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Sugarcane Bagasse Biochar for Sustainable Inland Saline Aquaculture

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Abstract—*Soil and ground water salinization is now one of the major threats to the global agriculture food production. Nearly 6.73 million ha of salt-affected lands and 1.93 million hectares with ground saline water is available in India. The vast availability of inland saline water (2.32 million ha) in Haryana provides an emerging scope to increase farmer's income by aquaculture of commercially important fish/shrimps, but the nutrient concentration and composition is not in range of normal saline cultivable species. The inland saline aquaculture system is deficient in critical potassium element and Ca:Mg ratio is very less than required level. In this context, an experiment was conducted to assess the effects of biochar produced through pyrolysis of sugarcane bagasse on selected nutrient properties of inland saline pond water in CIFE-Rohtak centre, Haryana by application @ 9 tha^{-1} and 18 tha^{-1} to pond sediment and water. The pyrolysis of dried sugarcane bagasse was done at 500℃ in electrical heating kiln and its nutrient parameters were analysed by APHA method. There was significant increase in sediment organic carbon (3.78times), CEC (59%) and potassium (30%), available phosphorous (69%), available-N (ammonium-N and Nitrate-N) but no changes in Ca:Mg ratio in inland saline pond water respectively. Bagasse biochar also increase the primary productivity (0.251 mgm^{-3}) after one month and stabilise high fluctuation of the alkalinity in inland saline pond water (ISPW). For environmental sustainability, application of biochar to the inland saline aquaculture system not only improves the health status of the system but also reduces the problem of biomass burning particularly in Haryana & Punjab and thus helps in better resource management.*

1. INTRODUCTION

In India about 146.8 mha of agriculture land is degraded due to direct/indirect human interventions (Bhattacharyya *et al*., 2015). Soil and ground water salinization is now one of the major threats to the global agriculture food production. In India nearly 6.73 million ha of salt-affected lands and 1.93 million hectares area with ground saline water (Sharma and Singh 2015: Lakra *et al*., 2014) is available. The worst affected states are Punjab, Haryana, Rajasthan, and Uttar-Pradesh. The vast availability of inland saline water (2.32 million ha) in Haryana provides an emerging scope to increase farmer's income by aquaculture of commercially important fish/shrimps, but the nutrient concentration and composition is not in range of normal saline cultivable species. There is increasing aquaculture practise especially white leg shrirmp (*Lettopenaeus vennamei*) by pumping the inland saline ground water to earthen ponds. The major problem in inland saline aquaculture system is ponds seepage and less concentration of potassium and Ca: Mg ratio. In this regard some believe that biochar may provide a win- win scenario for the inland saline soil (Laird *et al*., 2008). The recent studies gives an idea that biochar addition is effective in improving physical, chemical and biological properties of salt-affected agriculture soils (Lashari *et al*., 2010) but no studies till now performed to improve the inland saline pond productivity. Biochar is a fine-grained, carbon-rich, porous product remaining after plant biomass has been subjected to thermo-chemical conversion process (pyrolysis) at low temperatures (~350–600°C) in an environment with little or no presence of oxygen (Amonette and Joseph, 2009). It can be produced from any organic waste like agricultural crop waste, industrial, urban waste and animal waste (Lehmann and Joseph, 2009).

2. MATERIALS AND METHODS

Biochar was produced by pyrolysis of dried sugarcane bagasse (<14% moisture) in electrical heating kiln for 4 hour at 500^{0}C. The chemical properties of biochar (Table no.1) estimated by American Society for Testing and Materials (ASTM), 2013. 50 days of experiment was conducted to assess the effects of biochar produced through pyrolysis of sugarcane bagasse on primary productivity and physicochemical properties of inland saline pond water at C.I.F.E-Rohtak, centre, Haryana. The 100 g and 200 g of biochar applied to 25 kg of sediment (i.e. 9 t ha^{-1} and 18 t ha^{-1}) and saline pond water in 300 L capacity FRP. Treatment combination is given in Table 2. For physicochemical parameter and primary productivity (in the form of chlorophyll-a concentration) water sample collected at 10 day and 7 day interval respectively. The primary productivity (spectrophotometric method) and water physicochemical properties (NH_4^+-N, $N0_3^-$ -N, total alkalinity, phosphorous, TSS, Ca, Mg, K) was estimated by APHA, 2005.

Table No.1. Chemical properties of sugarcane bagasse biochar produced at 500^{0}C.

Si. No.	Chemical properties	Value
1	pH	7.1
2	EC (dSm^{-1})	0.62
3	Ash (%)	7.89
4	Available Nitrogen (%)	0.24
5	Total elemental Carbon (%)	56.6
6	CEC ($cmol^{(+)}kg^{-1}$)	52.7
7	Available Phosphorus (gkg^{-1})	1.8
8	Total Potassium (gkg^{-1})	24
9	Available Potassium (gkg^{-1})	19.7
10	Available Sodium (gkg^{-1})	0.3
11	Available Calcium (gkg^{-1})	4.4
12	Available Magnesium (gkg^{-1})	3.8

Table No.2. Treatment combinations of the experiment.

Treatments	Components
Control (C)	Sediment + ISPW
T_1	(Sediment+BC100gm)+ISPW
T_2	(Sedimet+BC200gm) +ISPW
T_3	Sediment+(ISPW+BC100gm)
T_4	Sediment +(ISPW+BC200gm)

3. RESULTS AND DISCUSSION

3.1 Water Quality Parameters

There was a significant increase in ammonium-N (NH_4^+) and nitrate-N (NO_3^-) concentration recorded in T_4 (0.02 to 0.35 mgL^{-1}) treatment and lowest value for control (0.01 to 0.14 mgL^{-1}) in inland saline water (Fig 3.1 & Fig 3.2). This increase of ammonium-N/nitrate-N in the water column is due to the decomposition of soil organic matter (Prakash, 1997) and labile organic carbon of bagasse biochar. The bagasse biochar is the rich source of available nitrogen (0.24%) in the form of Nitrate-N (NO_3^-) (Denyes *et al.*, 2014) which causes the remarkable increase in NO_3^- concentration in the water column of T_4 and T_3 treatments.

Total alkalinity (Fig. 3.3) in C, T_1 and T_2 treatment shows significant decrease to 106,103 and 106 mgL^{-1} in 10th day from initial value () and increase at low rate after 30th day respectively. The T_4 and T_3 treatment causes the lowest decrease in total alkalinity in 10th day than other treatment and the final value at 50th day is 158 and 149 ppm respectively. When the dry saline sediment comes in contact with the water the hydrolysis of sodium carbonate (Na_2CO_3) occurs which may leads to formation of sodium hydroxide (NaOH) and unstable weak carbonic acid (H_2CO_3) (Handa, 1975; Chhabra, 1996). The unstable carbonic acid dissociates into carbon dioxide and water. This carbon dioxide is neutralise by the carbonate alkalinity of water which may cause reduction in total alkalinity but biochar has high total alkalinity (Fidel *et al.*, 2017) which cause the less reduction of alkalinity by contribution of carbonate ion to the water system. Om (2015) also reported that in inland saline water of Rohtak, there was increase in pH by (1.37 to 2.86%) with decrease in alkalinity (11 to 22%) in phytoremediation of calcium by *Eichhornia crassipes.*

There was a significant increase in potassium concentration in the water column in all biochar treatments and no changes in control (without biochar) water tank (Fig. 3.4). The highest increase in potassium was in T_4 (30.8%) and lowest in control (2%) at the end of the experiment respectively. Potassium is the key elemental nutrient for the primary producer (Wakeel, 2013) whose availability significantly decreases in soil-water solution due to the high concentration of sodium in inland saline soil (Cakmak, 2005). The water application of sugarcane bagasse biochar facilitates more increase of K in T_4, T_3 than T_2, T_1 treatments as biochar is rich in available potassium (5.6 to 5.5 g/kg), high CEC (51 $cmol^{(+)}/kg$) .

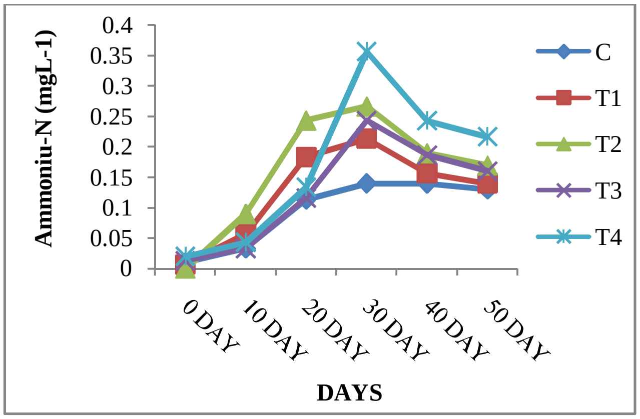


Fig.3.1. Changes in Ammonium-N mgL^{-1} of water

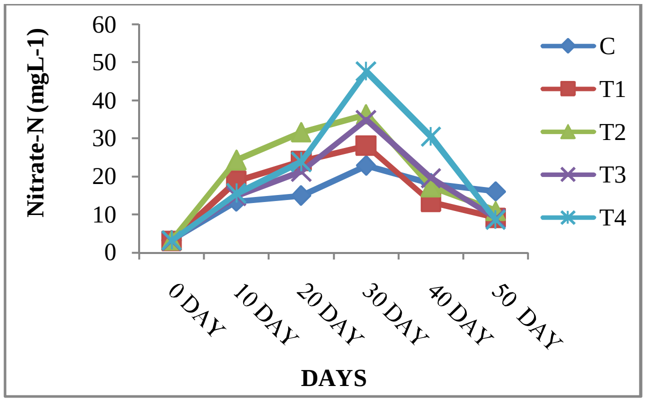


Fig.3.2. Changes in Nitrate-N (mgL-1) of water

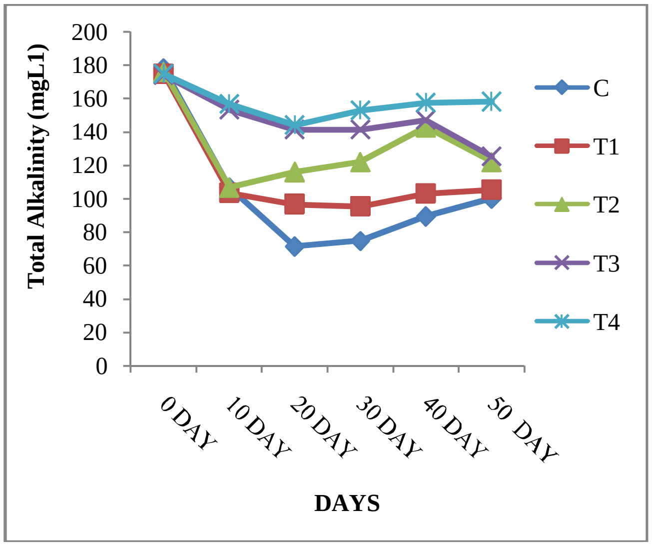


Fig.3.3. Changes in Total Alkalinity of water.

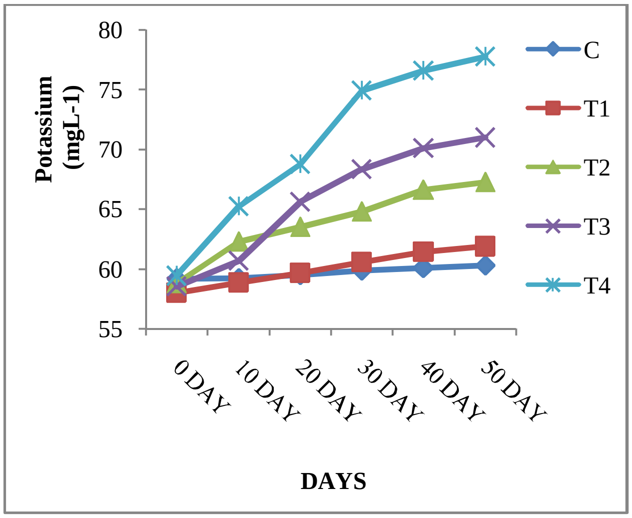


Fig.3.4. Changes in potassium of water

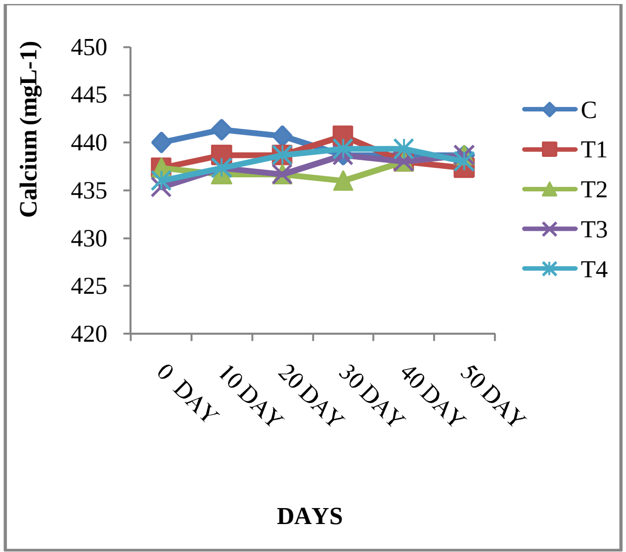


Fig.3.5. Changes in Calcium (mgL^{-1}) of water

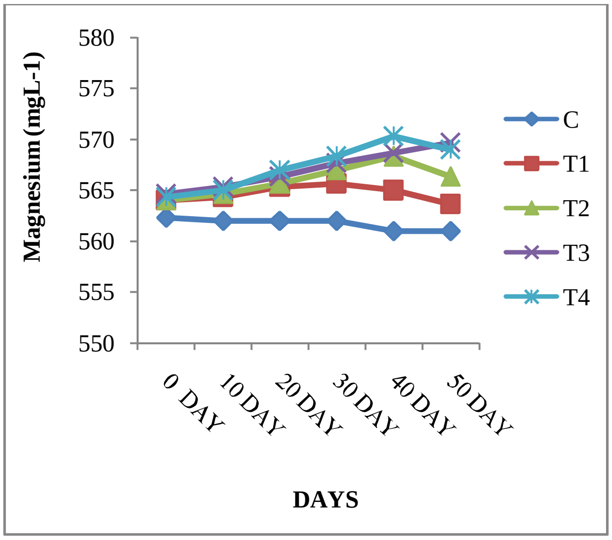
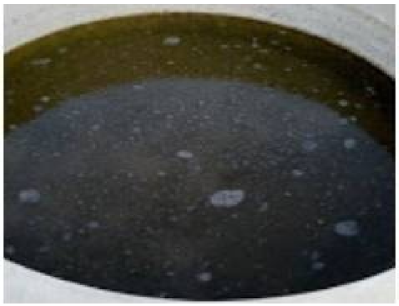


Fig.3.6. Changes in Magnesium (mgL^{-1}) of water.

a. Control at 7th day



b. Control at 50th day

c. T_1 Treatment at day 50th

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d. T_2 Treatment at day 50th day **e.T_3Treatment at day 50th day** **f. T_4 Treatment at day 50th day**

Plate 1. Primary productivity in control (0th days and 50th days) and in treatments at the end of the experiment.

There was no significant changes in calcium (Fig. 3.5), magnesium (Fig. 3.6) of inland saline water in all treatment and control because the available calcium and magnesium quantity of sugarcane bagasse (Table 1) is very less in comparison to the initial level in 300 lt of experimental inland saline water. There was a significant increase in TSS in all treatments except control till 10th day (Plate 1) of the experiment period and then attains the initial level for the rest of the experiment period. The biochar is a very light material whose application to water medium causes a high increase in TSS. In T_1 and T_2 treatments some biochar suspended in water column which was less than the T_3 and T_4 treatment. In T_2 treatment the TSS is less than T_4 (though does is similar), as in T_4 sediment particle forms flocks with biochar particle on water surface where as it is lesser when biochar is uniformly mixed with sediment.

There was significant increase in phosphorus (PO_4^{-3}) nutrient level of water in all treatments than control until 30th days of the experiment and then decreases till the 50th day (Fig 3.7). In all treatment, T_4 treatment shows the highest increase in phosphorus (0.136 to 0.231 mgL^{-1}). The sugarcane bagasse biochar have high concentration of available phosphorous than saline water (Table 1) which causes more availability of phosphorus to the water column in T_4 and T_3 treatments than T_1 and T_2. After 30th days of the experiment, there was a decreasing trend in phosphorus of water column due to its utilization by the primary producer for biomass production.

3.2 Primary productivity

The initial chlorophyll-a concentration of inland saline pond water varies between 0.088 to 0.0913 mgm^{-3}. After adding the pond water into different treatments of the tank the primary productivity crashed and there is no revival till one month (Plate 1). After one month the primary productivity appears first in T_4 and T_3 treatments, then other treatments and control tank. The increase in nutrients of water column, decrease in turbidity and sunlight availability causes increase of primary production till the end of the experiment. The significant increase in the nutrient level of water was due to the microbial supplement (mainly N nutrient) from sediment and available nutrient release from biochar application. As biomass of primary producer increases, it causes a decrease in NH_4^+, NO_3^-, PO_4^{3-} a nutrient in the water. It is reported that biochar amendment increases plant (maize, radish, acacia) growth in agriculture field of normal and saline soil (Chan *et al.*, 2008; Uzoma *et al.*, 2011; Drake *et al.*, 2016). Aquatic ecosystem productivity is different from agriculture ecosystem but from above water quality parameter observations we can conclude that the nutrient availability from biochar to the water column cause significant bloom of primary productivity.

4. CONCLUSION

Based on the result obtained during the study, it can be concluded that, in water biochar addition increases NH_4^+, NO_3^-, PO_4^{3-}, thus increases primary productivity and stabilise the high fluctuation in alkalinity. It enhances the crucial deficit nutrient in ISW that is K, without significant changes in sediment. The ratio of Ca:Mg (1:1.27) in ISPW remain unchanged by addition of biochar but the minimum required ratio is 1:2.25. Among all the treatment T_4 gives best result for water quality parameters and primary productivity and T_3, T_2 shows comparable same result. If biochar supply is limited then 100 g biochar application to ISW is better than 200g in sediment. For environment sustainability application of biochar to the inland saline aquaculture system not only improves the health status of the system but also reduces the problem of biomass burning particularly in Haryana & Punjab and thus helps better resource management.

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