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Effects of rice-husk biochar on sand-based rootzone amendment and creeping bentgrass growth

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ABSTRACT

Turf provides an irreplaceable surface for recreational and sport activities in urban landscape. Sand-based rootzone is recommended for turf establishment because of its excellent compaction resistance. It is necessary to improve the water and nutrient retention of sand-based rootzone by soil amendments in maintaining healthy turf. The objective of this research was to evaluate the effects of rice-husk biochar on sand-based rootzone amendment and creeping bentgrass (*Agrostsis stolonifera*) establishment. The results showed that bulk density was linearly decreased in proportion to rice-husk biochar. Total porosity and capillary porosity, water retention, and saturated hydraulic conductivity were significantly increased in proportion to rice-husk biochar. Sand-based rootzone amended with 10% of rice-husk biochar promoted the seed germination and young seedling growth with the significantly higher growth rate, leaf emergence rate, shoot and root biomass, and turf coverage than the control. These results indicate that rice-husk biochar had superior characteristics to previous reported biochars in the sand-based rootzone amendment and could be used to improve soil physical properties and turf healthy in sports and recreation playgrounds.

1. Introduction

Turfgrass offer not only the ecological, environmental, and aesthetic benefits to urban landscape, but also the playgrounds for various recreational and sports activities (Lilly et al., 2015; Martiniello, 2007). Soil compactions resulted from the traffics during recreation or sports games are the biggest concern to maintain a quality turf (Glab and Szewczyk, 2014, 2015). As the soil become compacted, the soil bulk density increases, non-capillary pores in the soil destroyed, the poor drainage and lowering oxygen levels in the rootzone will greatly restrict turfgrass root growth and lead to significant decline of turf quality, and even to plant death (Matthieu et al., 2011; Shah et al., 2017).

Sand-based rootzones are recommended to use in sports fields as well as high traffic recreational playgrounds due to its excellent compaction resistance and rapid drainage (Bingaman and Kohnke, 1970; Waltz et al., 2003). However, sands have very poor water and nutrient retention capacities, which can not meet the requirements of turfgrass growth (Jiao et al., 2006; Uzoma et al., 2011). Some organic materials (peat moss or composts) have been used as sand rootzone amendments to improve water and nutrient retention and maintain enough turfgrass vigor (Aamlid et al., 2014; Adams, 2008). However, these organic matters significantly reduced the saturated hydraulic conductivity of sand rootzones and results poor drainage in putting greens (Bigelow et al., 2004; Chong et al., 2004). Another concern of organic amendments is that they decompose with time, reducing their beneficial effects (Lannan et al., 2013; Lewis et al., 2010). An ideal amendment for sand-based rootzone in sports turf should supply adequate water and nutrient retention to maintain turfgrass vigor and be stable over time in the soil profile as well (Bigelow et al., 2004; Waltz et al., 2003).

Biochar is a carbonaceous material obtained from pyrolysis of biomass residues in the absence of oxygen (Lehmann, 2007). Biochar could be stabilized in soil for long periods with the half-life in excess of 1000 years (Laird, 2008; Lehmann et al., 2006; Mia et al., 2017; Weng et al., 2017; Yao et al., 2010). Many studies indicated that biochar can be used as amendment to improve the soil water availability (Belyaeva and Haynes, 2012; Karhu et al., 2011; Xiao et al., 2016) and nutrient retention (Gao et al., 2016; Sorrenti et al., 2016; Yao et al., 2012). However, Biochar is pyrolyzed from different sources of biomass (woody, agricultural, aquatic, animal waste, and industrial waste), which may have different characteristics. Jeffery et al. (2011) showed that biochars produced from different biomass can vary greatly in their impact on soil amendments and crop growths. Jeffery et al. (2015) reported that no significant effects of biochar application on soil water retention and saturated hydraulic conductivity in the sandy soil field

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experiments. Major et al. (2012) reported no significant effect on either the water holding capacity or the saturated hydraulic conductivity of a clay soil following the addition (20 t ha^{-1}) of a biochar produced from woods. Brockhoff et al. (2010) also showed that the biochar made from swithgrass (*Panicum virgatum*) decreased the saturated hydraulic conductivity and rooting depth of *Agrostis stolonifera*. These contrasting results might be related to the different biochar products as well as different biochar particle size added into the soil (Liu et al., 2016, 2017) and the changes of the soil microstructural behaviour (Ajayi et al., 2016).

Rice husk is a by-product of rice mill. Approximately 150 MT of rice husk was generated globally in 2015 according to recent estimations (Pode, 2016). The biochar from rice-husk have the more uniformly distribution of the particle size than other biochar products (Evans et al., 2017; Milla et al., 2013), presenting a widely application in urban landscape, especially in the amendment of sand-based rootzone in sports and recreation turf. However, the effects of rice-husk biochar on the physical parameters of sand-based rootzone and the turfgrass growth have not been well elucidated. The objectives of this research were to (i) evaluate the impacts of rice-husk biochar on the physical properties of sand-based rootzone and the growth of creeping bentgrass, (ii) whether rice-husk biochar could be used as the sand-based rootzone amendment in sports and recreation turf.

2. Materials and methods

2.1. Sample preparation

Sand-based rootzone is commonly used for sports turf because of its compaction resistance and excellent water infiltration and drainage. The sand used in this study was the greens sand samples from Shanghai Hongqiao Golf Course and meets the USGA recommendations for putting green construction. The particle size distribution was shown in Table 1. Particle size distribution was determined using the sieve-pipette method and classified according to USDA textural classification. The biochar was produced from rice (*Oryza sativa*) husk and was pyrolyzed at 400 °C under an O_2-free atmosphere in a ceramic fiber muffle furnace for 5 h according to Shang et al. (2013). The speed of the furnace heating was 10 °C min^{-1}. The biochar was then removed from the furnace and cooled in a desiccator. The physico-chemical properties of the rice-husk biochar was 47.86% of carbon, 2.37% of hydrogen, 10.32% of oxygen, 0.68% of nitrogen, 2.66 $m^2 g^{-1}$ of specific surface area, and 6.14 nm of average pore radii (Shen et al., 2016). The rice-husk biochar used in this experiment was washed by deionized water to remove all dissolved nutrients. The particle size distribution of rice-husk biochar was shown in Table 1.

2.2. Physical properties

Saturated hydraulic conductivity, water retention, porosity, and bulk density were measured according to ASTM f1815-11. Saturated hydraulic conductivity was determined on compacted, saturated sand or mix soil cores by an TST-70 Laboratory Permeameter (Shanghai ZheTi Machinery Manufacturing, China). Water flow through the core is maintained at a constant hydraulic head until a steady flow rate is achieved, at which time aliquots of the outflow are collected. The average volume of water outflow over the three runs was used to calculate the Ksat value for each core. The saturatedhydraulic conductivity was calculated as:

$$K_{sat} = QL/hAt$$

where: Ksat = saturated hydraulic conductivity (cm/h); Q = quantity of effluent collected (cm^3) in period of time (t); L = lenth of soil column (cm); h = hydraulic head (cm); A = cross sectional area of the soil core (cm^2); t = time required to collect Q (hour).

Water retention was determined at a soil core of 30 cm. After the soil cores were fully saturated and extracted by a tension table and achieved the equilibrium, the weights were recorded. The cores were oven dried at 105 ℃ to constant weight (72 h). Water retention was calculated on an oven dried basis as follows.

$$\Theta_{dw} = (M_w/M_d - 1) \times 100$$

where: Θ_{dw} = water retention on dry weight basis (%); M_w = net weight on the equilibrium; M_d = net dry weight mass.

Bulk desity was calculated from the sand or mix dry weight and volume.

$$P_b = (M_1\text{-}M_2)/V$$

where: P_b = dry soil bulk density (g/cm^3); M_1 = mass of oven-dried sand or mix and cylinder (g); M_2 = mass of cylinder (g); V = volme of the sand or mix core (cm^3).

Total porosity was calculated from the bulk density and particle density.

$$S_t = (1 - P_b/P_d) \times 100$$

where: S_t = total porosity (%); P_b = dry soil bulk density (g/cm^3); P_d = particle density of root zone sand or mix (g/cm^3).

Capillary porosity was calculated from the bulk density and water retention information.

$$\Theta_{vb} = P_b \times \Theta_{dw}$$

where: Θ_{vb} = capillary porosity; P_b = dry soil bulk density; Θ_{dw} = water retention.

Air-filled porosity was calculated from the difference of total and capillary porosity.

$$S_a = S_t - \Theta_{vb}$$

where: S_a = air filled porosity; S_t = total porosity; Θ_{vb} = capillary porosity.

2.3. Experiment design

The turf establishment experiment was repeated in two times. each experiment was arranged in a randomized complete block design with 4 replications. Biochar treatment was 10% (v/v) of rice-husk biochar

Table 1
Particle size distribution of sand and rice-husk biochar.

Samples	Gravel 2 mm %	Sand factions (% Retained)					Silt 0.002-0.05 mm %	Clay < 0.002 mm %
		Very coarse 1 mm	Coarse 0.5 mm	Medium 0.25 mm	Fine 0.15 mm	Very fine 0.05 mm		
Sand	–	0.76	24.55	58.29	14.59	1.61	0.14	0.06
Rice-husk biochar	31.98	35.89	25.15	3.88	1.19	0.69	1.15	0.08
USGA recomendation	≦10% (≦3% gravel)		60% minimum		≦20%	≦5%	≦5%	≦3%

USGA recomendation: Total fines (very fine sand + silt + clay) should be less than (<) 10%.