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NUTRIENT LEACHING BEHAVIOUR OF AN ALFISOL AS AFFECTED BY TOBACCO STALK BIOCHAR AND SYNTHETIC ZEOLITE

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Organic soil amendment tobacco stalk biochar (TS Biochar) and inorganic soil amendment synthetic zeolite (SZ) application to light textured soils of tobacco in order to minimize the nutrient leaching losses was studied in a laboratory column experiment. The organic amendment TS Biochar was produced from tobacco stalk biomass under pyrolysis conditions of 500 ^{0}C temperature and 90 minutes holding time and synthetic zeolite was procured from zeolite and allied products, Mumbai. The two soil amendments alone and their combinations with recommended dose of nitrogen and potassium were tested in the present experiment. Each leaching event was performed with 5cm irrigation equivalent. 60 g of TS Biochar, 15 g of SZ, and their combinations with fertilizer (ammonium sulphate @ 7.1 g and potassium sulphate @ 6.72 g) and without fertilizer were mixed with 5cm soil layer of columns. Amount of water leached in each leaching event was measured and the leachate samples were analyzed for ammonium and potassium. The results indicated that on an average maximum retention of water was recorded in TS Biochar treated columns. The column that received fertilizer alone without any soil amendment has retained minimum amount of water. Cumulative ammonium (NH_4^+) and potassium (K^+) leaching was measured in treated and control plots. Cumulative ammonium and potassium concentrations were higher in fertilizer alone without any amendment treated column. The TS Biochar has effectively inhibited the leaching of ammonium and potassium by 28.10 and 25.28 per cent, respectively. Whereas the SZ, inhibited leaching of 5.09 and 4.71 % of ammonium and potassium, respectively. The inhibition of ammonium and potassium leaching by TS Biochar could be attributed to appreciable cation exchange capacity and amount of increased water retention over fertilizer alone control and unamended unfertilized control.

Keywords: Nutrient leaching, TS Biochar, synthetic zeolite, column studies, northern light soil

INTRODUCTION

Fertilizer application results in the leaching of nutrient elements, such as nitrogen and potassium from light soils of FC Virginia tobacco. Leaching of nutrients from surface to lower depths depletes soil fertility, increases fertilizer costs for the farmers, reduces crop yields and most importantly causes environmental pollution. One of the options to reduce nutrient leaching could be the application of biochar and zeolite to soils. It was suggested that the application of biochar can increase soil fertility and crop productivity by reducing the leaching of nutrients or even supplying nutrients to plants (Glaser *et al.*, 2002; Lehmann *et al.*, 2003; Major *et al.*, 2009). The biochar amended soil has high capacity of holding water and ions (Lehmann *et al.*, 2005). Ding *et al.*,(2010) showed that bamboo biochar sorbed ammonium ions by cation exchange and retarded the vertical movement of ammonium into deeper soil layers within the 70-d observation time. The addition of zeolite has improved the nutrient status of sand-based root zones, especially selective retention of NH_4^+ and K^+ ions (Nus and Brauen, 1991; Petrovic, 1993). Hence the present study was taken up to evaluate the effect of tobacco stalk biochar and synthetic zeolite on leaching of ammonium, and potassium in sandy soils of FCV tobacco.

MATERIALS AND METHODS

A surface soil (0–15 cm) was collected from CTRI-RS, research farm, Jeelugumilli, Andhra Pradesh. The soil was air-dried and ground to pass through a 2 mm sieve and thoroughly homogenized. TS Biochar was produced from the thermal decomposition of a TS Biomass and SZ was procured from the zeolites and allied products, Mumbai, were tested to evaluate the nutrient leaching minimization potential of sandy soils. The cation exchange capacity of TS Biochar was 30 C mol (p+) kg^{-1} (Poorna Bindu *et al.*, 2015). The experimental soil was sandy soil, acidic in reaction (pH 5.5) with CEC of 2.8 C mol (p+) kg^{-1} soil, low in $KMnO_4$-N, NH_4OAc-K and high in Brays-I P concentration. The organic carbon content of the soil was low (0.23%). DTPA extractable iron and manganese were sufficient whereas zinc and copper were deficient.

Column leaching experiment

Columns of PVC tubes, 45 cm long (i.d. = 6.7 cm) with a provision to collect leachate samples at bottom were used. Soil was air-dried, ground to pass though 2 mm sieve and filled to a height of about 30 cm by uniform tapping with a rod having wooden base to achieve a bulk density of 1.3-1.5 g/CC depending on field bulk density for the sandy soil collected from Jeelugumilli. Prior to leaching, the columns were saturated with distilled water by capillary flooding. The TS Biochar was applied @ 1 t/ha, SZ at the rate of 250 kg/ ha, ammonium sulphate (N) @ 120 kg/ha and potassium sulphate (K_2O) @ 120 kg/ha, application of above materials in the columns were 60g, 15g, 7.1g and 6g, respectively. Treatment structure includes T_1: N+K T_2: N+ K+TS Biochar, T_3: N+K +SZ, T_4: N+K+TS Biochar + SZ, T_5: TS Biochar+SZ and T_6: control. These materials were applied on the top soil of a polyvinyl chloride (PVC) column and mixed in the upper layer of the column (0–5 cm). The amount of water leached out from each treatment was recorded after each leaching event. After each leaching event, leachates were collected within 24 h and immediately transferred to the laboratory for analyzing pH, ammonium and potassium. The experiment was set up in duplicate and all the chemical analysis were performed in triplicate and results were presented in means and error bars with percentage.

RESULTS AND DISCUSSION

Effect of soil amendments on the leachate volume

Irrespective of the treatments, minimum volume of leachates were collected during the first leaching event, and it is increased with increasing the leaching events (Fig. 1). Approximately 40-45 % of the water applied was leached across the treatments containing TS Biochar, whereas in SZ, N+K and control showed 65 % leaching of the applied water. This could be attributed to the micro porosity of the biochar which has resulted in the increased water holding capacity. Studies conducted by Novak *et al.*, 2012; Basso *et al.*, 2012, Kinney *et al.*, 2012 and Abel *et al.*, 2013 reported that soil biochar mixtures have shown 0-30% increase in water holding capacity of the soil. TS Biochar in the present experiment also has resulted in 20-25 % increase in water holding capacity of the soil across various treatments.

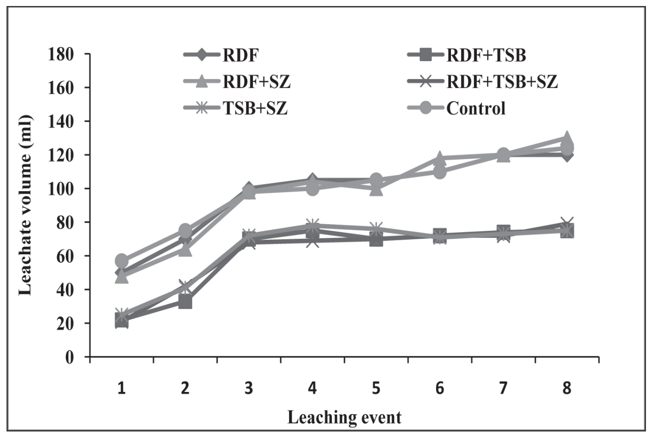

Fig. 1: Average leachate volumes (ml) per leaching event during the course of leaching experiment.

Effect of soil amendments on the pH of leachates

The pH measurements of the N and K leaching study reveals that leachates behaved differently at various treatments (Fig. 2). Control and TS Biochar+SZ treatments recorded neutral to basic pH than other treatments, which might be attributed to the basic reaction of the soil amendments as well as the absence of acid forming fertilizers. The treatment which received N and K fertilizer without any soil amendments recorded acidic pH followed by the treatment N+K+SZ indicating poor buffering capacity of the soil. Treatments including TS Biochar have recorded higher pH values than the treatments without TS Biochar. The reason could be due to the neutralization of acid formed due to the fertilizers by the TS Biochar. Although SZ is basic in reaction it failed to neutralize the acid formed by the fertilizers.This could be due to it's in- ability to mix properly with fertilizer and soil. The decrease and increase in pH at different leaching events indicates that acid forming nature of the fertilizers and redox reactions occurring over a period of time.

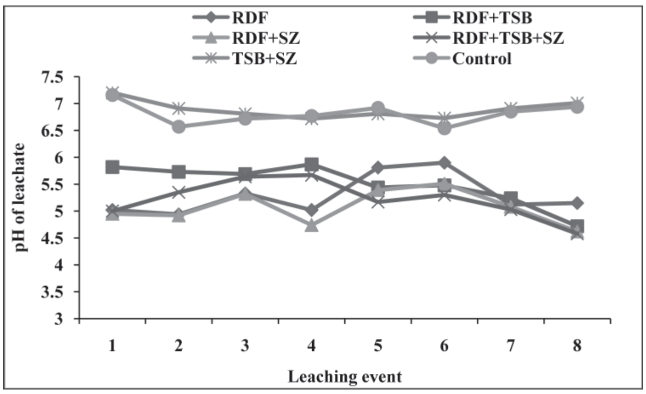

Fig. 2: Changes in pH of the leachates at different leaching events as affected by soil amendments.

Effect of soil amendments on the leaching behaviour of N and K applied

TS Biochar and SZ application to the sandy soil resulted in reduced leaching of both ammonium and potassium ions from the soil (Fig. 3&4) compared to the columns fertilized without amendment. Irrespective of biochar treatment, the amounts of leached ammonium and potassium decreased with increase in the number of leaching events. The treatments N+K and N+K+SZ behaved similarly and were subjected to maximum loss of nutrients within a short span of two leaching events whereas N+K+TS Biochar and N+K+TS Biochar+SZ treatments reduced the losses and it continued upto the last leaching event. As evidenced from the study the tobacco stalk biochar is suitable for curtailing the nutrient losses, which would provide greater opportunity for crop to take up those nutrients and therefore reduce nutrient losses through leaching. Similar results observed by other biochars reported by (Ippolito *et al.*, 2012; Kemeyama *et al.*, 2012). The reason could be that the biochars have some CEC arising from organic functional groups on biochar surfaces which allows them to absorb and there by reduces leaching of cationic nutrients. The concentration and nature of organic functional groups on biochar surfaces is critical to the interaction between biochar and nutrients in soil solutions. Cation exchange sites on surface of biochar are dominant due to formation of carboxylate functional groups during oxidation. (Cheng *et al.*, 2006; Uchimiya *et al.*, 2011), In contrast although the CEC of SZ is very high it was not performed as expected could be due to the inorganic in nature and the exchange sites of SZ were not readily mixing with the fertilizers applied, hence the performance of SZ was less compared to TS Biochar. In addition to soil carbon storage, soil biochar additions are known to improve N retention. Both effects may have environmental benefits and lead to a decreased use of fertilizers with an important enhancement of agricultural sustainability. Biochar has been shown to reduce ammonium leaching in acidic tropical soils (Lehmann *et al.*, 2003).

The per cent inhibition of leaching of ammonium and potassium applied by tobacco stalk biochar were 28.10 and 25.28 whereas synthetic zeolite has recorded 5.09 and 4.71, respectively. (Fig. 5). The percent inhibition of leaching of ammonium and potassium by TS Biochar were more or less than that of other reported biochars such as peanut shell biochar (14% for ammonium), mixed wood biochar (31% K) (Yao, *et al.*, 2012; Major *et al.*, 2012). Tobacco stalk biochar has the potential to hold the moisture and there by reduced the nutrient leaching and it curtailed the leaching of ammonium and potassium. The effectiveness of different soil amendments in the per cent inhibition of leaching of N and K applied were in the order of TSB> (TSB+SZ) >SZ.

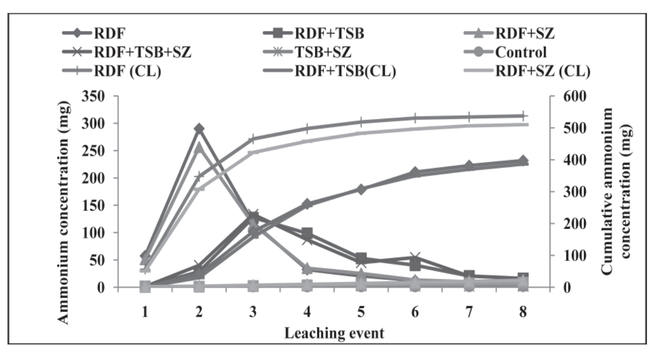

Fig. 3: Pattern of ammonium concentration in the leachates and cumulative ammonium concentration leached during the course of leaching experiment as affected by soil amendments

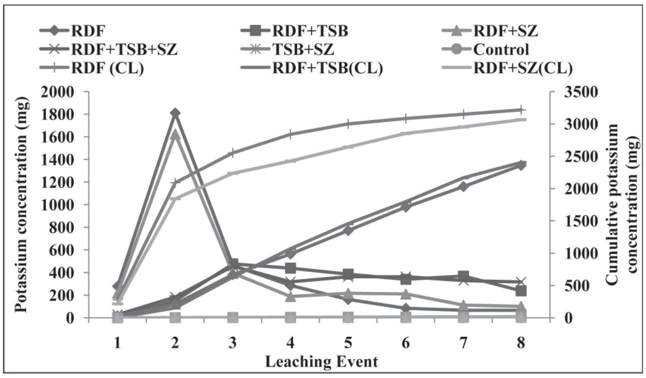

Fig. 4: Pattern of potassium concentration in the leachates and cumulative potassium concentration during the course of leaching experiment as affected by soil amendments.

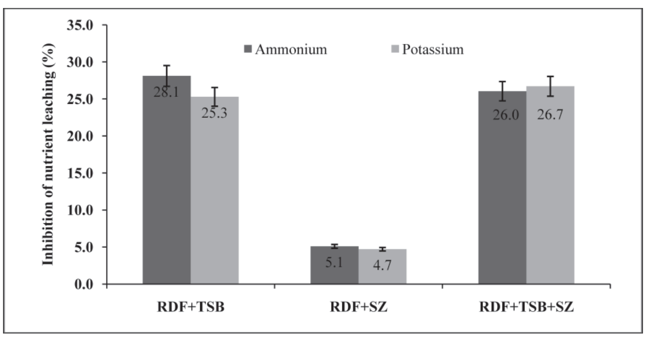

Fig. 5: Percent inhibition of N and K leached in an Alfisol amended with TSB and SZ.

REFERENCES

Abel, S., A. Peters, S. Trinks, H. Schonsky, M. Facklam, and G. Wessolek. 2013. Impact of biochar and hydrochar addition on water retention and water repellancy of sandy soil **Geoderma**. 202: 183-191.

Basso, A.S., F.E. Miguez, D.A. Liard, R. Horton, and M. Westgate. 2012. Assessing potentialofbiochar for increasing water-holding capacity of sandy soils, **Glob. Change. Biol. Bioenergy**. 5(2): 132-143

Cheng, C.H., J. Lehmann, J.E. Thies, S.D. Burma and M.H. Engelhard. 2006. Oxidation of blackcarbon by biotic and abiotic processes, **Org. Geochem**.37: 1477-1488.

Ding, Y., Y. X. Liu, W. X. Wu, D. Z. Shi, M. Yang, and Z. K. Zhong. 2010. Evaluation of biochar effects on nitrogen retention and leaching in multi-layered soil columns. **Water Air Soil Pollut.** 213: 47-55

Glaser, B., J. Lehmann, and W. Zech. 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal: A review**. Biol. Fertil. Soils.** 35:219–230.

Ippolito, J. A., J. M. Novak, W. J. Busscher, B. M. Ahmedna, D. Rehrah, and D. W. Watts .2012. 'Switchgrassbiochar affects two Aridisols'**, J. Environ. Quality**. 41: 1123-1130.

Kameyama, K., T. Miyamoto, T. Shiono, and Y. Shinogi. 2012. 'Influence of sugarcane bagasse-derived biochar application on nitrate leaching in calcaric dark red soil', **J. Environ. Quality**. 41: 1131-1137.

Kinney, T.J., C.A, Masiello, B. Dugan, W.C. Hockaday, M.R. Dean, K. Zygoualkis and R.T. Barnes. 2012. Hydrologic properties of biochars produced at different temperatures, **Biomass.Bioenerg.** 41: 34-43.

Laird, D. A., Fleming, P. D., Wang, B., Horton, R. and Karlen, D. L. 2010a. 'Biochar impact on nutrient leaching from a Midwestern agricultural soil. **Geoderma.** 158: 436-442.

Laird, D. A., P. D. Fleming, D. D. Davis, R. Horton, B. Wang and D.L. Karlen, 2010 b. 'Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. **Geoderma.** 158: 443-449.

Lehmann, J., J. Pereira da Silva, C. Steiner, T. Nehls, W. Zech, and B. Glaser. 2003. Nutrient availability and leaching in an archaeological Anthrosol and aFerralsol of the Central Amazon basin: Fertilizer, manure, and charcoalamendments. **Plant.Soil.** 249: 343–357.

Major, J., C. Steiner, A. Downie, and J. Lehmann. 2009. Biochar effects onnutrient leaching.

In: J. Lehmann and S. Joseph, editors, *Biochar for environmental management: Science and technology*. Earthscan, London.p. 271–288.

Major, J., M. Rondon, D. Molina S.J. Riha, and J. Lehmann. 2012. Nutrient leaching in a Colombian savannaOxisol amended with biochar. J. Environ. Quality. 41: 1076-1086.

Novak, J. M., I. Lima, B. Xing, J. W. Gaskin, C. Steiner, K. C. Das, M. Ahmedna, D. Rehrah, D. W. Watts, W. J. Busscher, and H. Schomberg. 2009. Charecterization of designer biochar produced at different temperatures and their effects on a loamy sand, **Annals of Environmental science.** 3: 195-206.

Nus, J. L., and S. E. Brauen. 1991. Clinoptilolite zeolite as an amendment for establishment of creeping bentgrass on sandy media. **Hort. Sci.** 26(2): 117-119.

Poorna Bindu, J. D. Damodar Reddy, P. Santhy, K.M. Sellamuthu, M.Mohammed Yassin and Ravindra Naik. 2015. Production and characterization of tobacco stalk biochar. **Tob. Res.** 41(2): 91-96.

Petrovic, A. M. 1993. Potential for natural zeolite uses on golf courses. USGA Green Section,31-1114

Uchimiya, M., S. Chang and K. T. Klasson. 2011. 'Screening biochars for heavy metal retention in soil: role of oxygen functional groups', **J. Hazard. Mat.** 190: 432-441.

Yao, Y., B. Gao, M. Zhang, M. Inyang, and A. R. Zimmerman.2012. Effect of Biocharamendmenton sorption and leaching of nitrate, ammonium and phosphate in a sandy soil. **Chemosphere.** 89: 1467-1471.