INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 18, No. 4, p. 93-100, 2021

RESEARCH PAPER OPEN ACCESS

# Effect of fertilizer doses with biochar on soil fertility and crop productivity of wheat-maize-rice cropping pattern in drought prone area

**Md. Ilias Hossain[1], Md. Israil Hossain[2], Md. Zillur Rahman[3], M. Malek[4], Md. Shah Newaz Chowdhury[5*]**

[1]*Agronomy Division, Regional Station, Bangladesh Wheat and Maize Research Institute, Rajshahi-6212*

[2]*Engineering Division Bangladesh Wheat and Maize Research Institute-5200*

[3]*Agronomy Division, CARITAS, Rajshahi, Bangladesh*

[4] *Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh*

[5]*Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh*

**Key words:** Biochar, Drought, Soil chemical properties, Yield.

http://dx.doi.org/10.12692/ijb/18.4.93-100 Article published on April 29, 2021

## Abstract

A two years experiment was conducted to study the productivity and soil fertility of intensified rice-wheat (RW) systems by adding a third pre-rice crop of maize. The trial comprises five packages of practices including crop residue retention, seeding methods with recommended fertilizer with biochar imposed on the component crops in wheat-maize-rice cropping pattern. The results indicated that biochar in the field with minimum disturbance of soil had a significant contribution to grain yield and yield component of wheat compare to conventional practice and without biochar application. System productivity and fertility were evaluated under three levels of tillage options (zero, strip, raised bed, PTOS and conventional tillage practice (CTP) in a RW- Maize cropping pattern. Both raised bed and strip-till with 80% recommended fertilizer with 2.0 t/ha biochar produced the highest grain yield in wheat and maize crop but the non-significant effect of rice grain yield and lowest yield was also found from conventional practice with control plot. Biochar had increased the soil organic matter by 0.08. While some of the parameters increase may have been due to added biochars from topsoil, the change in organic carbon increased with the rate of different doses of biochar application. Biochar application slightly increased N, P, K, S, B and Zn availability and low pH levels in the wheat crop in two seasons. So, Biochar has a positive effect on soil properties and sustainable productivity ofcereals crop in drought-prone areas.

* **Corresponding Author:** Md. Shah Newaz Chowdhury ✉ shahnewaz18@sau.edu.bd

## Introduction

Biochar is defined simply as charcoal that is used for agricultural purposes. It is created using a pyrolysis process, heating biomass in a low oxygen environment. Once the pyrolysis reaction has begun, it is self-sustaining, requiring no outside energy input. Byproducts of the process include syngas ($H_2$ + CO), minor quantities of methane ($CH_4$), tars, organic acids - and excess heat. Once it is produced, biochar is spread on agricultural fields and incorporated into the top layer of soil (Khan *et al.,* 2008). Biochar has many agricultural benefits.

It increases crop yields, sometimes substantially if the soil is in poor condition. It helps to prevent fertilizer runoff and leeching, allowing the use of fewer fertilizers and diminishing agricultural pollution to the surrounding environment. It retains some moisture, possibly helping plants through periods of drought more easily (Ikbal*et al.,* 2017). Most importantly, it replenishes exhausted or marginal soils with organic carbon and fosters the growth of soil microbes essential for nutrient absorption. Studies have indicated that the carbon in biochar remains stable for millennia, providing a simple, sustainable means to sequester historic carbon emissions that is technologically feasible in developed or developing countries alike( Mia *et al.,* 2015). The syngas and excess heat can be used directly or employed to produce a variety of biofuels.

When biochar is created from biomass, approximately 50% of the carbon that the plants absorbed as $CO_2$ from the atmosphere is "fixed" in the charcoal. As a material, the carbon in charcoal is largely inert, showing a relative lack of reactivity both chemically and biologically, and so it is strongly resistant to decomposition (Ahmed *et al.,* 2017). Research scientists have found charcoal particles as old as 400 million years in sediment layers from wildfires that occurred when plant life first began on earth. *(Sediment Records of Biomass Burning and Global Change, James Samuel Clark)* of the many organic and inorganic substances that contain carbon atoms, only diamonds could potentially provide a more permanent carbon store than charcoal (Piash*et al.,* 2018). Hence, biochar offers us a golden opportunity to remove excess $CO_2$ from the atmosphere and sequester it in a virtually permanent and environmentally beneficial way.

Land degradation and soil fertility decline are among the main causes of the stagnation and fall of agricultural production in many tropical countries, including those with intensive irrigated cropping systems (Khan *et al.,* 2015).

The inclusion of maize in the dry-wet transition of the rice-wheat cropping system as a third crop may be another option for increasing cropping intensity, soil fertility and productivity of the system. Although the non-rice season across the rice-wheat area is low rainfall, heavy pre-monsoonal rain can have disastrous effects on the third crop, such as maize grown after wheat or before rice, both during establishment and grain filling because of waterlogging (Timsina and Connor, 2001; Quayyam*et al.,* 2002). Crop residues are an important source of soil organic matter vital for the sustainability of agricultural ecosystems. About 25% of N and P, 50% of S and 75% of K uptake by cereal crops are retained in crop residues, making them valuable nutrient sources (Singh, 2003). However, straw retention is not a common practice in the RW systems of Bangladesh, as is also the case elsewhere in SouthAsia. Wheat and rice straw are usually removed from fields for use as cattle feed and purposes such as livestock bedding, thatching material for houses, or fuel, leaving little for incorporation into the soil. Due to the limited number of livestock, farmers throughout the IGP have access to very limited amounts of organic manure. As a result, soil organic matter levels have declined in these cropping systems, and optimization of nutrient uptake and absorption efficiency has become one of the most important goals in crop production strategies. Limon-Ortega *et al.* (2000) observed that permanent beds with straw retention had the highest mean wheat grain yields (5.57 t/ha), N use efficiency (28.2 kg grain/kg of N supply) and total N uptake (133 kg/ha), with positive implications for soil health. Thus, crop residue management along with efficient fertilizers doses, are likely to be key components of new farming practices that can increase and maintain yields from the intensive RW system in Bangladesh. Potassium is one of the key limiting nutrients for plant growth and development. Due to intensive cropping mining of potassium from soil reserves is now a great concern to researchers. Removal of potassium through crop harvest and non-recycling of crop residues is being posed as a thread for sustainable crop production in the country. Though silica is not considered an essential plant nutrient, many kinds of research claim that it gives substantial resistance capacity to plants against stress conditions including pests and disease. Kaya *et al.* (2006) also reported this element helps to improve yield traits and yield of crops through the contribution of potential physiological processes. Biochar (after burning of crop residues) is now available in Bangladesh is considered a good source of all nutrients and silica. Climate change induces different stress ina farming environment. The objectives of the research work are 1) to determine the optimum doses of wheat-maize-rice cropping pattern with Biochar application, 2) to evaluate the effect of biochar to improve the system productivity, andto study the change in soil properties over time in the intensified cropping pattern.

## Materials and methods

A rabi season wheat (*Triticumaestivum*)-kharif 1 Maize (*Zea mays*)-monsoon rice cropping pattern was implemented starting with wheat sown on November 30, 2018, for wheat at the Regional Wheat Research Centre, Shyampur, Rajshahi, Bangladesh (24°3'N, 88°41E, 18 m above sea level).

The site has a subtropical climate and is located in Agroecological Zone 11 (High Ganges River Flood Plan) on flood-free high land, with coarse-textured, highly permeable soil (BARC, 2012). The area receives 1072 mm mean annual rainfall, about 95% of which occurs from May to September. Total rainfall was highest during the mungbean season and lowest in the wheat season in all years.

Wheat (Variety BARI Gom 30) was planted at the nationally recommended seeding rate. The trial consistedof five treatments combination which was below.

T1=Control
T2=Recommended Fertilizer
T3= 90%+Recommended Fertilizer+ Biochar 1.0 t/ha
T4= 80%+Recommended Fertilizer+ Biochar 2.0 t/ha
T5= 70%+Recommended Fertilizer+ Biochar 3.0 t/ha

The area of each plot was 50 m² (10m × 5m). The recommended rate and reduce doses of fertilizers were applied during land and top dress. In wheat, two-thirds of the N was applied before seeding and the remaining one-third at crown root initiation (CRI) (Zadoks growth stage 1.3). Sufficient irrigation water was applied to fill the furrows between permanent raised beds and the strip-tillage method. The conventional plot was flood irrigated. The wheat received three irrigations-at CRI (Z1.3), booting (Z4.0-4.9) and grain-filling stages (Z8.0-8.9). Generally, all tillage options were irrigated on the same days, but less water was needed to fill the furrows with raised bed and strip method compared to CTP. Weed control was done after the first irrigation by the application of Affinity on wheat.

CROP STAT and Microsoft Excel and DMRT were used to measure the variation of mean data of treatments. Treatment means were compared at $P \leq 0.05$. The data were analyzed statistically following computer package CROP STAT - All the data were statistically analyzed following the ANOVA technique and the significance of mean differences was adjusted by said method.

## Results and discussion

Before experimentation, initial soil sample was collected and analyzed to know the nutrient status and the results were presented in Table 1. The soil was slightly alkaline (7.8 pH) having low organic matter content (0.94%) and the total N & boron content was very low (0.05% & 0.27 µg). The overall soil fertility status was low.

**Table 1.** Fertility status of initial soil sample of the experimental site at RWRC, BARI & Rajshahi.

| Sample | PH | OM (%) | Total N (%) | K | P | S | Zn | B |
|---|---|---|---|---|---|---|---|---|
| | | | | Meq/100g | µg/g | | | |
| Value | 7.8 | 0.94 | 0.05 | 0.21 | 10 | 23.3 | 0.14 | 0.27 |
| Critical level | - | - | 0.12 | 0.12 | 10 | 10.0 | 0.60 | 0.20 |
| Interpretation | Slightly Alkaline | Very low | Very low | Medium | Low | Opt. | Very low | Very low |

*Chlorophyll content and canopy temperature of wheat by different treatments*

Chlorophyll content and canopy temperature of wheat by different treatments were significant effects but the insignificant effect in tillage options which are shown in Fig.1. In the case of chlorophyll content treatment $T_2$, $T_3$, $T_4$ and $T_5$ were non-significant effects but all are significant from the control plot. Maximum chlorophyll content was found from the booting stage and it was gradually lower in the heading and anthesis stage. Canopy temperature was a significant effect in all the treatments from the different stages. Mia *et al.,* 2018 got positive impact from their exp[eriment Maximum canopy temperature was found from control plot with anthesis stage and lower canopy temperature was found when 3.0 t/ha biochar application and it was gradually higher in control plot where no biochar application Khan *et al.,* 2014 got similar results from their trial.

**Table 2.** Yield components of wheat by different treatments.

| Treatments | Spike/m² | Spike length(cm) | Grains/spike | TGW (g) |
|---|---|---|---|---|
| $T_1$ | 427 | 6.4 | 27.3 | 40.4 |
| $T_2$ | 432 | 8.8 | 41.5 | 49.3 |
| $T_3$ | 447 | 8.9 | 41.9 | 49.7 |
| $T_4$ | 486 | 9.5 | 43.5 | 54.3 |
| $T_5$ | 460 | 9.4 | 43.2 | 54.4 |
| CV (%) | 11.53 | 12.45 | 10.54 | 8.79 |
| LSD (0.05) | 4.862 | 1.142 | 0.452 | 0.865 |

$T_1$= Control plot (except N), $T_2$= Recommended fertilizer (RF), $T_3$= 90% RF + 1.0 t/ha biochar, $T_4$= 90% RF + 1.0 t/ha biochar and $T_5$= 70% RF + 3.0 t/ha biochar.

*Yield components of wheat by different treatments*

Biochar application is influenced by different yield components of wheat. Consequently, spike/m2, spike length, grains/spike and thousand-grain weight were influenced significantly which was shown in Table 2. The maximum spike/m² was recorded in treatment $T_4$ is 2.0 t/ha biochar application (486) which was statistically identical with that of $T_5$ that is 3.0 t/ha biochar application (460). Shashi*et al.,* 2018 got similar findings from their experiment. The minimum spike/m2 was found from the control plot. Similarly, higher spike length, grains/spike and thousand-grain weight were recorded from T4 treatment that is 2.0 t/ha biochar application. This might be due to proper doses of biochar application. Minimum spike length, grains/spike and thousand grain weight were found from control plot.

*Grain yield & yield increase, biomass and harvest index of wheat*

Grain yield is the cumulative effect of spike/m2, grains/spike and 1000 grain weight. Yield and yield increase, biomass and harvest index data were significant effects from different treatments but it was non-significant from $T_4$ which was shown in Table 3 (average two years yield). Tillage systems had no significance on grain yield and other parameters. The maximum grain yield of 4.81 t/ha from treatment $T_5$ is 3.0 t/ha biochar application and the same yield was also found when 2.0 t/ha biochar application 4.52 t/ha. Grain yield was higher due to higher yield attributes and get more photosynthesis with reduce canopy temperature. Ali *et al.,* 2015 got positive canopy temperature from their trial.The lowest yield 1.89 t/ha were also found from the control plot where no nitrogen application due to lower yield components and less photosynthesis with higher canopy temperature. Maximum biomass and harvest index were found from same treatment with biochar application and yield increase was also higher from $T_5$ treatments and it was statistically significant in $T_4$ treatment. Mete *et al.,* 2015 found the same results from their trials.Minimum biomass and harvest index were also found from the control plot. The yield increase was also higher in treatment from $T_5$ and it was similar in $T_4$.

**Table 3.** Grain yield & yield increase, biomass and harvest index of wheat by different treatments.

| Treatments | 2018-19 Grain yield (t/ha) | 2019-20 Grain yield (t/ha) | Average two years yield (t/ha) | Yield increase over control (t/ha) | Yield increase over RF (%) |
|---|---|---|---|---|---|
| $T_1$ | 1.86 | 1.92 | 1.89 | - | - |
| $T_2$ | 4.21 | 4.30 | 4.25 | 2.36 | - |
| $T_3$ | 4.39 | 4.49 | 4.44 | 2.55 | 5.97 |
| $T_4$ | 4.52 | 4.62 | 4.57 | 2.68 | 7.52 |
| $T_5$ | 4.86 | 4.77 | 4.81 | 2.92 | 13.17 |
| CV (%) | 10.35 | 10.29 | 10.56 | 8.63 | - |
| LSD (0.05) | 0.465 | 0.375 | 1.253 | 0.435 | - |

$T_1$= Control plot (except N), $T_2$= Recommended fertilizer (RF), $T_3$= 90% RF + 1.0 t/ha biochar, $T_4$= 90% RF + 1.0 t/ha biochar and $T_5$= 70% RF + 3.0 t/ha biochar.

*Maize grain yield and components under different tillage options*

The effect of different levels of tillage options had significant on all yield attributes and grain yield of maize (Table 4). Shifting from different treatments resulted in a significant yield increase of maize, which was attributed to higher numbers of cobs $m^{-2}$, cob length and grains $cob^{-1}$. Biochar application produced higher grain yield over control. Mia *et al.,* 2014 found similar findings from their experiment. Recommended fertilizer with biochar application equally better in respect of improving cobs $m^{-2}$, grains $cob^{-1}$, thousand-grain weights but not significant and thereby produced higher grain yield of maize.

**Table 4.** Maize grain yield and yield attributes affected by different treatments in 2018-19.

| Treatments | Cobs $m^{-2}$ | Cob length (cm) | Grains $Cob^{-1}$ | TGW (g) | Grain yield (t $ha^{-1}$) | % yield increase over control |
|---|---|---|---|---|---|---|
| $T_1$ | 8.71 | 16.7 | 372.5 | 231.4 | 3.19 | - |
| $T_2$ | 9.56 | 17.4 | 417.7 | 233.5 | 7.19 | 55.6 |
| $T_3$ | 9.48 | 17.3 | 419.8 | 230.6 | 7.33 | 56.5 |
| $T_4$ | 9.53 | 17.6 | 421.3 | 232.5 | 7.43 | 57.1 |
| $T_5$ | 9.64 | 1.7 | 423.4 | 233.4 | 7.51 | 57.5 |
| CV (%) | 9.35 | 7.54 | 9.75 | 7.87 | 8.65 | |
| LSD (0.05) | 0.231 | ns | 0.231 | ns | 0.112 | |

$T_1$= Control plot (except N), $T_2$= Recommended fertilizer (RF), $T_3$= 90% RF + 1.0 t/ha biochar, $T_4$= 90% RF + 1.0 t/ha biochar and $T_5$= 70% RF + 3.0 t/ha biochar.

The yield data were shown in Table 4, the maximum grain yield was found (7.51 t $ha^{-1}$) was found from $T_5$ treatments and it was at par (7.43 t $ha^{-1}$) in the case of $T_4$ treatments. Mahmud *et al.,* 2014 got similar results from their trials. The lowest grain yield (3.19 t $ha^{-1}$) was found from $T_1$ treatment than it control treatment. Lauren *et al.* (2006) found a similar yield from this type of experiment.

**Table 5.** Yield and yield components of rice as affected from different tillage options in 2018-19.

| Treatments | Hills $m^{-2}$ | Panicles $Hill^{-1}$ | Grains $Panicle^{-1}$ | TGW (g) | Grain yield (t $ha^{-1}$) | % Yield increase over control |
|---|---|---|---|---|---|---|
| $T_1$ | 9.2 | 17.6 | 130.7 | 24.3 | 1.94 | - |
| $T_2$ | 30.7 | 18.4 | 135.2 | 25.1 | 4.41 | 56.0 |
| $T_3$ | 30.4 | 18.2 | 134.8 | 24.9 | 4.47 | 56.5 |
| $T_4$ | 30.8 | 18.8 | 135.4 | 25.2 | 4.49 | 56.7 |
| $T_5$ | 31.2 | 18.5 | 135.2 | 25.3 | 4.52 | 57.1 |
| CV (%) | 7.25 | 8.45 | 8.785 | 9.75 | 9.87 | |
| LSD (0.05) | 0.875 | 0.325 | 1.225 | 0.112 | 1.215 | |

$T_1$= Control plot (except N), $T_2$= Recommended fertilizer (RF), $T_3$= 90% RF + 1.0 t/ha biochar, $T_4$= 90% RF + 1.0 t/ha biochar and $T_5$= 70% RF + 3.0 t/ha biochar.

*Rice yield and yield components on different tillage options in 2018-19*

The rice crop was non-puddled transplanted in all treatments but puddle transplanted in the conventional method had a non-significant effect of biochar application which imposed in previous wheat and maize crops were induced in rice crop. The effect of different levels of treatments had significant on panicles $hill^{-1}$, grains $panicle^{-1}$ and 1000 grain weight and also a significant effect on hill $m^{-1}$ and grain yield of rice. The maximum grain yield (4.52 t $ha^{-1}$) was found from $T_5$ treatments and it was at par with Treatments $T_4$, $T_3$ and $T_2$. Singh *et al.,* 2003 found similar findings from their experiments.

**Table 6.** Chemical properties changes in soil for biochar in 2018-19.

| Characteristics | Initial | Final | Difference |
|---|---|---|---|
| pH (1:2.5 in water) | 8.1 | 7.9 | - 0.2 |
| Organic Matter (%) | 0.94 | 1.02 | + 0.08 |
| Total N (%) | 0.12 | 0.14 | + 0.02 |
| Exch. K (ml eq/100g soil) | 0.26 | 0.48 | + 0.22 |
| Avail. P (mg / g soil) | 24.5 | 27.5 | + 3.0 |
| Avail. S (mg / g soil) | 25.6 | 28.9 | + 3.3 |
| Avail. Zn (mg /g soil) | 0.84 | 0.87 | + 0.03 |
| Avail. B (mg / g soil) | 0.19 | 0.22 | + 0.04 |

The lowest grain yield (1.94 t $ha^{-1}$) was found from the control treatment. The transplanted *aman*rice was cultivated under the saturated to submerge soil conditions and the residual effect of CA did not result in a significant impact on rice grain yield (Table 5). The only number of grains $panicle^{-1}$ influenced by the treatments and both fresh and permanent bed produced higher grains $panicle^{-1}$. Maximum grain yield (4.40 $tha^{-1}$) was found from permanent bed systems and at par with fresh bed systems.

*Soil chemical properties*

Biochar had increased the soil organic matter by 0.08 (Table 6). While some of the parameters increase may have been due to added biochars from topsoil, the change in organic C increased with the rate of different doses of biochar application. Biochar application slightly increased N, P, K, S, B and Zn availability and low pH levels in the wheat crop in one season. M Alam and Khairul (2015) reported that, in the longer term, biochar can contribute to the formation of soil organic matter. It seems clear that further increases in the productivity of the RM system will depend on improvement in soil fertility through proper management and use of biochar and other agricultural wastes.

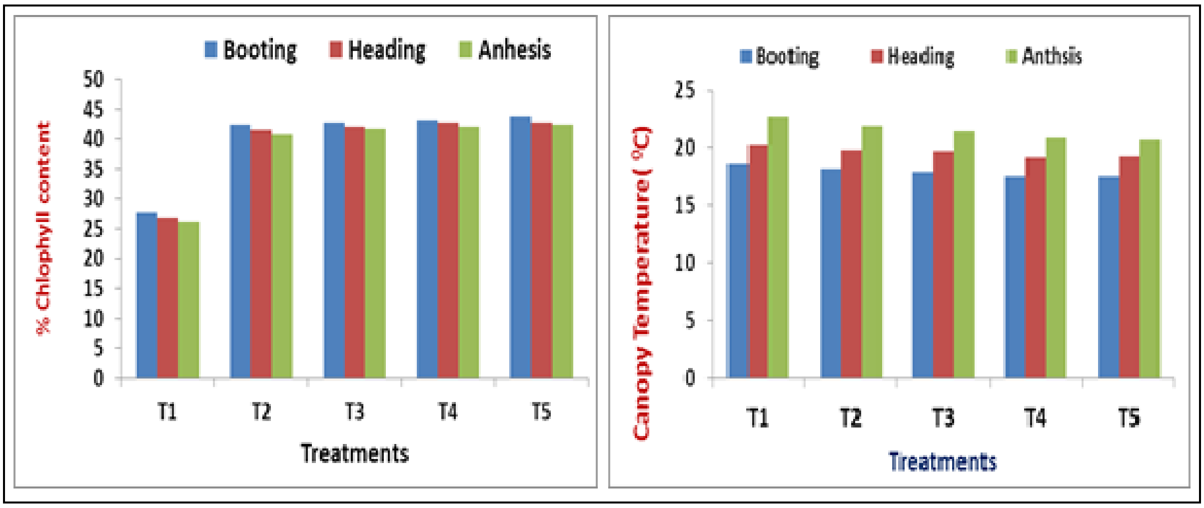


**Fig. 1.** Chlorophyll content and canopy temperature of wheat by different treatments.

## Conclusion

The yield of component crops in an intensive wheat-maize-rice cropping pattern was achieved under different tillage options with recommended fertilizer with biochar application. From the study, it was revealed that biochar application affected in terms of yield and yield components with canopy temperature which ultimately produced maximum yield due to its more photosynthesis and lower canopy temperature. Biochar has a long-term positive effect for getting a sustainable yield and higher productivity in intensified RW-maize systems in Bangladesh.

## References


**Mia S, Uddin ME, Kader MA, Ahsan A, Mannan MA, Hossain MM, Solaiman ZM.** 2018. Pyrolysis and co-composting of municipal organic waste in Bangladesh: A quantitative estimate of recyclable nutrients, greenhouse gas emissions, and economic benefits. Waste Management **75,** 503-513. Expand ABSTRACT.
http://dx.doi.org/10.1016/j.wasman.2018.01.038

**Shashi M, Mannan M, Islam M, Rahman M.** 2018. Impact of rice husk biochar on growth, water relations and yield of maize (*Zea mays* L.) under drought condition. The Agriculturists **16(2),** 93-101. Expand ABSTRACT.
https://doi.org/10.3329/agric.v16i02.40347

**Piash MI, Hossain MdF, Anyanwu IN, Al**

**Mamun S, Parveen Z.** 2018. Effect of biochar application on soil carbon fluxes from sequential dry and wet cultivation systems. American Journal of Climate Change **7,** 40-53. Expand ABSTRACT.
https://doi.org/10.4236/ajcc.2018.71005

**Khan TF, Didar-Ul-Alam M.** 2018.Effects of biochar on legume-Rhizobium symbiosis in soil. Bangladesh Journal of Botany **47(4),** 945-952. Expand ABSTRACT.

**Ahmed F, Islam MS, Iqbal MT.** 2017.Biochar amendment improves soil fertility and productivity of mulberry plant. Eurasian Journal of Soil Science **6**(3), 226-237. Expand ABSTRACT.
https://doi.org/10.18393/ejss.291945

**Iqbal MT.** 2017.Utilization of biochar in improving yield of wheat in Bangladesh. Bulgarian Journal of Soil Science **2(1),** 53-74. Expand ABSTRACT.

**Mete FZ, Mia S, Dijkstra FA, Abuyusuf M, Hossain ASMI.** 2015. Synergistic effects of biochar and NPK fertilizer on soybean yield in an alkaline soil. Pedoshpere **25,** 713-719. Expand ABSTRACT.
https://doi.org/10.1016/S1002-0160(15)30052-7

**Ali MA, Kim PJ, Inubushi K.** 2015. Mitigating yield-scaled greenhouse gas emissions through combined application of soil amendments: A comparative study between temperate and subtropical rice paddy soils. Science of the Total Environment **529**, 140-148. Expand ABSTRACT. https://doi.org/10.1016/j.scitotenv.2015.04.090

**Mia S, Uddin N, Al Mamun HAS, Amin R, Mete FZ, Hiemstra T.** 2015. Production of biochar for soil application: A comparative study of three kiln models. Pedosphere **25,** 696-702. Expand ABSTRACT. https://doi.org/10.1016/S1002-0160(15)30050-3

**Khan KT, Chowdhury MT, Huq SI.** 2015. Effects of biochar on the fate of the heavy metals Cd, Cu, Pb and Zn in soil. Bangladesh Journal of Scientific Research **28(1),** 17-26. Expand ABSTRACT

**Khan KT, Chowdhury MT, Huq SI.** 2014. Application of biochar and fate of soil nutrients. Bangladesh Journal of Scientific Research **27**(1):11-25. Expand ABSTRACT. https://doi.org/10.4236/ajcc.2018.71005

**Khan TF, Huq SMI.** 2014. Effect of biochar on the abundance of soil bacteria. British Microbiology Research Journal **4(8),** 896-904. Expand ABSTRACT.

**Mia S, Abuyusuf M, Sattar MA, Islam ABMS, Hiemstra T, Jeffery S.** 2014. Biochar amendment for high nitrogen and phosphorous bioavailability and its potentiality of use in Bangladesh agriculture: a review. Journal of the Patuakhali Science and Technical University **5(l),** 145-156 Expand ABSTRACT.

**Mahmud K, Chowhdhury MS, Noor N, Huq SI.** 2014. Effects of different sources of biochar application on the emission of a number of gases from soil. Canadian Journal Pure & Applied Sciences **8(2),** 2813-2824.

**Haque M, Mojammel M,Alam MM, Saiful M, Uddin, KMZ, Rahman GKM, Rahman M, Rahman MM.** 2018. Impact of Biochar on Soil Fertility and Crop Productivity in ShibalayaUpazila of Manikganj District. Department of Soil Science, Bangabandhu Sheikh MujiburRahman Agricultural University (BSMRAU), Gazipur, Bangladesh.

**Hasnat M, Rahman MM, Rahman GKM, Haque MM**. 2018. Role of Nitrogen Fertilizer on Mineralization of Organic Materials. Department of Soil Science &Department of Environmental Science Bangabandhu Sheikh MujiburRahman Agricultural University, Gazipur, Bangladesh.

**Murad KFI, Alam MK, Alam MJ, Sabuz AA**. 2018. Potentiality of Biochar to Enhance Productivity of Tomato Cultivated under Deficit Irrigation. Bangladesh Agricultural Research Institute (BARI).

**Sen R, Masud MM, Islam MM, Ferdous J.** 2018. Biochar Production by Akha and its Impact on Productivity of Tomato, Maize, Okra and Chili Grown in Acid Soil. Bangladesh Agricultural Research Institute & Christian Commission for Development in Bangladesh.