The Pharma Innovation Journal 2022; 11(7): 3590-3594

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 3590-3594

www.thepharmajournal.com
Received: 02-03-2022
Accepted: 10-06-2022

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Effect of fertility levels and biochar on yield of wheat (*Triticum aestivum* L.)

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Abstract
Aim: The present investigation was carried out to study the effect of fertility levels and biochar on yield of wheat (*Triticum aestivum* L.).
Methodology: The experiment was undertaken during *Rabi* 2017 and 2018 at Instructional Farm (Agronomy), Rajasthan College of agriculture, Udaipur (Rajasthan). The treatments comprised of four levels of fertility i.e. control, 75% RDF, 100% RDF, 125% RDF and Biochar (BC) i.e. control, BC @ 4.0, 8.0 and 12.0 t ha^{-1} and. The experiment was laid out in a factorial randomized block design with three replications.
Results: The increasing levels of 125% RDF and Biochar 12 t ha^{-1} and, respectively increased significantly the grain yield, straw yield and biological yield of wheat. However, the combined application of 125% RDF and Biochar @ 12 t ha^{-1} was found to record significantly grain yield, straw yield and biological yield.
Interpretation: The application of application of 125% RDF and Biochar @ 12 t ha^{-1} along with the recommended dose of fertilizer results in grain yield, straw yield and biological yield of wheat.

Keywords: Fertility, biochar, wheat, fertility, *Triticum aestivum* L.

Introduction

Wheat (*Triticum Aestivum* L.) is the most important stable food grain crop of the region. It has immense importance in Indian diet and major portion of the grains produced is used for "chapatti" making. It is the main source of protein and calories for a large section of Indian population. At present the per capita availability of food grains is around 170kg per year (156 kg cereals + 14kg pulses). During 2016-17 in India, wheat occupied over 30.42 million hectare area with a production level of about 92.29 million tonnes of grain with a productivity of 30.34 q ha^{-1}. In the state of Rajasthan, wheat occupied an area of 3.10 million hectare and production 9.87 million tonnes of grain with a productivity of 31.75q ha^{-1} (FAI, 2020-21). Soil fertility degradation, caused by erosion and depletion or imbalance of organic matter/nutrients, is affecting world agricultural productivity. Inorganic fertilizers have played a significant role in increasing crop production since the "green revolution" (Lui *et al.*, 2010); however, they are not a sustainable solution for maintenance of crop yields. Organic amendments, such as compost and biochar, could therefore be useful tools to sustainably maintain or increase soil organic matter, preserving and improving soil fertility and crop yield. Nitrogen (N) is a vital plant nutrient and a major determining factor required for wheat production. It is very essential for plant growth and makes up 1–4% of dry matter of the plants. Its availability in sufficient quantity throughout the growing season is essential for optimum wheat growth. It also mediates the utilization of phosphorus, potassium, and other elements in plants (Brady, 1984) [4]. Phosphorus is another essential nutrient required to increase wheat yield. Consequently, the lack of phosphorus is as important as the lack of nitrogen limiting wheat performance. Phosphorus plays an important part in many physiological processes that occur within a developing and maturing plant. Phosphorus is an essential factor for cell division because it is a constituent element of nucleoproteins which are involved in the cell reproduction processes (Bashir, 2012) [3]. Potassium is an essential nutrient and is also the most abundant cation in plants. It plays essential roles in enzyme activation, protein synthesis, photosynthesis, osmo-regulation, stomatal movement, energy transfer, phloem transport, cation-anion balance, and stress resistance.

Biochar is a black carbon manufactured through pyrolysis of biomass (Lehmann *et al.*, 2006) [14]; 'the high carbon materials produced from the slow pyrolysis (heating in the absence of oxygen) of biomass' (Chan *et al*., 2007); and a fine grained and porous substance, similar in its appearance to charcoal produced by natural burning or by the combustion of biomass under oxygen-limited conditions (Sohi *et al*., 2009) [25]. In fact, it is a product of biomass obtained from heating in a suitable temperature regime in the absence of oxygen (the process of fast or slow pyrolysis) or from a gasification system. Biochar is a solid by product resulting from partial pyrolysis, where biomass is heated with a minimum or absence of oxygen, the chemical composition of biochar is Carbon (98.58%), Hydrogen (0.4%), Nitrogen (1%), Sulphur (0.02%). Biochar addition to soils significantly decreases soil bulk density, increased microbial respiration as well CO_2 and CH_4 emissions (Wang *et al*., 2012). They also found that a decreased N_2O emissions and increase organic C by addition of biochar. The term 'biochar' was invented by the late Peter Read, a New Zealander, by describing it as a soil amendment for agricultural purpose but it was called 'agrichar' until an Australian Company trademarked it and it was the first ingredient in the Terra Preta recipe (Bates, 2010). Lehmann and Joseph (2012) [15] have distinguished the term biochar from charcoal in that it is charred organic matter that is applied to soil not only to improve soil properties but also to promote soil remediation or other environmental services while the charcoal is used as fuel or source of heat, as a filter, as a reluctant in iron-making or as a colouring agent in industry or art. Biochar is a carbon-rich solid material which is produced during pyrolysis, by thermal degradation of biomass under limited supply of oxygen and at relatively low temperature. It can be used as a soil amendment for increasing the agronomic productivity in the low potential soils. Furthermore it is identified as a soil conditioner, as biochar does not contain high levels of nutrients (Glaser *et al*., 2002) [9]. Biochar can be produced using a wide range of biomass sources including woody materials, agricultural wastes such as coconut husks, green waste, and animal manure. Application of biochar to soil improves soil quality parameters such as soil pH, CEC, total C, total N, available P, water holding capacity, exchangeable captions, nutrient cycling and attract more beneficial fungi and microbes (Laird *et al.*, 2010). Furthermore, biochar is beneficial in decreasing available soil Al and soil bulk density as well. These beneficial effects of biochar are important in agricultural practices in order to increase biomass yield and crops yield under variable soil and fertile conditions. According to Ippolito *et al.* (2012) [12] application of biochar into degraded or sandy soils where low nutrient or water holding capacity seems to be more beneficial compared to addition of biochar into highly productive soils. The efficiency of native nutrients is further improved when these are used in conjunction with organic manures especially when the soils are belonging to arid and semi-arid areas having coarse texture, low in organic carbon, low moisture retention and microbial activity. Improvement in available nutrient status of the soil with the incorporation of biochar alone or integration with chemical fertilizers could be attributed to the slow decomposition of organic manure and enhancing soil biological activity. These in turn provides congenial physical condition, conserves soil nitrogen and increases the availability of other nutrients. The mineralization of nutrients in the rhizosphere improves crop growth and provides a better source-sink relationship by enhancing synthesis and allocation of metabolites to reproductive organs.

Materials and Methods

Experimental site and soil: The experiment was conducted during R*abi* 2017 and 2018 at the Instructional Farm (Agronomy), Rajasthan College of agriculture, Udaipur situated at an altitude of 579.5 meters above mean sea level and at $24^0$34' latitude and $73^0$42' longitude. The region falls under agro-climatic zone-IVa (Sub- humid Southern Plain and Aravalli Hills) of Rajasthan. The wheat crop experienced maximum and minimum temperature ranged between 23.47 to 37.85 °C and 5.21 to 19.83 ºC during *Rabi* 2017-18, respectively. Soil of the experiment was clay loam in texture, saline in reaction, medium in organic matter; low in available N, P, high in available K and low in available zinc (Table 1).

Table 1: Fertility status of the soil of experimental site

Properties	Value
pH	8.22+0.16
Electrical conductivity (DS m^{-1})	0.56+0.01
Organic carbon (%)	6.18+0.01
Available N (kg ha^{-1})	273.43+5.45
Available P_2O_5 (kg ha^{-1})	17.25+0.32
Available K_2O (kg ha^{-1})	354.32+7.12
Available Zn (mg kg^{-1})	0.569+0.012

Preparation of BC: In the present experimental field legume biochar was used through slow pyrolysis in biochar production system (Pratap Kiln) which was prepared in the CTAE, Udaipur. Biochar was being made by the partial oxidation of the biomass at high temperature to convert into a carbon - rich porous substance. Haulms of legume were fed to the pyrolysis reactor in oxygen limiting condition where the temperature goes up to 450 ^{0}C for the period of 4 minutes. The process occurs in 3 stages, first where the moisture content of the biomass was reduce to <10 percent at the temperature of 180 ^{0}C, second where the biochar production starts with the breakdown of hemicellulose and cellulose at the temperature range of 180-360 ^{0}C and last stage where lignin breaks down at the temperature of 450 ^{0}C. In slow pyrolysis the final yield of the converted biochar goes up to 35 per cent which was more in comparison to the fast pyrolysis.

Table 2: Nutrient contents of Biochar at the final stage of decomposition

Nutrient content	Value
N (%)	2.7
P (%)	0.26
K (%)	1.26
Zn (ppm)	35.2

Experimental design and treatments: The experiment was laid out in factorial randomized block and replicated thrice in the plot size of 2.25 m x 3.0 m (6.75 m^2). The treatments comprised of four levels of fertility *viz*., control, 75% RDF, 100% RDF and 125% RDF and Biochar level *viz*., control, 4.0, 8.0 and 12.0 t ha^{-1} and The wheat var. Raj-4037 was sown in lines 22.5 cm apart. As per the treatments, whole quantity of Biochar was broadcasted and incorporated in to the soil at the time of sowing. The recommended dose of nitrogen (120 kg ha^{-1}) was applied in three equal splits, the half as basal and the remaining half was top dressed at the time of first irrigation. The basal dose was applied through urea after adjusting the quantity supplied through diammonium phosphate. The whole quantity of phosphorus (60kgha^{-1}) through diammonium phosphate and potassium (40 kg ha^{-1}) through muriate of potash. The test crop was sown on 26th Nov 2017 (Ist crop), 27th Dec, 2018 (IInd crop) and harvested on 8th April, 2017 (Ist crop) and 10th April, 2018 (IInd crop), respectively. The seeds obtained from the produce of individual plot were recorded as seed yield kg plot^{-1} and later it was converted into kg ha^{-1}.

Observations recorded: The observations on growth parameter (number of tillers per meters length) and yield attributes (test weight) were recorded as per the standard method. The data obtained from various characters under study were analyzed by the method of analysis of variance as described by (Panse and Sukhatme, 1985) [19].

Statistical analysis: The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique for a factorial randomized block design. The results are presented at 5% level of significance (P = 0.05).

Results and Discussion

Yield

The significantly maximum seed yield (5195.42 kg ha^{-1}), straw yield (6339.63 kg ha^{-1}) and biological yield (11535.05 kg ha^{-1}) was recorded under F_3 (125% RDF) followed by F_2 (100% RDF) and F_1 (75% RDF) treatments as compared to control (F_0) during in pooled basis, respectively. The per cent increase in seed, straw and biological yield of wheat were in order of 36.00, 32.54 and 34.08 in pooled analysis due to application of 100% RDF((F_3), 100% RDF (F_2) and 75% RDF (F_1) as compared to control (F_0), respectively (Table 3). The improvement in both growth and yield attributes which in turn might be increased the yield of wheat. The increase in seed, Stover and biological yield might be due to better nutritional status of the crop in the soil as evidenced by their uptake in the plant. The increased supply of nitrogen, phosphorus and potassium their higher uptake by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters and resulted in increased yields (Harender *et al*., 2018 [10] and Reddy *et al*., 2018) [21]. The significant improvement in seed, Stover and biological yield under the influence of application of fertilizer was largely a function of improved growth and the consequent increase in different yield and yield attributes (Abrol *et al*., 2007) [1]. Similar results were also reported by Jha *et al*. (2015) [13] and Belay and Adare (2020) [5]. The significant increase in straw yield due to application of 125% RDF could be ascribed to their direct influence on straw production by virtue of increased photosynthetic efficiency (Kumar *et al*., 2015). The profound influence of nutrient application on biological yield seems to be on account of its influence on vegetative (Stover) and reproductive growth (seed) (Kumar *et al*., 2017). Similar results were also reported by Vimalan *et al.* (2019) [26] and Belay and Adare (2020) [5]. The application of fertility levels and biochar enhanced the seed, straw and biological yield of maize significantly during both the years as well as in pooled analysis. The significantly maximum seed yield (5147.98kg ha^{-1}), straw yield (6322.89kg ha^{-1}) and biological yield (11470.88kg ha^{-1}) ware observed under the treatment BC@ 12t ha^{-1} during pooled analysis (Table 3). The increase in seed, straw and biological yield was the extent of 16.28, 28.47 and 33.49 per cent, 15.60, 28.16 and 31.21 per cent and 15.90, 28.29 and 32.22 per cent in pooled analysis with the application of BC@ 4, 8 and 12 t ha^{-1}, respectively as compared to control. The significant increase in seed, straw and biological yield under the influence This might be due to the vigorous vegetative growth resulting in higher photosynthates production and translocation from source to the sink which is apparent on reproductive growth *viz.* number of pods plant^{-1}, seed weight plant^{-1} and 1000 seed weight which were the important yield attributes having significant positive effect on seed yield. Rondon *et al.* (2007) [22] got the similar results where bean yield was increased by 46% and biological yield by 39% over the control. The similar results were found by Hiama *et al.* (2019) [11] who observed that soil application of 2.5 and 5 t ha^{-1} biochar enhanced the nutrient levels of the soil accounting for the increase in yield attributes *viz.* the above ground biomass, pod weight and grain yield over the control. A recent meta-analysis by Ye *et al.* (2020) also observed that biochar application along with organic and inorganic fertilizers led to higher crop yields. In a similar study there was significant increase in yield of maize in biochar amended plots (Arif *et al.* 2021) [2].

Table 3: Effect of fertility levels and biochar on seed, straw and biological yield of wheat

Treatment	Seed yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Biological yield (kg ha^{-1})		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
Fertility levels ((kg ha^{-1})									
Control (F_0)	3773.47	3866.97	3820.22	4776.98	4789.48	4783.23	8550.45	8656.45	8603.45
75% RDF(F_1)	4401.16	4495.92	4448.54	5514.35	5528.33	5521.34	9915.51	10024.24	9969.88
100% RDF (F_2)	4931.21	5027.02	4979.11	6236.43	6251.85	6244.14	11167.63	11278.87	11223.25
125% RDF (F_3)	5147.30	5243.54	5195.42	6331.82	6347.43	6339.63	11479.12	11590.97	11535.05
S.Em+	76.79	76.94	39.03	74.88	75.02	38.06	128.43	128.68	65.28
CD (P=0.05)	221.79	222.23	110.42	216.26	216.69	107.66	370.93	371.67	184.67
Biochar (t ha^{-1})									
Control (BC_0)	3809.83	3903.40	3856.62	4812.71	4825.28	4818.99	8622.54	8728.68	8675.61
4 (BC_1)	4436.90	4531.73	4484.31	5563.60	5577.68	5570.64	10000.50	10109.40	10054.95
8 (BC_2)	4906.49	5002.26	4954.38	6168.17	6183.45	6175.81	11074.66	11185.71	11130.18
12 (BC_3)	5099.91	5196.06	5147.98	6315.10	6330.68	6322.89	11415.01	11526.74	11470.88
S.Em+	76.79	76.94	39.03	74.88	75.02	38.06	128.43	128.68	65.28
CD (P=0.05)	221.79	222.23	110.42	216.26	216.69	107.66	370.93	371.67	184.67

Interaction effect of PEC and fertility on seed, Stover and biological yield

The combined effect of fertility levels and biochar showed positive interaction on seed yield of wheat in both the years and in pooled analysis (Table 4, 5, 6). Application of fertility on each levels of fertility resulted in significant increase in seed yield (5646.22kg ha^{-1}), straw yield (6860.20 kg ha^{-1}) and biological yield (12506.42kg ha^{-1}) of wheat with maximum was found under 125% RDF + 12 t biochar ha^{-1} (F_3 BC_3) while the minimum under control (F_0BC_0) during in pooled analysis, respectively. The increase in yield is associated with the release of macro-micronutrients during the course of microbial decomposition. The biochar also act as source of energy for soil micro flora, which bring about transformation of inorganic nutrients held in the form of fertilizers in a form that is readily utilized by growing plants. The beneficial effect of biochar addition is also related to improvement in soil physical properties (Devi *et al*., 2018 [7] and Patil *et al*., 2018) [20]. The beneficial response of biochar to yield might also be attributed to the better availability of plant nutrients in sufficient amounts throughout the growth period and especially at critical crop growth stage, which resulted in better plant vigor and superior yield attributes. Combined use of biochar and fertilizer has been found to be promising not only in maintaining higher productivity but also in stable crop yields (Verma *et al*., 2018 and Pandiyana *et al*., 2020) [18]. The interaction effect on the seed yield could be explained by the positive coupling action of fertility on below ground modifications to increase the nutrient availability and biochar on the above ground control on the stomatal activities and enhanced photosynthesis through higher light use efficiency (Maghsoudi *et al.* 2016) [17] increasing the seed production of fenugreek. The higher growth and development due to the synergistic effect of biochar and silicon (Sattar *et al*. 2020) [23] led to higher seed yield. Similar results were found by Seleiman *et al.* (2019) [24].

Table 4: Interaction effect of fertility levels and biochar on seed yield of wheat

Treatments	2017				2018				Pooled			
	Seed yield (kg ha^{-1})											
	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3
BC_0	2228.42	3013.02	3609.22	3958.74	2246.12	3043.97	3669.66	4037.04	2237.27	3028.49	3639.44	3997.89
BC_1	3122.18	3579.06	3701.81	4052.69	3173.76	3637.33	3780.10	4140.02	3147.97	3608.20	3740.96	4096.36
BC_2	3638.02	3757.65	4253.55	4553.95	3699.91	3819.50	4342.88	4647.26	3668.97	3788.58	4298.22	4600.61
BC_3	3816.78	4147.50	4661.96	4939.43	3882.25	4217.14	4759.45	5037.76	3849.52	4182.32	4710.71	4988.59
S.Em+	153.58				153.89				78.07			
CD (*P* = 0.05)	443.58				444.48				220.84			

Table 5: Interaction effect of fertility levels and biochar on straw yield of wheat

Treatments	2017				2018				Pooled			
	Straw yield (kg ha^{-1})											
	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3
BC_0	3370.87	4610.94	5582.89	5686.12	3380.57	4623.11	5597.00	5700.44	3375.72	4617.02	5589.95	5693.28
BC_1	4779.01	5360.17	6006.10	6109.12	4791.52	5373.84	6021.06	6124.29	4785.26	5367.00	6013.58	6116.70
BC_2	5406.40	5975.14	6610.96	6680.16	5420.17	5990.04	6627.13	6696.47	5413.28	5982.59	6619.04	6688.32
BC_3	5551.64	6111.14	6745.76	6851.87	5565.69	6126.32	6762.20	6868.52	5558.66	6118.73	6753.98	6860.20
S.Em+	149.51				150.05				76.12			
CD (*P* = 0.05)	432.51				433.38				215.33			

Table 6: Interaction effect of fertility levels and biochar on biological yield of wheat

Treatments	2017				2018				Pooled			
	Biological yield (kg ha^{-1})											
	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3
BC_0	5889.63	8259.48	10011.25	10329.79	5990.31	8364.90	10120.17	10439.35	5939.97	8312.19	10065.71	10384.57
BC_1	8581.31	9634.16	10734.02	11052.52	8687.37	9742.33	10844.38	11163.53	8634.34	9688.25	10789.20	11108.02
BC_2	9692.80	10720.79	11800.43	12084.63	9801.08	10831.13	11912.93	12197.70	9746.94	10775.96	11856.68	12141.17
BC_3	10038.07	11047.61	12124.84	12449.52	10147.05	11158.61	12237.99	12563.32	10092.56	11103.11	12181.41	12506.42
S.Em+	256.86				257.37				130.56			
CD (*P* = 0.05)	741.85				743.34				369.33			

Conclusion

On the basis of experimental finding, it can be concluded that the application of 125% RDF and Biochar @ 12 t ha^{-1} results in significantly higher yield of wheat.

References

1. Abrol V, Sankar GRM, Singh M, Jaiswal JS. Optimization of fertilizer requirement of maize based on yield and rainfall variation from permanent manurial trials under dry-sub humid Inceptisol. Indian Journal of Dryland Agriculture Research and Development. 2007;22:15-21.
2. Arif M, Ali S, Ilyas M. Enhancing phosphorus availability, soil organic carbon, maize productivity and farm profitability through biochar and organic–inorganic fertilizers in an irrigated maize agro ecosystem under semi-arid climate. soil use management. 2021;37:104–119.
3. Bashir S. Response of brown sarsen to NPK application under early, normal and late sown conditions. Ph.D. Thesis, Division of Agronomy, SKUAST-Kashmir, 2012.
4. Brady NC. The Nature and Properties of Soils,

Macmillan Publishing Company, New York, USA, 1984.
5. Belay M, Adare K. Response of growth, yield components, and yield of hybrid maize (*Zea mays* L.) varieties to newly introduce blended NPS and N fertilizer rates at Haramaya, Eastern Ethiopia. Cogent Food & Agriculture. 2020;6(1):1771115.
6. Chan K, Dorahy C, Tyler S. Determining the agronomic value of composts produced from garden organics from metropolitan areas of new south wales, Australia. Australian Journal of Experimental Agriculture. 2007;47(11):1377-1381.
7. Devi YS, Luikham E, Singh MS, Lhungdim J, Chanu YB. Influence of integrated nitrogen management practices on yield attributes, yield, nutrient uptake and economics of hybrid maize *Zea*, 2018.
8. FAI. Fertiliser Statistics. The Fertilizer Association of India, New Delhi, 2020-21.
9. Glaser B, Lehmann J and Zech W. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal - A review. Biology and Fertility of Soils. 2002;35:219-230.
10. Harender HS, Singh N, Rathi N, Malik K, Kavinder. Influence of different dose of plant nutrient on growth rate, nutrient uptake and yield of maize (*Zea mays* L.). International Journal of Pure and Applied Bioscience. 2018;6(1):795-801.
11. Hiama PD, Ewusi-Mensah N, Logah V. Nutrient uptake and biological nitrogen fixation in cowpea under biochar-phosphorus interaction. The Journal of Animal and Plant Science. 2019;29(6):1654-1663.
12. Ippolito JA, Laird DA, Busscher WJ. Environmental benefits of biochar. Journal of Environmental Quality. 2012;41:967-972.
13. Jha DP, Sharma SK, Amarawat T. Effect of organic and inorganic sources of nutrients on yield and economics of blackgram (*Vigna mungo* L.) grown during Kharif. Agricultural Science Digest. 2015;35(3):224.
14. Lehmann J, Gaunt J, Rondon M. Bio-char sequestration in terrestrial ecosystems – A review, Mitigation and adaptation strategies for global change. 2006;11(2):395-419.
15. Lehmann J, Joseph S. Biochar for environmental management: An Introduction. In: Bio char for environmental management: science and technology. Lehmann J, Joseph S, Eds. Earth scan: London, 2012, 1-10.
16. Liu E, Yan C, Mei X. Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in north west China. Geoderma. 2010;158(3-4):173–180.
17. Maghsoudi K, Emam Y, Ashraf M. Foliar application of silicon at different growth stages alter growth and yield of selected wheat cultivars. Journal of Plant Nutrition. 2016;39(8):1194-1203.
18. Pandiyana VC, Balajib K, Sarava S, Shylajaa SG, Srinivasanc GR, Kiresee PR, *et al.* Effect of vermicompost on soil health and yield of sesamum (*Sesamum indicum* L.). Journal of Soil Science and Plant Nutrition. 2020;2:311-316.
19. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers. ICAR, New Delhi, 1985.
20. Patil P, Nagamani C, Reddy APK, Umamahesh V. Effect of integrated nutrient management on yield attributes, yield and quality of pearlmillet [*Pennisetum glaucum* (L.) R br. Emend. Stuntz]. International Journal of Chemical Studies. 2018;6(4):1098-1101.
21. Reddy U Vijayabhaskar, Reddy G Prabhakara, Reddy M, Srinivasa, Kavitha P. Effect of different nitrogen and phosphorus levels on growth and yield of maize during *Kharif* season. International Journal of Current Microbiology and Applied Sciences. 2018;7(1):3548-3555.
22. Rondon MA, Lehmann J, Ramirez J. Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with biochar additions. Biology and Fertility of Soils. 2007;43:699-708.
23. Sattar A, Sher A, Ijaz M. Interactive effect of biochar and silicon on improving morpho-physiological and biochemical attributes of maize by reducing drought hazards. Journal of Soil Science and Plant Nutrition. 2020;20:1819–1826.
24. Seleiman MF, Refay Y, Al-Suhaibani N, Al-Ashkar I, El-Hendawy S, Hafez EM. Integrative effects of rice-straw bio char and silicon on oil and seed quality, yield and physiological traits of *Helianthus Annuus* L. grown under water deficit stress. Agronomy. 2019;9(10): 637.
25. Sohi S, Lopez-Capel E, Krull E, Bol R. Biochar, climate change and soil: A review to guide future research, CSIRO land and water science report. 2009;5(9):17-31.
26. Vimalan B, Thiyageshwari S, Balakrishnan K, Rathinasamy A, Kumutha K. Influence of NPK fertilizers on yield and uptake of barnyard millet grain (*Echinochloa frumentacea* (Roxb.) Link) in Typical Rhodulstalf soil. Journal of Pharmacognosy and Phytochemistry. 2019;8(2):1164-1166.