Biochar as a Solution to Manage the Rice Crop Residue

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Abstract - Agriculture waste management is a big challenge across the world, owing the huge quantity and lack of efficient disposal methods. In case of rice crop residue, burning of rice straw is a commonly used method for the disposal and is being followed in large parts of India. However, burning of this waste is a serious problem worldwide, because this is a prevalent cause of ambient air pollution It has an adverse effect at native as well as universal level and possess a serious risk to human life.In this paper, emission of various pollutants from burning of agriculture waste have been reviewed and the associated challenges have been produced. Production of Biochar from the rice straw through pyrolysis method offers a good opportunity to manage the rice straw waste. Biochar has some unique properties like tendency to treat pollutants,large surface area and association with different types of functional groups.These properties can play an important role in amendment in soil properties. In the present paper, potential of biochar to improve the soil properties has been investigated considering its different roles in amendment of the soil properties.

I. INTRODUCTION

Food has always been a basic necessity for the human being and this need keep on increasing with the increasing population of world. India also faces the same problem, with growing pressure of population increase. So there is always a need to enhance the crops productionto meet the future demands of food. Correspondingly, a lot of focus has been on the increase of food grain production. However, this has resulted in the generation of huge amount of crop residues after the crops have been harvested. Worldwide annual total crops residue production in the has been estimated as 3758×10^6 Mg/yr , out of which 74% are of the cereal crops like wheat, rice, barley and maize (Lal. 2005). Wheat and rice are two most important foodgrains, being used around the world. Out of these also, Rice is more popular and cultivated in 111 countries of the world, whereas only 92 countries grow the wheat(Aggarwal et al., 2004).Correspondingly, the production of rice is very high across the Globe. This in turn, also raises the amount of crop residue for the Rice fields, which is generally in the form of Rice straw.

Farmers find it difficult to find alternate methods of disposal for rice straw and burning is the most common technique used for the disposal of rice straw in India. This residual burning is generally carried out in the open agriculture fields, which causes different types of problems like air pollution, water pollution and also soil pollution Burning of crops residues lead to air pollution and reduce the amount of nutrients in the soil. Carbon, Sulphur, phosphorus and Nitrogen are present in the crops residue, which get lost during burning of crops residues in the form of different gases and particulate matter that result in air pollution (Jain et al., 2014). It also effects the next cultivation of crops as the fertility of soil gets reduced and its badly affects the production of next crop (Mandal et.al, 2004). Degradation of environment is presently a serious and big problem worldwide, in particular relation with organic pollutants, air pollution and soil contaminated with heavy metals (Zhang et. al, 2013).

According to Estrellan et.al. (2010), open burning of agricultural residues is a cheap way to promote rotation of crops and control insects diseases, as well as the development of invasive weed species. While the financial and practical advantages of agriculture residue burnings are evident, it is necessary to recognize reasonably the environmental and health hazards of this practice. Records from stimulated and in-situ open burning experiments of various agricultural residues like *Oryza sativa*, *Triticum aestivum*, *Saccharum officinarum* showed a different variety of emissions such as PM, CO, CH_4 , organic compunds, polycyclic aromatic hydrocarbons(PAHs), were identified in the gaseous phase emissions. Gadde et al., (2009) reported emission of air pollutans during straw burning of rice in India are CO_2 (1460 g kgdm^{-1}) , CH_2 (1.2 g kgdry fuel^{-1}) , N_2O (0.07 g kgdry fuel^{-1}) , CO (34.7 g kgdm^{-1}) , SO_2 (2 g kg^{-1}) , PM 2.5 (12.95 g kgdm^{-1}) , PM 10 (3.7 g kgdm^{-1}) , PAHs (18.62 mg kgdry fuel^{-1}). According to Yang et al. (2006), rice straw burning has been discovered to be an important cause of fine particulate PAHs. During the *Oryza Sativa* straw burning days analyzed for 21 PAHs, atmospheric samples showed an average of (33.0 mg m^{-3}) complete particulate concentration and (1160 mg m^{-3}) in the gaseous phase. Pollutants present during the burning days as compared to non-burning days are found to be high.

Crops residue burning (Table 1.1) contributes towards the emissions of greenhouse gases (CO_2, NH_3, and CH_4) and air pollutants (CO, NH_3, NO_2, SO_2 and Volatile Organic Compounds), Particulate matter and smoke which possess threat to human health (Jain.,2014). Huge amounts of air pollutants are produced during rice straw burning in India. Data on emission of air pollutants from three major contributing states in India have been presented in the Table 1 (Gadde et al, 2009).

Table 1.1 Emissions of air pollutants due to burning of crops residues (Gg / Year)

States	CO_2	CO	NO_x	SO_x	NMHC	NH_3	PAH	TPM	$PM_{2.5}$
Punjab	32299.2	1961.4	53.3	8.5	149.2	27.7	0.5	277.1	83.1
Haryana	13907.7	844.5	22.9	3.6	64.2	11.9	0.2	119.3	35.8
Uttar Pradesh	33701.4	2046.5	55.6	8.9	155.7	28.9	0.5	289.1	86.7

Hence, there is a big need to find some other alternatives to solve the problems of open burning of crops residue.Biochar production offers a good option, because it has some unique properties like tendency to treat many pollutants,large surface area and different types of functional groups are present in the biochar (Abdullah and Wu, 2009). Biochar has porous structure and fine grained material, similar to charcoal. It is generated primarily through pyrolysis is a thermo-chemical process in which raw material (plant residue, crop residue) heated in little supply or absence of O_2, which leads to the formation of strong biochar products (Demirbas2006). Pyrolysis product rice straw derived biochar contains huge amount of carbon content in it .

II. BIOCHAR AS A SOIL AMENDMENT

Amendment of biochar derived from rice straw increases the soil properties like pH, organic matter, cations exchange capacity, and water holding capacity (Wardle et al., 2008). In latest years, Biochar have many potential advantage for environment and agriculture such as climate change mitigation and global warming (Molina et al., 2009, Enhance the soil properties (Baronati et al., 2010), Improves growth of plants (Zhang et al., 2012), nutrients retention capacity of soil (Liard et al., 2010).Purpose of accepting the biochar based strategies are carbon sequestration, soil management, reduction in greenhouse gases emissions, enhancing crops growth. Carbon initiates from the ambient carbon dioxide, climate change can be mitigate with the addition of biochar in soil (Lehmann et al, 2006). Maximum 12% reduction of current CO_2 can be done with the help of biochar application in soil without endangering food safety, loss of habitat and soil conservation (Woolf et al., 2010). Some of the most important applications of Biochar may include:

III. EFFECT ON CATIONS EXCHANGE CAPACITY

Whang et al., (2014) reported that the implementation of biochar has no effect on the Cations exchange capacity of cambosols soil apart from a small increase (0.47 cmol / kg) in the 22.5 mg / ha biochar treatment after the millet season, whereas CEC in oxisols showed a growing trend with an increase in the implementation rate of biochar over the two consecutive seasons. It was increased by 1.8 cmol / kg at the end of the millet season under the 22.5 Mg / ha biochar treatment.Singh et al. (2010) investigated the effects of biochar on soil quality, addition of biochar derived rice starw to soil enhanced chemical and physical properties of soil compared to soil without biochar. The biochar soil had higher exchange capacity of cations (CEC= 10.2) than soil control.

Jiang et al. (2012), have also studied the effects of rice straw derived biochar on CEC of variable charge soil. In this experiment they considered 3 soil samples which are rich in free Fe and Al oxides because they were formed under the high weathering and leaching conditions in tropical and subtropical regions. Consequently, CECs of tested soils were relatively small. Adding biochar obtained from rice straw also improves soil CEC. The CEC of Hainan's Oxisols soil improved from 5.63 cmolc kg-1 for control to 6.42 and 8.45 cmolc kg-1 when 3% and 5% biochar were added to the CEC soil by 14% and 5% respectively. The CEC of Guangxi ultisols therefore increased from 3.55 to 4.90 and 6.12 cmolc kg-1, i.e. by 38% and 72% respectively ; the CEC of Hainan ultisols enhanced from 4.69 to 7.90 and 8.83 cmolc kg-1, i.e. by 68% and 88% respectively.

IV. PH IMPROVEMENT

Whang et al., (2014) indicated that biochar use improves soil pH. In this study they applied biochar in two crops season one is millet and another one was wheat season. They observed an increase in soil pH in the consecutive application of 22.5 Mg / ha in the oxisols was 5.92, while no change in pH was observed in the cambisols. Peng et al., (2011) investigated rice straw-dependent temperature and duration derived biochar features and their impacts on Ultisol soil properties in southern China. Biochar modification has influenced the pH of soil and rises up to 0.1-0.40 compared to control.

Xiang-Hong & Xing-Chang (2012) has studied effect of biochar on soil pH. They observed that when biochar is prepared at different temperature by pyrolysis method, their alkanity increases and it also increase soil pH when it is used for soil amendment.Jiang et al. (2012), observed that biochar produced from the rice straw impacts the soil pH and noted that the addition of 3% and 5% of biochar changes soil pH 4.99 for control to 5.84 and 6.13 in oxisols, respectively whereas for Guangxi Ultisols the pH changes from 4.82 for control to 5.97 and 6.10 for 3% and 5% respectively for rice straw biochar addition.Lehman et al. (2011)have reported the impact of biochar addition on soil properties. They have concluded that properties of biochar(Physical, Chemical or Biological) play an important role in determining the effect of biochar on soil biota.

V. INCREASE IN SOIL ORGANIC CARBON

HE Xin-hua et al., (2014) studied the impact of biochar derived from rice straw on organic carbon of soil. In this study, two types of biochar produced from rice straw were used (B250 and B350). After 112 days of incubation, with an increasing trend the organic carbon of soil increases under biochar B250 where on the other hand in B350 there is no significant difference was observed. Zhang and Bian et al. (2012), have also reported the impact on soil quality of wheat straw biochar. After addition of different concentrations of biochar, like 10ton/ha, 20ton/ha and 40ton/ha and the results have shown that soil organic carbon increases.
Steinbeiss et al. (2006) studied the impact of biochar on the soil properties and their results show that biochar can contribute in carbon storage and enhance process of carbon sequestration.

VI. INCREASE IN CONCENTRATION OF SOIL NUTRIENTS

Guerena et al., 2013 studied that application of Biochar additions to soils reduces N leaching and control the circulation of N within the soil.
Major et al. (2012) has studied the effects of biochar on soil hydrology and nutrient leaching in field experiments . It was observed that leaching of nutrients increase up to depth of 0.6 m and it starts decreasing at the depth of 1.2 m. This is due to difference in concentration in soil.
Biederman & Harpole, (2013) have reported that effect of biochar on plant on plant productivity and nutrient cycling. It was observed that the addition of biochar to soils increases productivity , soil inorganic Nitrogen and crop yield of soil as compared with control.

VII. DECREASE IN CONCENTRATION OF HEAVY METALS

Zheng et al., (2013) reported impacts of rice straw biochar on soil quality of polluted soil with heavy metals and the results shows that an application of biochar decreases the concentrations of Cadmium, lead and zinc in the soil.Zang et al.,(2013) also studied impacts of biochar on extractability of heavy metals in the soil and their results shows biochar reduces the bioavailability and concentration of both heavy metal and organic pollutants in soil. Efficacy of reduction in heavy metal concentration in soil depends on properties of biomass, and different pyrolysis temperature.

VIII. GROWTH OF CROPS

Baronti et al., (2010) reported the impact of biochar on crops growth and production. Experiment was done in pots at different concentrations of biochar. It has been found that even small concentration of biochar promotes crops growth.Chan et al. 2005 reported the impact of biochar on crop yields and their findings showed that biochar addition improves plant height, tilling amount and dry weight biomass of *Oryza sativa.* Zhang and Bian et al., (2012) also reported effects of *Triticum Aestivum* biochar on rice crop growth and the results shows that additions of biochar for two crops cycles of rice increases rice yields by 2-9 percent in the second season whereas in first season it was 9-12 percent only.

IX. BIOCHAR AS AN ADSORBENT

Zheng et al. (2013) studied the effects of straw, bran and rice husk biochar on uptake of heavy metals by wheat seedlings grown in pots in a polluted soil historically. Application of these different biochars considerably decreases in the levels of cadmium, zinc and lead extracted in a historically multi-element polluted soil by an (NH_4NO_3) solution, although the concentration of As increased. Biochars addition in soil also reduces concentrations of cadmium, zinc and lead in shoots of plants. Rice straw derived biochar shows drastic decrease in shoot zinc and cadmium concentrations, whereas bran biochar caused low shoot lead concentration and the high shoot arsenic concentration. Reduces the particles of biochar which favours immobilization of lead, cadmium and zinc in soil and dercrease their accumulation in shoots of wheat. Addition of biochar also promoted wheat seedlings shoot development and root elongation and enhanced shoot P and K concentration.
Yakkala et al. (2013)has studied adsorption of cadmium (II) and lead (II) adsorption in single and mixed system by using Buffalo weed (Ambrosia trifida L. var. trifida) biochar . Three types of Biochars (BWBC 300,

BWBC 500 and BWBC 700) were prepared from buffalo weed (*Ambrosia trifida L. var. trifida*) at different pyrolysis temperatures of 300, 500 and 700°C .They have found that biochar from buffalo weed is a low cost adsorbent and can be used for effective removal of Cd(II) and Pb(II) in waste waters.

researched soil quality impacts of biochar derived from rice straw and early biomass yield and development of two types of rice variety. Biochar yield or rice straw restoration was 29.7 percent on average with 34.2 percent ash content. Biochar obtained from rice straw had low volume density of 0.75, elevated pH of 9.3 and phosphorus (biochar of 738 mg P / kg). Cation exchange capacity (CEC= 44.2 cmol+/kg biochar) was high and rice straw biochar was also rich in exchangeable cations versus (5.8 cmol+/kg biochar) and calcium (12.6 cmol+/kg biochar). Application of biochar in soil improved physico-chemical properties of soil compared to control. The soil treated with biochar had greater available phosphorus (11.5 mg / kg soil), exchangeable cations (sodium, potassium, calcium and magnesium-0.05,0.023,0.34 and 0.31 cmol+/kg soil respectively) and higher exchange capability of cations (CEC= 10.2) than the soil control . Improvements in properties of soil owing the use of biochar have been expressed in the enhanced development of different variety of rice grown in the soil treated with biochar. Height of plants, numbers of tilling, and dry weight biomass of rice cultivated in the biochar modified soils considerably more than control. For both rice varieties, the implementation of biochar as a soil amendment to soil showed significant differences in biomass of plants (root and shoot). Biochar treated ROK3 shoot and root biomass were considerably greater than those on soils without biochar therapy.

X. CONCLUSION

Biochar offers a very successful alternative for management of the rice crop residue. It can be easily fabricated by pyrolysis method, which is an expensive technique. Most importantly, the fabrication can be done at large scales without any sophisticated facilities. This can be even arranged at the agricultural field level. Further, the Biochar can be successfully used for amendment of soil properties including the pH, cation exchange properties, soil nutrients, removal of heavy metals by using biochar as an adsorbent. This can further lead to good opportunity to again use the Biochar in the agriculture and for the benefit of crops. Hence, the commercial and filed level applications of this disposal method can be easily harnessed.

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