ABSTRACT

Biochar a pyrolysis product of biomass has wide application in environmental and agricultural management. Due to the unique physico-chemical properties, biochar has been proved as a cost effective and eco-friendly soil amendment to support crop growth and productivity. Moreover, it helps in remediating pollutants and sequester soil carbon. Thus, biochar aids towards climate change mitigation by reducing emission of GHGs from soil. In this study, tea pruning litter and mixed wood chips were used as feedstock to produce six different biochars by conventional (using kilns, production temperature = 350°C), pyrolysis and gasification methods (production temperature = 650°C). The physico-chemical characteristics of the produced biochars differed significantly due to feedstocks and production methods. Conventional method yielded greater amount of biochar (35-40%) followed by gasification (20-35%) and pyrolysis (18-30%). Regardless of the feedstocks, biochars obtained from conventional method had destructed pore structures leading to reduction in their specific surface area (SA) compared to the biochars produced from pyrolysis and gasification methods. Production temperature, pH and SA of the pyrolyzed and gasified biochars are significantly ($p < 0.05$) correlated (r = 0.905, 0.870 and 0.740, respectively) with their improved adsorption capacity (TLG = 332.28 mg g^{-1}, WCG = 321.15 mg g^{-1}). Conventionally made tea pruning litter biochar was grouped under minimal degradation (R50 = 0.60) whereas, rest of the biochars were categorized as most recalcitrant (R50 = 0.76 to 1.12). Biochars produced from tea pruning litter possess maximum concentration of poly aromatic hydrocarbons (PAHs) compared to mixed wood chips. Whereas, biochar obtained from mixed wood chips showed maximum yield, higher fixed carbon, specific surface area, water holding capacity and calorific value. Significant variations were observed in laboratory experiments assessing the effects of produced biochars on the germination of mustard (*Brassica juncea* L., variety TS 38) and french bean (*Phaseolus vulgaris* L., variety Arka Anoop) seeds, particularly in relation to the type of biochar, application dosage, and seed type. Biochars application at 10 t ha^{-1} enhanced seed germination and seedling growth in both the tested seeds. However, biochar application at 20 t ha^{-1} inhibited the same. Tea pruning litter conventional biochar exhibited highest rate of seed germination at 10 t ha^{-1} of application dose. Contrastingly, application of same biochar at 20 t ha^{-1} decreased the seed germination and seedling growth to a considerable extend. Field experiment was carried out for two consecutive years (November to February 2018 and 2020) to study the effects of produced biochars on soil properties, growth and yield of mustard (*Brassica juncea* L., variety TS 38) and french bean (*Phaseolus vulgaris* L., variety Arka Anoop) crop. Moreover, impacts of the biochars on emission of nitrous oxide (N_2O) and soil carbon dioxide (CO_2) efflux from the mustard and french bean fields were estimated. Tea pruning litter conventional (TLC), tea pruning litter gasification (TLG), mixed wood chips conventional (WCC) and mixed wood chips gasification (WCG) biochars were used as soil amendments and compared with farmyard manure (FYM) and inorganic NPK fertilizers. N_2O samples from mustard and french bean fields were collected at ten-days interval from the sprouting of seeds until harvest and analysed in a gas chromatograph (Varian, 3800 GC) using ECD detector. While, soil CO_2 emission was measured (in the form of soil respiration) using a soil respirometer (LI-8100A, LICOR) during seedling, vegetative, flowering and maturation stages of the crops. Plant growth parameters for both the crops were recorded at vegetative, flowering and maturation stages whereas, soils were sampled at harvest and analysed for various soil physico-chemical parameters. Significant impacts of the applied treatments were noted on soil physico-chemical properties. Soil organic carbon (SOC), humic acid carbon (HAC), fulvic acid carbon (FAC), soil pH, electrical conductivity (EC), cation exchange capacity (CEC), water holding capacity (WHC) and elemental contents increased under biochar application (at 10 t ha^{-1}) in both the crop fields. Whereas, available nitrogen fractions (NO_3-N, NH_4-N) and urease activities were higher under application of recommended doses of inorganic NPK fertilizers. Addition of FYM at 10 t ha^{-1} exhibited maximum number of bacterial colonies and soil MBC. Highest yield for mustard and french bean was recorded (1.312 t ha^{-1} and 5.556 t ha^{-1}, respectively) under application of conventionally made tea pruning litter biochar at 10 t ha^{-1} application dose (TLC10) and lowest (0.87 t ha^{-1} and 2.540 t ha^{-1}, respectively) of the same was recorded from control (C). The highest cumulative N_2O emission was found during flowering stages of both the crops in all the treatments. Application of inorganic fertilizers at recommended dose (NPKR) hiked the cumulative N_2O emission in mustard field upto 21.31% compared to control (C). Whereas, addition of FYM at 10 t ha^{-1} (FYM10) reduced the same upto 6.59%. Co-application of biochar and FYM (at 5 t ha^{-1} each) also revealed notable result by reducing N_2O emission (10.48 to 20.29%) from mustard field. Besides, co-addition of NPK fertilizer (50% of

recommended dose) and biochar (5 t ha^{-1}) decreased the same to 2.01 to 16.52%. Whereas, addition of biochars at 10 t ha^{-1} in mustard field significantly reduced (24.92 to 45.83%) N_2O emission. Highest cumulative soil CO_2 efflux in mustard field was recorded from treatment FYM10 (23.97 µmol m^{-2} s^{-1}) while application of biochars (10 t ha^{-1}) reduced it upto 35.91%. Likewise, treatment NPKR displayed a considerable upsurge (12.78%) of cumulative N_2O emission from french been field compared to the control (C). Whereas, addition of FYM at 10 t ha^{-1} dose (FYM10) reduced N_2O flux (upto 13.60%) from the same field. Co-addition of biochar and FYM (each at 5 t ha^{-1} dose) also displayed a significant result by reducing N_2O emission (10.48 to 20.29%) from french bean field. Besides, significant reduction of N_2O flux (24.59 to 51.69%) were recorded from the french bean field under application of 10 t ha^{-1} biochar. Nevertheless, cumulative soil CO_2 efflux for whole french bean growing season was between 16.15 µmol m^{-2} s^{-1} (WCG10) to 24.40 µmol m^{-2} s^{-1} (FYM10). Thus, it can be concluded that differences in feedstocks, production methods as well as the production temperature significantly influence the characteristics of the produced biochars. Use of biochar as soil amendment showed positive impact on soil health and growth of mustard and french bean crop compared to farmyard manure. This two year's study revealed that conventionally made tea pruning litter biochar (TLC) as better soil amendment for mustard and french bean crop to improve yield and reduce soil N_2O and CO_2 flux. Moreover, higher specific surface area, recalcitrance potential and adsorption capacity of the gasification and pyrolysis based biochars have the potentiality to sequester soil carbon and thus has long term benefits as soil amendment.