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Mixed Solid Municipal Waste-Based Biochar for Soil Fertility and Greenhouse Gas Mitigation

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Municipal solid waste management is one of the major challenges facing Qatar with more than 2.5 million tons of municipal solid waste each year, a very high waste generation rate in a country with small land mass. Solid waste in Qatar consists mostly of organic materials (60%) with the remaining made up of recyclables, such as glass, metals and plastics. Qatar's ambitious development strategy targets environmental sustainability and invests in research on key grand challenges including water/food security. Fortunately both can be addressed through value-added conversion of solid organic waste into biochars. Solid municipal wastes such as newspaper, cardboard, woodchips and plant residues from landscaping can be converted to biochar for mitigation of their environmental impact and value-addition. On the other hand, agricultural soils have significant deficiencies in a range of essential trace elements and macronutrients and often exhibit low water holding capacity. These deficiencies impact both the yield and the nutritional quality of edible crops with direct consequences cost-effectiveness and human health. Fortunately, these challenges can be advantageously addressed by production of biochars from organic sources such as mixed organic solid waste from municipalities as well as agricultural and landscaping operations. The landfill and composting of these solid municipal wastes generate greenhouse gases that contribute to climate changes. Biochars prepared from solid municipal wastes can greatly benefit the carbon content of soil. Additionally, biochar may interact with fertilizers to deliver indirect improvements in plant growth and reduce the emission of greenhouse gases from native organic matter. Biochars can also be custom-designed to increase/decrease native soil pH to bring it closer to the optimum range for microbial and plant growth. These applications give solid organic municipal wastes promising potential as precursors for value-added biochars with varied physicochemical characteristics allowing them to be used not only as an alternative to bio-waste management and greenhouse gas mitigation but also as means to improve depleted soil. We hypothesize that soil deficiencies in soil can be remedied by the application of biochars that are custom-designed to possess the right physicochemical characteristics suitable to improve soil fertility. The aim of this study was to: (1) produce

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biochars from mixed solid organic waste for use in soil quality enhancement, (2) investigate the effect of biochar addition to soil on plant germination and growth and (3) evaluate the potential of biochars in mitigating green house gas (GHGs) emissions. Select solid organic municipal wastes (newspaper, cardboard, woodchips and landscaping residues) were used as a precursor for biochar preparation. A blend of 25% of each precursor was used and pyrolyzed at 700°C for 2 hrs under N_2 gas at a flow rate of 0.1 mL min^{-1} using a Lindberg box programmable furnace equipped with an air-tight retort. Soil fertility parameters such as pH, water retention and macro and micronutrients were analyzed. Fine sandy clay loam soil from the Ap horizon (0–15 cm deep) was amended with biochar at the rate of 2% (w/w). To test the germination rate in soils, with and without biochars (produced from municipal solid waste precursors of 25% blend of four types of waste materials), hybrid savoyed spinach seeds were sown in germination trays (3 seeds/well) for two weeks in climate controlled greenhouse settings. Trays were watered twice daily to maintain moisture level between 10 and 12 percent. The percentage of seed germination was calculated and the plant growth measured as dry biomass. Incubation experiments were conducted to measure GHGs production in sealed glass vials containing soil with and without biochar or raw materials from which this biochar was produced. Greenhouse gases emission differential between the biochars and their corresponding raw feedstocks in treated soil was used as indicator of GHGs emission by biochars during the incubation period Biochars prepared from blends produced at 700°C pyrolysis temperatures and used at 2% application rate to soil showed higher pH (6.8), increased water retention, and high K and NO_3-N content. The net effect of these changes in soil properties positively impacted both seed germination and biomass yield of the plants (up to two folds in soil amended with biochars). At the same time, conversion of solid organic wastes into biochar enabled 14% reduction in GHGs emission compared to the solid waste precursors, as indicated by lower CO_2 emission. Biochar amendment in soil significantly reduced the CO_2 emission (14%), which would otherwise have increased greenhouse gas due to solid waste decomposition in soil. This differential is mainly due to respiration controlled by microbes. Soil amended with biochar closely followed the trend of soil treatment signifying no additional contribution to CO_2 efflux. The increase in CO_2 efflux seen in feedstock-amended soil can be attributed to the decomposition of feedstock during the time incubation period. In summary, biochars from mixed solid organic wastes at 2% carbon to soil ratio improved seed germination, increased plant biomass yield, and reduced GHGs emission compared to precursors. To reach the maximum benefits, pyrolysis conditions and feedstock selection are critical steps to produce biochars with desirable properties for specific soil amendment. From the present study, it is clear that constituents of municipal solid organic wastes hold promising potential as inexpensive precursor for value-added biochar manufacturing with varied and customizable physicochemical characteristics that would be beneficial in soil amendments while alleviating the problem of solid waste disposal and contributing to mitigation of GHGs. Further studies are need needed to confirm the reported advantages in natural field settings.