International Journal of Advance Research in Science and Engineering
Vol. No.9, Issue No. 06, June 2020
www.ijarse.com
IJARSE
ISSN 2319 - 8354

Probing the impact of Biochar based amendments on growth-yield and soil fertility status of wheat crop in rice-wheat cropping system.

Anita Jaswal [1], Dr. Chandra Mohan Mehta [2]

[1](*Department of agronomy, Lovely Professional University, Punjab India*),

[2](*Department of agronomy, Lovely Professional University, Punjab India*)

Abstract:

The long term fertility of soil is maintained by the application of organic matter. Organic matteracts as a reservoir of metabolic energy which enhanced the soil biological processes. Two years field experiment was conducted at Lovely Professional University, Phagwara Punjab for probing the impact of Biochar based amendments on growth-yield and soil fertility status in rice-wheat cropping system. The experiment comprised with nine treatments and three replications. 50% RDF+50% FYM+10tonnes ha-^{1} biochar increased plant height(74.13cm),effective tillers(432m^{-2}) ,spikelet length(11.47cm) ,number of grains per spikelet(56),Chlorophyllcontent(46 SPADUNIT),test weight(45.31g) ,grain yield(4282kgha^{-1}) and biological yield(5032kgha^{-1}). The availability of N,P,K and organic carbon in soil were also increased with this treatment. Similarly,50%RDF+50%vermicompost+10tonnes ha-^{1} recorded significantly higher yield components ,grain yield, soil organic carbon ,P and K .All the Biochar amended plots improved wheat yield components .It is concluded that application of Bio char either alone or in combination with manures and synthetic fertilizers improved yield and yield components of wheat and soil qualityin rice-wheat cropping system.

Key words: *Biochar, soil physico chemical properties, synthetic fertilizers and organic manures*

1. **Introduction:**Cereals play an important role to meet the food demands of growing population specifically in developing countries where cereal based cropping system is only source of nutrition and calorie intake. Rice (*Oryza sativa*)-wheat (*Triticum aestivum*) are the major staple food crops consumed in Asian countries. Rice-wheat cropping system is the major cropping system that is followed in India. Wheat (*Triticum aestivum*) is one of the primary cereal crop cultivated worldwide and food for 2.5 billion world population (USDA, 2019). Wheat crop originated from South-western Asia and many species of wheat cultivated with common genus *Triticum.* India is the second largest producer of wheat worldwide. 30 million hectare acreage under the cultivation of wheat which produced 99.7 million tonnes with average productivity of 337 kg ha-1(USDA, 2019).Degradation of soil fertility and quick loss of nutrients are major problems for crop production (Jones *et al*., 2012). Inorganic fertilizer application is more as compared to organic manures due to quick release of nutrients.To increase the crop yield we cannot ignore the use of synthetic fertilizers which doubled the grain yield of crop (Widowati *et al*., 2011). But the use of synthetic fertilizers year after year increased for the same yield might be due to decrease in soil fertility. The sole application of fertilizers not only decreasing crop yield but also responsible

for soil deterioration and environmental problems (Liu *et al*., 2010). For sustainable crop production and to improve the soil physical chemical, biological properties it is critical to maintain threshold level of organic matter. Proper use of biomass by transforming into useful product which can be used as soil amendment is one method to manage the soil health and fertility(Murali *et al*., 2010).The recent availability of biomass in India is 500 million tons per year approximately. These crop residues are partially utilized due to various problems.in India 93 million tons of crop residues are burned every year. A fast way to clear agricultural field from residues is residue burning which helped in facilitating further land preparation (Punia *et al*., 2008). On the other hand, burning of residues leads to loss of valuable biomass and nutrients but also responsible for emission of toxic gases .In this regard, Biochar is a pyrolysis product of plant biomass provides a positive, multidimensional opportunity to convert agriculture residues from financial and environmental liability to valuable assets(Gebremedhin et al. (2015). To deal with this problem,the trending practices for increasing crop yield and nutrient use efficiency not at the cost of soil health is the integrated cop management by the use of organic manures and inorganic fertilizers along with organic material like Biochar.

By following 3R's credit strategies means application of fertilizer at right time, in right amount by right method increased the soil fertility (Manqiang *et al*., 2009). The selection of the source of nutrients such as FYM, poultry manure and vermicompost are the alternative to inorganic fertilizers because it provides nutrients to soil and maintain its quality(Ali *et al*., 2011).The addition of organic manures improved soil N and organic matter status which increases crop yieldThe previous research on use of Biochar showed that soil properties like pH,EC, CEC, bulk density, porosity, available N, P, K and organic carbon improved. Continuous use of Biochar increases the availability and retention of nutrients. Integrated use of bio char with FYM and N improves wheat nutrients uptake and soil N content (Ali *et al*., 2015). Likewise, it also enhances cation exchange capacity which then also increases nutrient retention capacity (Castaldi *et al*., 2011). Application of bio char accelerates nutrients uptake (Ali *etal*., 2015).NUE improved in bio char amended plots. It also affects the soil biological properties. The conversion of rice husk into Biochar should be promoted by local governments to enhance fertilizer use efficiency and promote the use of cost effective recycle agriculture waste (Elad *etal* ,2011). After the pyrolysis of rice husk at 600^0C temperature, the combination of organic and inorganic fertilizers made Si bonds which prevent degradation of carbon. The application of Biochar with fertilizers and manures increased the aeration of soil (Agboola and Moses 2015). The authors recommend that by use of organic materials the mineral fertilizer use efficiency increased in soil. Sole application of Biochar @25 t ha^{-1} is not substitute for usual fertilizer application without adding NPK and organic manures. The repeated application of N from inorganic fertilizers enhances the cost of production of wheat consequently reduction of farm income therefore alternative approaches are required to reduce reliance on chemical fertilizers and increase the use of organic materials as source of nutrients ((Sohi et al., 2010). The objective behind this study was thus to determine the effectiveness of bio char, manures and fertilizers, in particular and in various combinations on aspects of wheat yield and soil fertility in rice-wheat cropping systems..

2. Materials and Methods

2.1Site description and experimental details**:** The experiment was conducted at Agronomy research fields of Lovely Professional University, Phagwara, and Punjab to probe the impact of Biochar combined fertilizers on soil nutrient status in relation to growth and yield of rice-wheat cropping system. The agriculture farm is located at latitude 31.25^0N and longitude 75^0 E along with altitude of above mean sea level. Generally Rice-wheat cropping system followed in this area. The experiment was carried out an area of $600m^2$ having uniform topography with gentle slope and proper drainage.The experimental site enjoys subtropical climate wherehot winds during summer flow for longer time during day time and temperature remain high during night. The hottest months are May, June and July (mercury touches 49^0C) and temperature falls down in last week of July. The winter comes in October. December and January months are the coldest months.

The soils of the site where experiment was conducted are classified as coarse loamy mixed with hyperthermia family of Typic Haplustept. The soil was dug from the depth of 0-15cm and collected from different parts of experimental site and analysed for physical, chemical and biological properties. The experimental site contains high amount of sand (77%) and considered as sandy loamy soil. The results showed that soil is slightly acidic in nature, non-saline with low organic carbon, nitrogen and potassium content and medium phosphorous content. The experiment was conducted during Rabi Season of 2018-2019 and 2019-2020.The experiment was laid out in randomized complete block design with three replications and nine treatments. The total number of plots were 27.The different treatment combinations were T0 Control (no fertilizer),T1 100%RDF, T2 50%RDF + bio char, T3 50%RDF+25%FYM+bio char, T4 50%RDF+50%FYM+bio char, T5-50%RDF+ 25%Vermi-compost + bio char,T6 50%RDF+ 50%Vermi compost+ bio char,T7 50%RDF+ 25%poultry manure+ bio char, T8 50%RDF+50% poultry manure+ bio char.Recommended doses of fertilizers for wheat were vermi compost: 2.5 tonne ha-^{1}, poultry manure: 6 tonnes ha^{-1}, FYM: 10 tonne ha-^{1}, Rice straw bio char- 10 tonnes ha^{-1}, RDF (N: P2O5:K2O):120:60:60kg ha^{-1}).Farmyardmanure, vermicompost ,poultry manure and biochar were applied at sowing whilenitrogen in form of urea was applied in two splits, half at sowing and theremaining at tillering stage. Biochar was applied in firstyear of the experiment while its residual effect wasstudied in the second year. Phosphorous in the form ofsingle super phosphate (SSP) and potash in the form of Muriate of potash (MOP) was applied at sowing as basal dose. Biochar used in experiment was made from rice straw.PBW550 is the variety used for the experiment. The physico-chemical properties of theexperimental soil and bio char before the conduction of experiments are Sand-77%,10.9% Silt,13.1% .The soil is sandy loamy in texture.pH-6.18, Electrical conductivity(dsm^{-1})-0.18, Organic carbon (%)-0.47, Available N ($kgha^{-1}$)-147, Available P($kgha^{-1}$)-15.71, Available K($kgha^{-1}$)=172.

2.2 Observations recorded (crop related):The height of the highest tiller was recorded from 5 tagged plants from the base to the tip of the highest plant part by measuring tape. Average of 5 plants was taken to calculate mean plant height. The total tillers and productive tillers m^{-2} were counted. Highest leaf length measured from each plant which is considered as flag leaf length. Data on number of spike m^{-2} were recorded by counting total number of spikes in one meter row length. Gains from five randomly selected spikes of each treatment were threshed, counted and converted into average number of grains $spike^{-1}$. Thousand grains were counted at random from sample of each plot, weighed and were converted into thousand grain weight. Straw yield data were recorded by harvesting one square meter in each plot. The harvested crop was sun dried, weighed in kg and was then converted to kg ha^{-1}. Data regarding grain yield were recorded by weighing grains collected from the harvest of one meter square from each plot and were then converted to kg ha^{-1}.

2.3Laboratory analysis:The determination of soil organic carbon by Walkley-Black chromic acid wet oxidation method (Allison, 1965). Available nitrogen analysed by alkaline permanganate method by KEL Plus. Soil available phosphorus was determined by Olsen et al. (1954) and Jackson (1973) method, Available potassium was determined by Toth and Prince (1949) method. pH by pH meter and EC by EC meter followed the procedure of Jackson (1973).

2.4 Statistical analysis:The recorded data was tabulated treatment wise under three replications. The differences between the mean values were estimated by one way ANOVA (analysis of variance) with the SPSS 22 version software. To find out the efficient treatment Duncan's multiple range test (DMRT) a mean separation technique was applied with probability $p< 0.05$. Fisher's LSD test as post hoc test was used to test the significance of the variation components. The significant difference among the means was calculated on the basis of LSD (least significant difference) at 5% level of significance.

3. Results:

3.1 Effect of Biochar based amendments on growth and yield of wheat crop: Plant height is an important parameter which can be used to study the effect of different treatments on crop growth. The plant height ranged from 52-74.13cm.The highest plant height (74.3cm) recorded with T4 (50%RDF+50%FYM+bio char) which were immediately followed by T6 with 71.9cm (Fig1). The lowest plant height(52.4 cm) recorded with T0 (control) .All the Biochar amended treatments increased the number of tillers per plant. The highest number of tillers (454) recorded per m^{-2} by the application of 50%RDF+50%FYM+Biochar which was statistically at par with T7,T6,T5 and T3.Minimum number of tillers (213) recorded with control(Fig2). The treatments which were amended with Biochar showed more chlorophyll content than unamended plot. The chlorophyll content recorded maximum (47.4) with T4 and lowest (36.27) in control (Fig1). The number of spikes per m^{-2}wasinfluenced by the different treatment combinations. The highest number of spikes (434 per m^{-2}) recorded with the application of 50%RDF+50%FYM+Biochar which was followed by T8 (50%RDF+50%PM+Biochar) with 421 spikes per m^{-2}. Lowest spikes (198.67) per m^{-2} were recorded in control. Spike length is directly related to the number of spikelets and grains per spikelet and important parameter of grain yield. T4 significantly increased spikelet length up to 11.47 cm which was followed by T3,T8 and T6 with10.49,10.40 and 10.36 cm spikelet length. Minimum spikelet length (11.47cm) recorded with control. The grain is fully fertilized ripened ovule of a spikelet which contributes to yield. T4 recorded maximum (50.6) grains per spikelet followed by T3 and T8 (45.67, 45 grains) (Fig3). Test weight is the weight of 1000 grains which is an important yield attributing parameter. The test weight of wheat ranged from 28.27-45.31g. Maximum (45.31g) recorded with the application of 50%RDF+50%FYM+Biochar(Fig1).Maximum grain yield (4282 kgha-1) and straw yield (5038 $kgha^{-1}$) recorded with 50%RDF+50%FYM+Biochar and minimum with control(Fig4). This result corroborates with the findings of Maqsood *et al.*, 2013 and Major *et al.*, 2009.

3.2Effect of Biochar based amendments on soil physico-chemical properties**:** The physico-chemical properties are soil pH, bulk density and electrical conductivity. Nutrient uptake by wheat grain and its availability in soil was significantly increased with bio char application. The mass of soil per unit volume including pore space is known as bulk density. Compactness and porosity of soil indicateby bulk density. The combined application of Biochar with manures and fertilizers decreased bulk density of soil. The maximum bulk density (2.10g cm^{-3}) recorded in T0 and minimum bulk density(1.55g cm^{-3}) recorded in T4 followed by T6having 1.59g cm^{-3}bulk density. Soil pH is considered as an important soil health indicator. Variations in pH of soil after the addition of Biochar were statistically different among treatments. The highest pH(7.88) recorded with T4 which was statistically at par with T6 having pH 7.79.Control recorded lowest pH(6.22). Maximum EC value (2.76dsm^{-1}) recorded in T8 which was at par with T4 and T6 (Fig5). The maximum available N (563.8 kg ha^{-1})recorded with the application of 50%RDF+50% FYM+biochar which was at par with T6(50%RDF+50% VC+ bio char) with 562.3kg ha^{-1} available N. Minimum available N (284.7 kg ha^{-1}) was recorded in control. Soil available phosphorous was recorded higher in all treatments except control. Highest available P recorded in T4(27.23 kg ha^{-1}) followed by T6(26.67 kg ha^{-1}). Lowest available P recorded in control(7.15 kg $ha^{-1)}$.Highest available potassium was recorded in T4 (386.7 kg $ha^{-1)}$ followed by T6(309 kg ha^{-1}). The lowest available potassium was recorded in T0(238 kg ha^{-1}) which was followed by T1(100% RDF) having 312.9 kg ha^{-1} available potassium (Fig. 6). Soil organic carbon (%) was increased in Biochar applied plots as compared to control and 100% RDF. The highest SOC content found in T4(1.45%) followed by T6(1.32%) and lowest(0.60%) in T0. These results are in confirmity with the findings of (Manqiang *et al*., 2010) and Atkinson *et al*., (2010).

4.General Discussion: The improvement in soil physicochemical properties due to combined application of rice husk bio char with fertilizers and manure was reflected in the vegetative growth of wheat. Plant height, tiller numbers, chlorophyll content and flag leaf length were significantly increased relative to the control (Maqsood & Shehzad, 2013).In our study, interaction between bio char, manures and inorganic fertilizer increased the growth attribute of wheat. The combined application of bio char, manure and inorganic fertilizers increased plant height, tillers over RDF of fertilizer alone, likely as a result of increased nutrient availability. The nutrient supplying capacity of bio char, manure and inorganic fertilizer applied in combination are higher than single application of bio char alone. The synergistic effect of bio char, manure and inorganic fertilizer is considered to be the result of increased plant nutrient uptake, less nutrient losses and improved availability of cationic elements. Another mechanism responsible for this improvement could be that bio char served as a direct source of nutrients for plant uptake and changes in the soil chemical and physical properties caused by bio char. It is also possible that the direct release of nutrient (P, K, Ca and Mg) for plants is not the only possible explanation for the increased crop growth. Biochar addition can also strongly increase the availability of soil nutrients from co-applied manures & inorganic fertilizer, increase the soil pH and CEC, improving the physical structure of the soil and reducing the level of soluble soil Al3+. The application of bio char, manures and inorganic fertilizer had a greater effect on plant physiological parameters than on soil nutrient distribution and availability. In our study, the addition of Bio char with manures, fertilizer resulted in clear effects on yield and yield components wheat crop. Wheat yield was substantially improved in all doses of Bio char applied and combined with fertilizers and manure. The positive effects of this interaction on yield was due to changes in the soil, including soil physical properties modification, reduced soil acidity and increased level of available P and K and micronutrients. The reduction in soil acidity was probably an important effect. The positive effect of the bio char combination was significant. The interactive effect of bio char, manure and inorganic fertilizer on grain and straw yield is a function of enhanced photosynthetic rate and proportion of the assimilatory surface area induced by the increased level of available nutrient. The increase in straw yield relative to the control with increasing rates of combined bio char ,fertilizer and manures could be ascribed to better crop growth rate, LAI and accumulation of photo-assimilate by the crop, which ultimately produced more straw yield.

In our study, increases in yield and yield components were more pronounced when bio char, manure and fertilizer were applied in combination, in comparison to N-fertilizer or bio char alone. Interaction between bio char and N-fertilizer stimulated plant growth and improved N-use efficiency, this may be due to the fact that the bio char and N fertilizer can surrogate for each other, i.e. with a small amount of labile N supply from rice straw bio char. The direct effect on the performance of wheat of available soil nutrients and plant nutrient uptake from bio char, manures and fertilizer soil amendments exceeded the direct effect of available nutrients and nutrient uptake from fertilizers alone. The increase in yield component including (number of spikes/m^2, no. of grains per spikelet, and 1000 grain weight) due to bio char and inorganic fertilizer amendment might be due to the increased availability and utilization of necessary nutrients (N, P, and K) as these nutrients increased. However, their interaction caused significant increases relative to the control. Improved yield component parameters observed on our study could be due to the production of more chlorophyll content, enhanced cell division, more translocation of assimilates towards grain-filling parts than vegetative parts because of higher partitioning of assimilates towards sink due to interactive effect of bio char and N fertilizer.

Soils amended with bio char were acidic in nature and results have shown an increased soil pH level due to the presence of carboxylic functional groups and oxidation of added Biochar. Our result confirmed that bio char could serve as a liming agent to improve soil pH. Soil conditions such as soil pH, moisture, temperatures, and clay mineral content affected soil organic matter mineralization (Ali *et al*., 2015). The increase in OC and available N could be associated with the increasing wheat yield and biomass, which help returned more plant below ground biomass and root exudates to the soil. The significant increase in soil available P contents in bio char amended soil might be caused by several mechanisms. First, the rice straw bio char used in our study had a considerable proportion of labile P which may have directly released phosphate into the soil. Biochar produced from rice husk could be a source of bioavailable P, directly releasing phosphate to the soil solution. The rice straw bio char and N-fertilizer interaction stimulated microbial biomass and phosphate solubilizing microorganism thus indirectly promoted organic P mineralization and release of non-active P bounded within oxides of soil minerals(Castaldi *etal*.,2011)Biochar and N-fertilizer improved the available K content. This was probably due to the high K concentration which is in bio-available form in the rice straw bio char used. The increased exchangeable K+ relative to the control could have been induced by electrostatic attraction forces on the surface of bio char-soil matrix whichhelp retained K (Manqiang *et al*., 2010).

5. Figures:

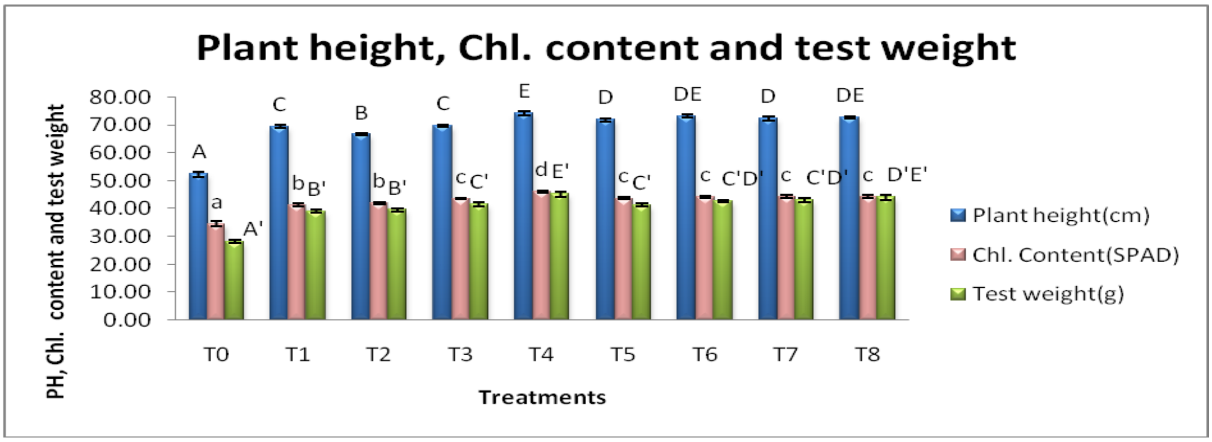

Fig.1Representing the plant height (cm),chlorophyll content (SPAD), test weight(g). Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$.

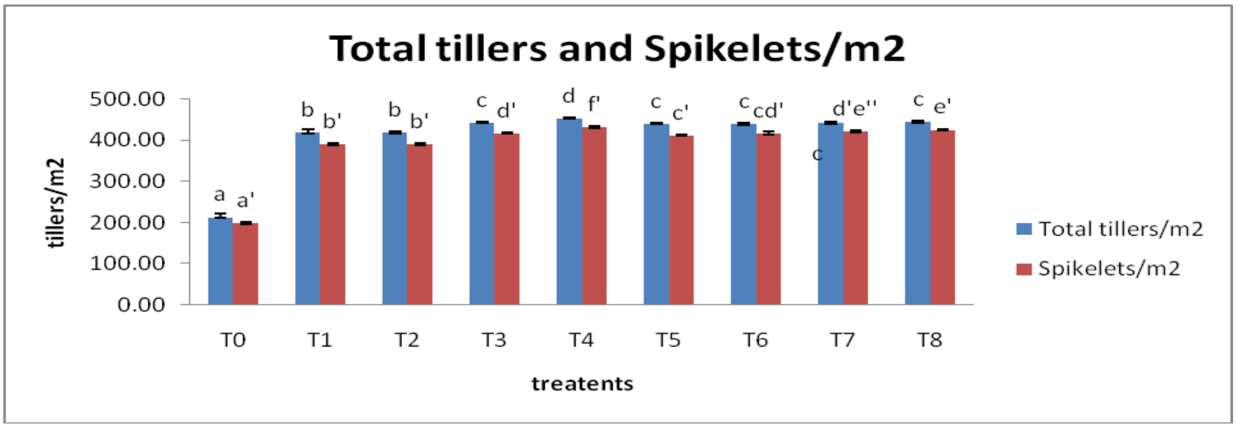

Fig.2Representing the total tillers and spikelet /m^2. Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$.

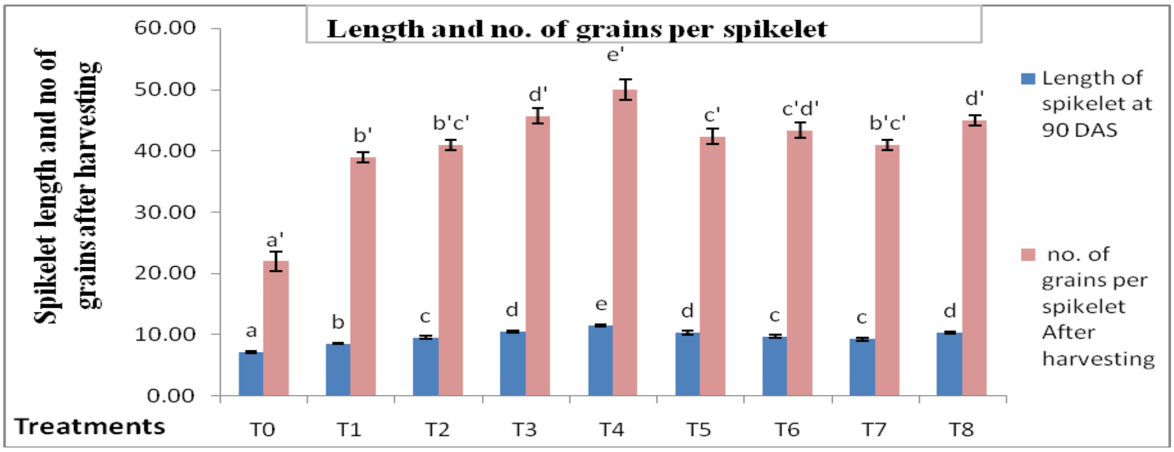

Fig.3 Representing the spikelet length in cm and grains per spikelet. Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$.

International Journal of Advance Research in Science and Engineering
Vol. No.9, Issue No. 06, June 2020
www.ijarse.com
IJARSE
ISSN 2319 - 8354

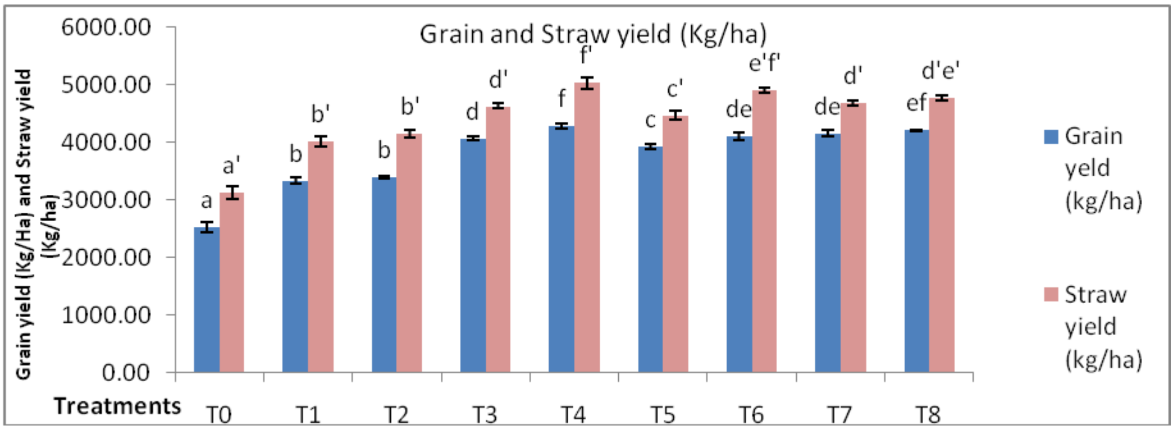

Fig.4.Representing the grain yield and straw yield. Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at p<0.05.

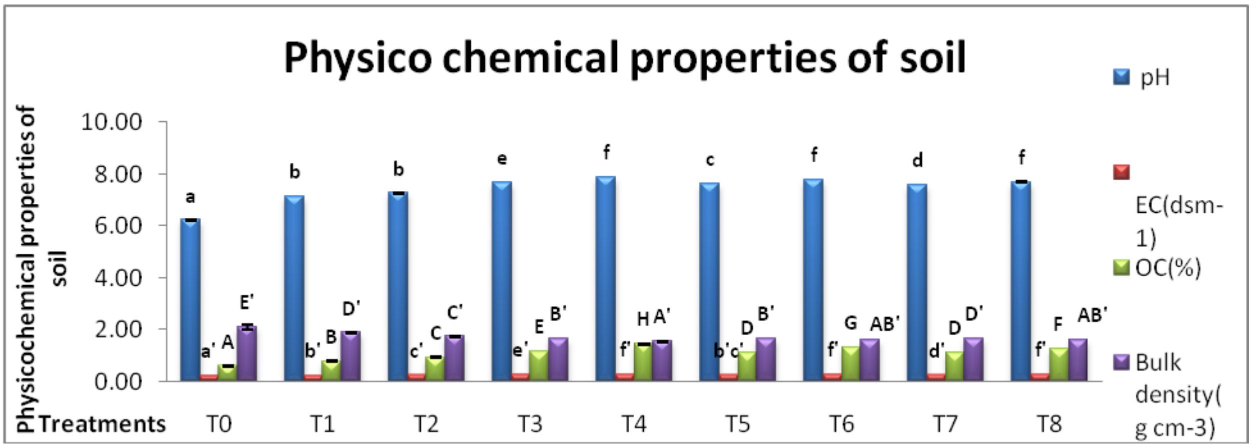

Fig5. Representing the impact of Biochar combined with inorganic fertilizers on pH ,EC,OC and bulk density of soil. The mean followed by different letters are significantly different at p<0.05 according to DMRT (Duncan's multiple range test) for separation of means.

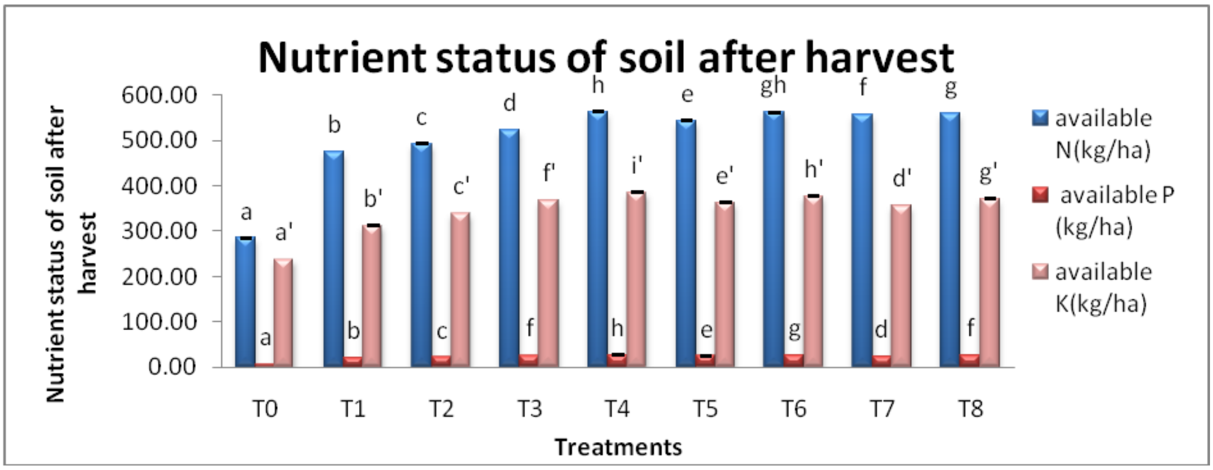

Fig6. Representing the impact of Biochar combined with inorganic fertilizers on available N,P, K of soil. The mean followed by different letters are significantly different at p<0.05 according to DMRT (Duncan's multiple range test) for separation of means

6. Conclusion: Crop residues in fields can cause considerable crop management problems as they accumulate.In India, about 435.98 million tons of agro-residues are produced every year. These residues are either partially utilized or un-utilized due to various constraints. Efficient use of biomass by converting it as a useful source of soil amendment/nutrients is one way to manage soil health and fertility.One of the approaches for efficient utilization of biomass involves carbonization of biomass to highly stable carbon compound known as bio char and its use as a soil amendment. Use of Biochar in agricultural systems is one viable option that can enhance natural rates of carbon sequestration in the soil, reduce farm waste and improve the soil quality.

7. Acknowledgement: This paper is part of author's PhD dissertation project. The author is higher thankful to Lovely Professional university for financial assistance and for providing field and laboratory facilities.

8 References:

1. United state department of agriculture, Source: Directorate of Economics & Statistics, DAC&FW
2. Jones, D.L., J. Rousk, G. Edwards-jones, T.H. Deluca and D. Murphy. 2012. Biochar-mediated changes in soil qualityand plant growth in at three year field trial. *Soil Biology and Biochemistry*., 45: 113-124.
3. Widowati, W., H. Utomo, L. A. Soehono and B. Guritno. 2011. Effect of biochar on the release and loss ofnitrogen from urea fertilization. *J. Agri. and Food Tech*., 1: 127-132.
4. Liu, E., C. Yan, X. Mei, W. He, S. H. Bing, L. Ding, Q. Liu, S. Liu and T. Fan. 2010. Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. *Geoderma*, 158: 173-180.
5. Murali, S., Shrivastava, R. and Saxena, M. 2010. Greenhouse gas emissions from open field burning of agricultural residues in India. *Journal of Environmental Science and Engineering*, 52(4): 277-84.
6. Punia, M, Prasad, N.V. and Yogesh, Y. 2008. Identifying biomass burned patches of agriculture residue using satellite remote sensing data. Current Science, 94 (9): 1185-1190.
7. Gebremedhin, G.H., Bereket, H., Berhe, D., Belay, T., 2015. Effect of biochar on yield and yield components of wheat and post-harvest soil properties in Tigray, Ethiopia. *Journal of Fertilizers and Pesticides* 6: 158
8. Manqiang, L., H. Feng, C. Xiaoyun, H. Qianru, J. Jiaguo, Z. Bin and L. Huixin. 2009. Organic amendments with reduced chemical fertilizer promote soil microbial development and nutrient availability in a subtropical paddy field. The influence of quantity, type and application time of organic amendments. *Appl. Soil Ecol*., 42: 166-175.
9. Ali, K., F. Munsif, M. Zubair, Z. Hussain, M. Shahid, I.U. Din and N. Khan. 2011. Management of organic and inorganic nitrogen for different maize varieties. *Sarhad. J. Agri.*, 27(4): 525-529.
10. Castaldi, S., M. Riondino, S. Baronti, F.R. Esposito, R. Marzaioli, F.A. Rutigliano, F.P. Vaccari and F. Miglietta. 2011. Impact of Biochar Application to a Mediterranean Wheat Crop on Soil Microbial Activity and Greenhouse Gas Fluxes. *Chemosphere*, 85: 1464-471
11. Ali, K., M. Arif, M.T. Jan, M.J. Khan and D.L. Jones. 2015. Integrated use of biochar: a tool for improving soil and wheat quality of degraded soil under wheat-maize cropping pattern. *Pak. J. Bot*., 47(1): 233-240.
12. Elad, Y., Cytryn, E., Harel, Y.M., Lew, B., Graber, E.R., 2011. The biochar effect: plant resistance to biotic stress. *Phytopathologia, Mediterranea* 50(3): 335–349.

13. Agboola, K., Moses, S.A., 2015. Effect of biochar and cowdung on nodulation, growth and yield of soybean (Glycine max l. Merrill). *International Journal of Agriculture and Biosciences* 4(4): 154-160.
14. Sohi, S., Krul, E., Lopez-Capel, E., Bol, R., 2010. A review of biochar and its use and function in soil. *Advances in Agronomy* 105: 47–82.
15. Allison, L.E., 1965. Organic carbon. In: Methods of Soil Analysis Part 2, C.A. Black et al., Ed. Agronomy. Am. Sot. of Agron., Inc., Madison, WI. 9, 1367-1378.
16. Olsen, S. R., Cole, C. V., Watanabe, F. S., Dean, L. A. 1954 Estimation of available phosphorus in soil by extraction with sodium bicarbonate. Circ. U.S. Dep. Agric. 939.
17. Jackson, M.L., 1973. Soil Chemical Analysis. Second Indian Reprint, Prentice Hall of India, New Delhi, 498.
18. Toth, S.J., Prince, A. L., 1949. Estimation of cation exchange capacity and exchangeable Ca, K and Na contents of soils by flame photometric techniques. Soil Sci. 67, 439-445.
19. Maqsood, M. and M.A. Shehzad. 2013. Optimizing nitrogen input and harvest time to maximize the maize fodder yield in Punjab, Pakistan. *Pak. J. Agri. Sci*., 50: 75-81.
20. Major, J., C. Steiner, A. Downie and J. Lehmann. 2009. Biochar effects on nutrient leaching. In: *Biochar for environmentalmanagement: Science and technology*. (Eds.): J. Lehmann and S. Joseph. Earthscan, London; Sterling, VA, pp. 271-287.
21. Atkinson, C.J., J.D. Fitzgerald and N.A. Hipps. 2010. Potential mechanisms for achieving Agricultural benefits from biochar application to temperate soils: a review. *Plant Soil*, 337: 1-18.

****

.

.