

## Rice Yield Response to Biochar Application Under Different Water Managements Practices

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Increasing rice grain yield is critical for feeding rapid increasing of Asian population. However, global warming effect may be negative for sustainable rice production. Therefore it is essential to develop technologies not only for increasing grain yield but also for reducing global warming effect. Biochar, which is carbonized biomass, has a great potential of carbon sequestration and soil quality improvement, which can contribute grain yield increasing. In this study, rice yield responses to biochar application on the rice cropping system were evaluated with field experiments under different water management practices at the research farm of the University of Missouri-Columbia Delta Research Center, Portageville, MO. Biochar (i.e., 4 Mg ha<sup>-1</sup>) was produced using field scale pyrolyzer and incorporated into the field 4 months prior to planting. Rice was grown under three different water management practices. Result showed that no significant yield difference was found in the biochar application plots compared to rice hull and control plots from the 2 years field study at the very fertile soil. However, rainfed management results in severe reduction of yield. Research concludes that the biochar application does not significantly influence on rice yield increasing especially for very fertile soils.

**Key words:** Rice yield, Climate change, Biochar, Water management

### Introduction

Despite the positive CO<sub>2</sub> fertilization effect via photosynthesis, the decrease in net biomass productivity and increased floral sterility and lower grain quality at high temperatures can severely reduce use-efficiency of water and nutrients, decrease yield and reduce food security (Del Grosso et al., 2008; Peng et al., 2004; Prasad et al., 2006). Further, the CO<sub>2</sub> fertilization effect may be limited by drought stress and nutrient deficiencies, which depend on photosynthetic pathways, species, growing stage and management regimes (Wang et al., 2006). The net effect of climate change will be reduced crop yield, which may decrease by 7-8% for every 1°C increase in the growing-season temperature (Lal et al., 2004). Carbon dynamics on a global scale strongly interact with the abrupt climate change (ACC), and often result in a reduction in the stored carbon pool, much of which is in the soil (Wang et al., 2006). The ACC has the potential to adversely affect the global

terrestrial carbon pool and, through positive feedback, to enrich atmospheric CO<sub>2</sub> concentrations (Peng et al., 2004). Thus, an understanding of the C pools is fundamental not only to the global environment, but also to the productivity and sustainability of crop production systems. Agriculture is already confronting climate change by assessing green house gas (GHG) emissions to reduce their carbon footprint (Hillier et al., 2009). While agriculture is a major GHG producer (Searchinger et al., 2008), it must be reduced its carbon footprint to sustain crop production. Atmospheric CO<sub>2</sub> is usually captured through biological, chemical or physical processes in plants and soils. This carbon sequestration in soil is a technique for long-term storage of CO<sub>2</sub> or other forms of carbon to mitigate global warming (Baldock and Smernik, 2002; Lal, 2004). This process of CO<sub>2</sub> sequestration has been proposed as a way to mitigate accumulation of GHGs in the atmosphere, which is released by burning fossil fuels. Production of biochar using bio-waste (i.e., crop residues) as a feedstock will sequester carbon in a long-term state to help sustain food production and mitigate ACC impacts (Baldock and Smernik, 2002). Controlling the temperature under limited oxygen

condition during pyrolysis allows conversion of plant biomass (i.e., trees, grasses or crop residues) into biochar (Lehmann, 2007). When biochar is applied to soil, biochar resists microbial decomposition for a much longer time than regular biomass, thus providing for long-term storage (Ji-lu, 2007). “Biochar” is a highly porous charcoal made from biomass that is high in organic carbon. Biochar’s primary use is in soil to retain nutrients and water, and increase soil fertility. Properly made and used, biochar can provide a new technology to help mitigate climate change and other environmental effects. Biochar’s carbon bonds don’t break down, and stay in soil for centuries (Kuzyakov et al., 2009). Biochar in soil sustains food production through its ability to hold nutrients and increase soil productivity (Chan et al., 2007; Laird, 2008; Oasmaa et al., 2009). Biochar synthesis and application to the soil removes CO<sub>2</sub> from the atmosphere by withdrawing organic carbon from the cycle of photosynthesis and decomposition (Lehmann, 2009). In that sense, sequestration of carbon as biochar offers the potential to turn from pyrolysis of crop residue materials into a carbon negative crop production (Mathews, 2008). Both the conversion of biomass into biochar and its application to soil are readily monitored. Primary GHGs associated with the agriculture sector are nitrous oxide (N<sub>2</sub>O) and methane (CH<sub>4</sub>) (Smith et al., 2008). Cropland soils and grazing lands are both agricultural sources of CH<sub>4</sub> and N<sub>2</sub>O emissions. Especially, rice production systems produce significant amount of CH<sub>4</sub> under the anaerobic soil conditions such as in flooded fields. When applied to the soil, biochar can lower greenhouse gas emissions by substantially reducing N<sub>2</sub>O emissions (Smith et al., 2008). Emissions of N<sub>2</sub>O, a greenhouse gas that is approximately 300 times stronger than CO<sub>2</sub> in terms of global warming potential, were reduced by 40% by biochar application and appropriate management (Cayuela et al., 2009). Laboratory studies suggest that reductions of N<sub>2</sub>O emissions from biochar-treated soil depended on soil moisture and soil aeration. When biochar was applied to soil the GHG emissions were 12%-84% lower than when biochar was combusted directly for energy purposes (Hansen et al., 2008). Even though numbers of researches of biochar have been reported about the potential of sequestering carbon and reducing GHG emission, few studies have been reported in a practical field scale especially conventional

rice cropping system under the different water regime in the US. Therefore, objective of this research was to evaluate rice yield response to biochar application under different water management practices from the field scale experiment.

## Materials and Methods

Research was conducted for two years on the University of Missouri Delta Research Center research farm near Portageville Missouri. Conventional US Southern long-grain rice variety (i.e., Wells) was drilled and cultivated under conventional flooded condition with pre-flood surface fertilization based on the University fertilizer recommendation by soil testing (i.e., 150 kg N ha<sup>-1</sup>, 45 kg P ha<sup>-1</sup> and 50 kg K ha<sup>-1</sup>). The soil at the research farm is classified as a Sharkey soil (Vertic Haplaquepts, vary fine, montmorillonitic, nonacid, thermic) with a clayey surface soil overlying a slowly permeable clayey subsoil (Garrett et al., 1978). Insecticide and fungicide were not applied for this study. Three blocks of plots will be arranged in a split-plot design with water management practices (i.e., continuous flooding, 2-weeks interval intermittent irrigation and rainfed) as the whole plot treatment and crop residue (i.e., control, rice hull and biochar) as the split-plot

**Table 1. Rough rice yield response of water management and rice biochar application on directed seed rice. Different letter after a yield value indicates significance of treatment differences (P<0.05).**

Management	Rough rice yield, Mg ha <sup>-1</sup>	
	2010	2011
	<u>Water management</u>	
Rainfed	-	1.0b ± 0.83
Intermittent irrigation	8.51 ± 2.62	8.27a ± 0.61
Flooded	7.89 ± 1.68	6.8a ± 1.64
F-value	0.35	50.45
P<F	0.5632	<0.0001
	<u>Rice residue application</u>	
Control	8.72 ± 2.69	5.85 ± 3.64
Rice hull (4 Mg ha <sup>-1</sup> )	7.87 ± 1.74	6.02 ± 2.98
Rice hull biochar (4 Mg ha <sup>-1</sup> )	7.90 ± 2.13	5.86 ± 5.59
F-value	0.27	0.01
P<F	0.7639	0.99

treatment. Rice hull was collected from local rice mill. Feedstock was maintained moisture content of 12% to produce biochar using a field scale biomass pyrolyzer (Jung, 2011). Rice hull and biochar were broadcasted and incorporated 4 month prior to seeding by rate of 4 Mg ha<sup>-1</sup>. Each plot was harvested with a plot combine with an on-board weighing system. After harvest, paddy rice was stored in an air-conditioned room to reach 13% water content. SAS PROC GLM was employed to analysis of significance of the main effect of block and residue factor.

## Results and Discussion

Numbers of research have been reported that crop yield was increased with application of biochar for soybean (Tagoe et al., 2008), maize and upland rice (Asai et al., 2009). Possibility of yield response of biochar application on the conventional flooded rice cropping system was reported (Haefele et al., 2008). Reichenauer et al. (2009) reported that the application of 2-4 Mg rice-husk-bochar ha<sup>-1</sup> increased the grain yield. Not like other study, there was no significant difference of rough rice yield on biochar treatment compare to control and rice hull treatment for both 2010 and 2011 year. Significant lower yield was observed on the rain-red water management plots (Table 1). Due to the significant drought summer of 2010, yield data wasn't able to obtain in the rain-fed plots. In 2011, rice yield on the rain-fed system was significantly lower than other water management systems. Otherwise, no significant difference of rice yield was found between flooded and intermittent drainage system for both 2010 and 2011 year. These results may be explained that growing season's temperature has been abnormally hot and dry for both year (Gero and Turner, 2011). Unexpected environmental conditions resulted in greater of experimental error and it affected the significant test of experiment effect levels. Results showed that yield in the control plot were not significantly lower than other treatments but slightly higher than other treatments in 2010 year. These results can be explained that the Mississippi delta soils are often hard to figure out fertilizer effect due to the very fertile soils (e.g. Soil test results in 2010 showed high soil organic matter content (4.9%) and CEC (43.3 meq/100 g). Soil pH was 5.9). In conclusion, rice yield response to the

biochar application wasn't significantly able to figure out within a 2 year's experiment in the Mississippi delta soil. Therefore, research suggests that application of biochar into relatively poor quality soils may able to figure out yield responses through improving soil quality. Further studies of yield response to biochar application may be considered with environmental impacts, such as GHG emission, carbon sequestration soil and water quality studies.

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