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Physico-Chemical Characterization of Coconut Shell Biochar and its Influence on Growth of Soybean

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Abstract

Biochar derived from Coconut shell was produced in high temperature (600°C) pyrolysis in an oxygen limited environment. The coconut shell biochar was subsequently characterized regarding their main properties, in order to evaluate their potential use in soil and waste water remediation. In this characterization process, observed a pH of 9.6 and Electrical conductivity of 1.78 dS m^{-1}. The physical properties like bulk density (0.73 Mg m^{-3}) and maximum water holding capacity (68.54 %) were measured. Coconut shell biochar had higher total carbon content of 77.5 per cent, Nitrogen of 0.27 per cent, Phosphorus of 0.15 per cent, Potassium of 0.84 per cent and secondary nutrients like Calcium (0.22 %), Magnesium (0.13 %) and sulphur (0.02 %) were recorded. A higher micronutrient like Iron (423.06 mg kg^{-1}), Zinc (25.80 mg kg^{-1}), Manganese (273.26 mg kg^{-1}) and copper (31.20 mg kg^{-1}) were recorded. Generally, all treatments showed a significant increase in growth and quality as compared to plants grown in untreated soil. It was observed that addition of coconut shell biochar to soil influenced the overall growth and quality of plants positively. The treatment, RDF + coconut shell biochar at 10 t ha^{-1} + 50 per cent lime recommendation was found to be significant ($p<0.05$) in growth but quality parameters were non-significant

Keywords: Physico-Chemical characterization, Coconut shell biochar, Soybean

Soybean is a world oil seed crop cultivated on an area of 118.01 million hectares with 315.06 million tons of production and 2.67 t ha^{-1} productivity (Anonymous, 2015). The principal soybean producers are the USA (36 %), Brazil (36 %), Argentina (18 %), China (5 %) and India (4 %) (Tewadcha *et al.*, 2011). In India the crop is cultivated over an area of 10.02 million hectares with 11.64 million tons of production and 1062 kg ha^{-1} of productivity (Malavika *et al.*, 2018). Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka and Gujarat are predominant soybean growing states in India. Soybean in Karnataka covers an area of 0.29 million hectares with 0.24-million-ton output and 868 kg ha^{-1} productivity (Sharma and Dixit, 2015).

Biochar can be produced from various feed stock materials or waste, such as agricultural residues, manures, industrial wastes etc., providing an alternative option for waste management. Biochar refers to charcoal materials generated from incomplete combustion of carbon rich biomass with heat treatment and oxygen-limited conditions (Beesley *et al.*, 2011). After pyrolysis of biomass, biochar was found to contain many functional groups of hydroxyl and carboxyl, which improve the cation exchange capacity and make a potential adsorbent in aqueous solution (Liang *et al.*, 2010). Biochar is the carbonised end-product obtained following pyrolysis of biomass from wood, straw or other crop residues and waste. Compared to incineration the pyrolysis process is much more energy efficient and can substantially reduce total fuel consumption. Effects on crop growth and yield have been reported to vary from mildly negative to highly positive, depending on climate, soil, crop and type of biochar. A recent meta-analysis by Liang *et al.* (2010) showed that biochar added to soils in tropical agro-ecosystems increased crop yield by on average 25 per cent whereas, responses of crops in temperate regions were small or even negative. Biochar addition to soils also allows carbon from the atmosphere to be sequestered, because a large proportion of biochar decomposes very slowly and carbon remain in the soil for longer than carbon derived from manure, compost, sludge or raw residues. Only a few field experiments have addressed the effects of biochar addition on legume productions. Biochar inputs to soils have been demonstrated to increase soybean growth, owing to effects on nutrient availability and shifts in growth-promoting bacterial communities.

In the present paper, the findings from the soybean field trials on assessing the effect of biochar addition are reported. Specific objectives of the study was to analyse the effects of biochar input on the growth and quality of soybean without and with coconut shell biochar. The main for selecting soybean variety JS-2034 is its wide adaptability, high yielding adds lot of biomass to soil and fixes atmospheric nitrogen to soil and maintains the soil health sustainably.

Material and Methods

Coconut Shell Biochar

There are various grades of biochar available and the locally produced coconut shell biochar has been used in the present investigation. The coconut shell biochar was developed at a comparatively higher temperature (around 600 ^{0}C) in limited oxygen supply and it was purchased for the cost of Rs.2 per kg from company Kalpatharu products, Tiptur, Tumkur district, Karnataka.

Studies on Characterization of Coconut Shell Biochar for Physico-chemical Properties

The coconut shell biochar used in this study was defined by applying various standardized analytical procedures for its specific physico-chemical properties such as bulk density, water holding capacity, pH, EC and total elementary composition. Table 1 describes the method used for the study of these physico-chemical properties.

Field Experiment on Soybean

A field experiment was conducted in AICRP on Sunflower unit, ZARS, UAS, GKVK, Bengaluru (13^{0}04'37.7" N 77034'04.2" E) during *kharif* 2019 with a test crop soybean. The recommended dose of

Table 1

Standard methods employed for physico-chemical properties characterization of coconut shell biochar analysis

Parameters	Methods	References
pH	Potentiometry	Jackson (1973)
EC (dS m^{-1})	Conductometry	Jackson (1973)
MWHC (%)	Keen's cup method	Piper (1966)
Bulk density (g/cc)	Keen's cup method	Piper (1966)
Total carbon (%)	Dry combustion method (CHNS, LECO)	Page *et al.*,1982
Nitrogen (%)	Kjeldahl digestion and distillation method	Jackson (1973)
Phosphorus (%)	Diacid digestion and vanadomolybdate method	Jackson (1973)
Potassium (%)	Diacid digestion and flame photometer method	Jackson (1973)
Calcium (%)	Complexometric titration method	Jackson (1973)
Magnesium (%)	Complexometric titration method	Jackson (1973)
Sulphur (mg kg^{-1})	0.15 % $CaCl_2$ and turbiditary extraction method	Black (1965)
Iron (mg kg^{-1}) Copper (mg kg^{-1}) Manganese (mg kg^{-1}) Zinc (mg kg^{-1})	Di-acid digestion and atomic Absorption spectrophotometry	Jackson (1973)

fertilizer (25:62.5:25 kg ha^{-1} N, P_2O_5 and K_2O) applied as basal dose with recommended spacing of 30 x 10 cm. Randomized complete block design was used with nine treatment and three replications. The initial physical and chemical properties of experimental soil represented in Table 2. There are various grades of biochar available and the locally produced coconut shell biochar has been used in the present investigation.

TABLE 2
Physico-chemical characterization of coconut shell biochar

Parameters	Value
pH (1: 10)	9.6
EC (dS m^{-1}) (1: 10)	1.78
Maximum water holding capacity (%)	68.54
Bulk density (Mg m^{-3})	0.73
Total carbon (%)	77.50
Nitrogen (%)	0.27
Phosphorus (%)	0.15
Potassium (%)	0.84
Calcium (%)	0.22
Magnesium (%)	0.13
Sulphur (%)	0.02
Iron (mg kg^{-1})	423.06
Manganese (mg kg^{-1})	273.26
Zinc (mg kg^{-1})	25.80
Copper (mg kg^{-1})	31.20

Treatments Details

The experiment comprised of nine treatments. The treatment details are: T1-Absolute control; T2-Package of Practice (Recommended NPK + FYM); T3-Recommended NPK+Biochar @ 5 t ha^{-1}; T4-Recommended NPK + Biochar @ 7.5 t ha^{-1}; T5-Recommended NPK + Biochar @ 10 t ha^{-1}; T6-Package of Practice (Recommended NPK + FYM) + 100 per cent Lime Recommendation; T7-Recommended NPK + Biochar @ 5 t ha^{-1} + 50 per cent Lime Recommendation; T8-Recommended NPK + Biochar @ 7.5 t ha^{-1}+ 50 per cent Lime Recommendation; T9-Recommended NPK + Biochar @ 10 t ha^{-1} + 50 per cent Lime Recommendation with $ZnSO_4$ - 12.5 kg ha^{-1} for all treatments except in absolute control; Farm Yard Manure 6.25 t ha^{-1}; Recommended Lime 3.0 t ha^{-1}; NPK Provided through Urea, Diammonium Phosphate and Muriate of potash.

Studies on Growth Attributes of Soybean

The plant height was estimated at 30 DAS, 60 DAS and at the harvest by tagging randomly selected five plants. The mean plant height was worked out and expressed in centimetres (cm) at all these growth stages. From the five separate plants picked at random and tagged initially, the number of branches per plant was counted at all growth stages and the average number of branches per plant was documented.

Studies on Oil and Crude Protein Content of Seeds (%)

Approximately 15 g of seeds drawn randomly from each treatment was oven dried at 55 ^{0}C temperature. The oil and protein contents were estimated by Nuclear Magnetic Resonance (NMR) and kjeldhal estimation, Jackson (1973), respectively. The principle of NMR is that a weighed sample is transferred to a cell and placed in the sample cavity in the magnet unit. After selection of instrument parameters, the instrument automatically sweeps through the resonance condition. Concurrently, the integrator stores information on the amount of energy absorbed by the sample. At the end of the cycle, the total energy absorption is proportional to the amount of mobile hydrogen or oil in the seeds and the crude protein was calculated using the formula

$$\text{Crude Protein (\%)} = \text{Nitrogen content in seeds (\%)} \times 6.25$$

RESULTS AND DISCUSSION

Physico-Chemical Characterization of Coconut Shell Biochar

The locally produced coconut shell biochar has been used in the present investigation and characterised by various standardized analytical procedures for its specific physico-chemical properties such as bulk density, water holding capacity, pH, EC and total elementary composition. Representative samples were taken from coconut shell biochar. The coconut shell biochar was ground to move through a sieve of 2 mm and tested for various chemical parameters and findings are shown in Table 2.

The coconut shell biochar was characterized for various physical (Bulk density, maximum water holding capacity) and chemical (pH and Electrical Conductivity) properties and overall concentration of nutrients. The properties of the coconut shell biochar used in the present study is greatly varied. The variation in coconut shell biochar's physico-chemical properties may be due to influence of the type of feedstock and the temperature of pyrolysis. Singh *et al*. (2010) published identical findings of variation of physic-chemical properties according to type of feed stock and the temperature of pyrolysis.

The coconut shell biochar had shown the lower bulk density of 0.73 g cm^{-3} and higher maximum water holding capacity of 68.54 per cent (Table 1). Rodriguez *et al*. (2009) reported such lower BD values and higher maximum water holding capacity for the coconut shell biochar produced.

The biochar of coconut shell has a comparatively high pH (9.6) and is organically alkaline (Table 2). Singh *et al*. (2010) also reported such high pH-values of biochar. High coconut shell pH can be attributed to hydrolysis of the Ca, Mg and K salts present in the soil. In a previous study conducted on the biochar produced from *Prosopis juliflora* had an 8.57 pH and a paddy straw biochar had a higher pH (9.68). In contrast, coconut shell biochar recorded higher pH than crop residue biochar in the present study that can be attributed to production at high temperatures and the presence of higher exchangeable and soluble salts.

Higher soluble salts were present in the coconut shell biochar, resulting in higher EC (1.78 dS m^{-1}) value. For biochar produced at 200 ^{0}C and 400 ^{0}C, Wabel *et al*. (2013) observed EC values of 0.76 dS m^{-1} and 1.34 dS m^{-1}, respectively.

The carbon content (77.5 %) was higher in coconut shell biochar (Table 1). In coconut shell the values of various nutrients are similar to those reported in literature (Singh *et al*., 2010). In the coconut shell biochar, Total nitrogen, phosphorus and potassium amounts were respectively 0.27, 0.15 and 0.84 per cent. Coconut shell biochar contains a total of 0.22, 0.13 and 0.02 per cent respectively of calcium, magnesium, sulphur respectively. The iron, manganese, zinc and copper concentrations were 423.06, 273.26, 25.80 and 31.20 mg kg^{-1}, respectively. This is in accordance with the report of Emmanuel *et al.* (2010) and Sun *et al*. (2014).

Effect of Coconut Shell Biochar on Growth of Soybean

Plant Height (cm) of Soybean

Figure 1 and 2 present's data on plant height (cm) and Number of branches per plant of soybean as influenced by different biochar rates at different growth stages.

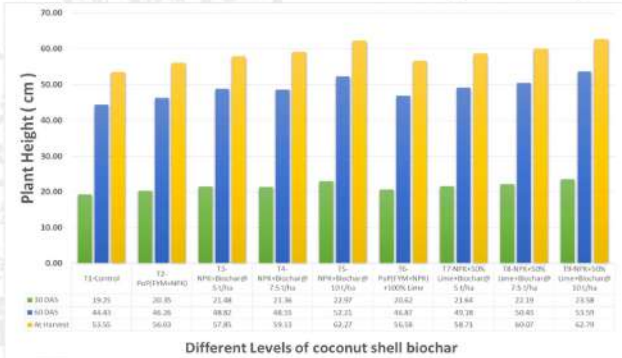

Fig.1: Effect of coconut shell biochar application on plant height (cm) at 30DAS, 60DAS and at harvest stages of soybean

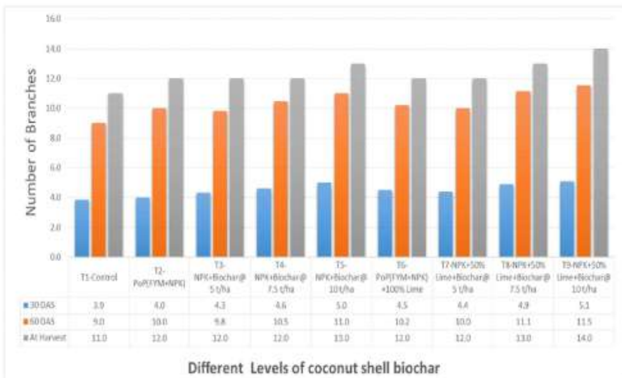

Fig. 2: Effect of coconut shell biochar application on number of branches per plant at 30DAS, 60DAS and at harvest stages of soybean

With different treatments, plant height and branches varied greatly at all growth stages. Plant height gradually increased with crop age rise up to 60 days after sowing and subsequently a slightly lower increase until harvest.

Treatment 9, which received Recommended NPK + Biochar @ 10 t ha^{-1} + 50 per cent lime recommendation had significantly higher plant height (23.6 cm at 30 DAS, 53.6 cm at 60 DAS and 62.8 cm at harvest) was recorded. These results were comparable to T5 (23.0 cm at 30 DAS, 52.2 cm at 60 DAS and 62.7 cm at harvest) which provided Recommended NPK + Biochar @ 10 t ha^{-1}. Lowest value was reported in absolute control which did not obtain any external nutrient and biochar sources. [A similar kind of trend was observed in case of number of branches (5 at 30 DAS, 12 at 60 DAS and 14 at harvest) per plant as well].

Due to application of Recommended NPK + Biochar @ 10 t ha^{-1} + 50 per cent Lime Recommendation (T9), significant increase in growth parameters such as plant height, number of branches of soybean plant was reported. Those factors will operate either individually or at the same time. Indeed, a reduction in soluble Al and Fe led to rise in pH, a controlled and gradual release of nutrients, and because of biochar specific physical-chemical properties with low bulk density, which would improve the porosity and aeration status of the soil, which would indirectly increase the available plant water and boost microbial function, should have led to the improvement of growth parameters of biochar and agricultural lime treatment over control and other rate of application (Santhosh *et al.*, 2019; Lyngdoh *et al.*, 2019) Most of these changes in soil's physical and chemical properties in biochar transformed soils are familiar with other research (Amonette & Joseph 2009).

Effect of Coconut Shell Biochar on Oil and Protein Content of Soybean Seeds

The oil content in soybean seeds was not significantly influenced by different level of biochar treatments. It ranged from 20.82 - 21.54 per cent due to various treatments. However, T_9 showed that received recommended NPK + Biochar @ 10 t ha^{-1} + 50 per cent lime recommendation recorded numerically higher oil content over package of practice and absolute

TABLE 3

Effect of coconut shell biochar application on oil (%) and crude protein (%) content of soybean seeds

Treatments	Oil content (%)	Crude protein content (%)
T1 – Absolute Control	20.82	35.31
T2 - Package of Practice (Recommended NPK + FYM)	20.93	35.50
T3 - Recommended NPK + Biochar @ 5 t ha^{-1}	20.95	35.68
T4 - Recommended NPK + Biochar @ 7.5 t ha^{-1}	21.01	35.75
T5 - Recommended NPK + Biochar @ 10 t ha^{-1}	21.27	35.93
T6 - Package of Practice (Recommended NPK + FYM)+ 100% Lime Recommendation	20.97	35.56
T7 - Recommended NPK + Biochar @ 5 t ha^{-1} + 50% Lime Recommendation	21.02	35.76
T8 - Recommended NPK + Biochar @ 7.5 t ha^{-1} + 50% Lime Recommendation	21.05	35.75
T9 - Recommended NPK + Biochar @ 10 t ha^{-1} + 50% Lime Recommendation	21.54	35.93
SEm±	0.01	0.02
CD @ 5%	NS	NS

Note: *$ZnSO_4$ @12.5 kg ha^{-1} common for all treatments except in absolute control

control. The protein content in soybean seeds was found to be non-significant with biochar in combination with agricultural lime. The highest protein content of 35.93 per cent was recorded in the treatment (T9) with Recommended NPK + Biochar @ 10 t ha^{-1} + 50 per cent lime recommendation. Comparison among the treatments receiving only biochar and in combination of lime. The combination revealed the slightly higher oil and protein contents but those were of non-significant among the treatments.

The coconut shell biochar was comprising of lower bulk density (0.73 Mg m^{-3}), higher water holding capacity (68.54 %) and total carbon (77.50 %). Higher surface area and more functional groups of biochar become deprotonated and the biochar surfaces become more negatively charged. This study was carried out to provide basic information as to the possibility of reuse of biochar derived from different biomass. Biochar production is a viable waste management option and coconut shell seems like a suitable feedstock that can be provided in great quantities. The biochar production from biomass such as coconut shell may be an effective way for recycling the waste resources.

The study demonstrated the effectiveness of biochar in improving soybean growth, quality and yield. Coconut shell biochar in combination with lime was found to have significantly better performance than coconut shell biochar alone application. With biochar use in combination with agricultural lime, there were several variables relating to the crop growth quality and yield attributes. Those factors will operate either individually or at the same time. Indeed, a reduction in soluble Al and Fe led to rise in pH, a controlled and gradual release of nutrients and because of biochar specific physical-chemical properties with low bulk density, which would improve the porosity and aeration status of the soil, that would indirectly increase the available plant water and boost microbial function. This might have led to the improvement of growth parameters of biochar and agricultural lime treatment over control and other rate of application.

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