based manures had a positive effect on number of tillers m^{-1} row length, number of grains spike^{-1}, test weight and grain yield of wheat crop. The application of biochar based enriched manures composted with carpet waste in ratio of 2:1 along with enrichment of PGPR consortium in two different ratios had significantly better response on number of tillers m^{-1} row length, number of grains spike^{-1}, test weight and grain yield of wheat which was comparable with yield of BM_5 in both the years while among the NPK levels, 50, 100% NPK of recommended doses; significantly increased plant yield attributes like number of tillers No. of grains/ear head, test weight (1000 seed) and grain yield of wheat over the values of these parameters obtained in respective control. 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.

Acknowledgements

I would like to gratefully acknowledge to the Ministry of Science and Technology, Department of Science and Technology (DST-INSPIRE) for financial assistance.

Table 1: Effect of RDF and biochar enriched manure on number of tillers m^{-1} row length of wheat during *rabi* season of 2013- 14 and 2014-15.

Treatments	Number of tillers m^{-1} row length							
	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	50.57	52.57	86.99	84.69	78.00	80.27	64.01	66.36
RDF_{50}	58.83	60.82	97.58	95.33	88.54	90.68	74.55	76.90
RDF_{100}	67.16	68.88	104.20	101.94	95.21	97.41	81.23	83.60
SEm±	0.35	0.38	0.39	0.41	0.45	0.47	0.37	0.38
CD (P = 0.05)	1.00	1.09	1.11	1.16	1.29	1.34	1.05	1.10
Factor – II BM								
BM_0	55.35	57.36	92.69	90.40	83.66	85.75	69.65	72.00
BM_1	56.02	58.03	93.46	91.14	84.49	86.65	70.50	72.84
BM_2	56.77	58.78	94.22	91.96	85.21	87.41	71.25	73.64
BM_3	58.20	60.19	95.93	93.76	86.93	89.13	73.02	75.36
BM_4	61.31	62.63	98.75	96.45	89.74	91.96	75.74	78.10
BM_5	61.83	63.82	99.20	96.91	90.17	92.38	76.15	78.52
BM_6	62.50	64.50	99.56	97.28	90.57	92.90	76.54	78.89
SEm±	0.54	0.58	0.59	0.62	0.69	0.72	0.56	0.59
CD (P = 0.05)	1.53	1.67	1.69	1.77	1.96	2.05	1.61	1.68
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 enriched manure Number of grains spike^{-1}, Test weight (g) and Grain yield (q ha^{-1}) of wheat during *rabi* season of 2013- 14 and 2014-15.

Treatments	Number of grains spike^{-1}		Test weight (g)		Grain yield (q ha^{-1})	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Factor - I RDF						
RDF_0	31.29	31.55	33.56	33.78	25.29	26.76
RDF_{50}	37.92	38.22	40.17	40.49	39.80	41.31
RDF_{100}	43.02	43.26	45.16	45.48	48.62	50.11
SEm±	0.16	0.18	0.10	0.12	0.30	0.27
CD (P = 0.05)	0.46	0.53	0.28	0.35	0.86	0.65
Factor – II BM						
BM_0	35.27	35.50	37.34	37.64	33.58	34.99
BM_1	35.77	35.92	37.75	38.09	33.95	35.43
BM_2	36.24	36.47	38.27	38.60	35.20	36.72
BM_3	37.02	37.29	39.24	39.59	37.49	39.02
BM_4	38.82	39.28	41.28	41.65	41.06	42.56
BM_5	39.24	39.53	41.62	41.82	41.66	43.13
BM_6	39.50	39.74	41.90	42.02	42.38	43.89
SEm±	0.25	0.28	0.15	0.18	0.46	0.35
CD (P = 0.05)	0.71	0.80	0.43	0.53	1.32	0.99
RDF × B	S	S	S	S	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.

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