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PRODUCTION AND CHARACTERIZATION OF OIL PALM BIOMASS WASTE BIOCHAR

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The production of palm oil generates biomass residue from plantation and mill sites. This biomass residue can be classi-fied into six types: oil palm fronds (OF) and oil palm trunks (OT) produced at plantation site, oil palm empty fruit bunches (OEFB), palm kernel shells (PKS), mesocarp fibre (MF) and palm oil mill effluent (POME) produced at mill sites. Since the large amount of biomass residue is generated ammually, Andhra Pradesh has the potential to utilize the biomass residue efficiently and effectively to other valued products. In this study, oil palm biomass waste viz., OF, OT and OEFB were used as a feedstock to prepare biochar using convetional pyrolysis process. Pyrolysis temperature and time are known to have profound influence on biochar yield. The optimum parameters of pyrolysis for preparation of biochar from the oil palm biomass waste are not known. In order to standardize the methodology of biochar production, they were subjected to different temperatures and holding time. The optimized conditions for complete charring of OF Biomass, OT Biomass and OEFB Biomass were 500 ^{0}C temperature and holding time of 60, 60 and 90 minutes, with yield recovery of 35.5%, 34.0% and 32.0%, respectively. Total organic carbon (TOC) content in OF, OT and OEFB biomass was 43%, 40% and 42%, respectively, while it was 68%, 57% and 67%, in corresponding biochars. Among the oil palm biomass wastes, OEFB biomass and biochar recorded maximum 2.88 and 6.07 % potassium content, respectively. The pH of oil palm biochars ranged from 6.55-9.97 neutral to alkaline nature indicating the effective liming potentiality for acidic soil management. OF, OT and OEFB biochars with CEC 12.82, 11.12 and 10.24 C mol (P+) kg^{-1} . have the nutrient retention capacity and thereby can have the potential to reduce the leaching losses in light textured soils.

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.), the most efficient oilseed crop in the world produces 4.0 to 6.0 tonnes of crude palm oil and 0.4 to 0.6 tonnes of palm kernel oil/ha/annum from 4th to 30th year of its productive life span. It is cultivated in many countries of world and Malaysia and Indonesia produce about 85% of the world's palm oil. In Andhra Pradesh, it is being cultivated in 170,000 ha area of which 70, 000 ha area lies in West Godavari district alone, where tobacco is one of the major crop. Tobacco is mainly grown in light textured soils and sufficient organic carbon in the soil is a pre requisite for good quality tobacco. One of the possible ways to effectively utlilize the oil palm biomass waste, is to convert into biochar. Application of biochar as soil amendment, will enhance the carbon sequestration, minimizes the nutrient leaching losses and to improve the nutrient use efficiency. Hence, studies were initiated to produce biochar from oil palm biomass waste and further to study the effect of oil palm biomass waste biochar as rooting medium for tobacco seedling production and also on yield and quality of FCV tobacco grown in light textured soils.

Oil palm plantations generate huge quantity of ligno-cellulosic biomass waste comprising oil palm empty fruit bunches (OEFB), oil palm fronds (OF) and oil palm trunks (OT) during oil extraction and cultivation that pose a major disposal problem. The oil palm plantation of ten-year-old produces 59.62 ton of biomass/ ha under irrigated and 36.53 ton of biomass/ha under rain fed conditions in India. Oil Palm produces about 24 leaves/palm/ year which is equivalent to 10.50 t/ha /year on

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dry matter basis and replacement of old plantation for new planting generates huge amount of trunk biomass. In general, these biomass generated from plantations are either unutilized or under-utilized. Conversion of biomass waste into biochar, a carbon – rich product, is an effective waste management approach for carbon sequestering, soil health improvement and enhancing crop productivity and soil quality. The optimized production parameters for different crop residues ranged from 300-500 ^{0}C and 30-120 min holding time. Reported temperatures of biochar production for different crop residues viz., tobacco stalks was 500 ^{0}C (Poorna Bindu *et al.,* 2015) and Cotton Stalks was 450 ^{0}C (Venkateswarlu, 2013). Biochar is a carbon rich and porous solid, often produced by slow pyrolysis of waste biomass without or with partial presence of ozygen (Lehman and Joseph, 2009). The pyrolysis reaction releases moisture, and volatiles in the biomass, leaving behind the porus structure whilst retaining the aromatic compounds and chemical functional groups (Tan *et al.,* 2017). These desirable attributes enable biochar to be used in various applications such as soil amendment, energy production and pollution control. Biochar when added to soil, can improves its fertility by enhancing nutrients and water retention (Beesley *et al.,* 2011; wang *et al.,* 2014; Zhang *et al.,* 2013). Quality of feed stock source influences end-product characteristics; in general, most plant-based biochars contain elevated C content and lesser quantitites of necessary plant nutrients as compared to manure-based biochar as plants uptake only a small fraction of elements from soil. Pyrolysis temperature is known to have an impact on biochar pH. Higher temperatures generally removes acidic functional groups and increases the ash content results in biochar more basic (Novak *et al.,* 2009). Because of basic pH, biochar can be used as a soil amendment for ameliorating acid soils thus it could serve as a liming agent (Kloss *et al.,* 2012). Liew et al., 2018 reported that , oil palm biochar is a highly porous structure with high BET surface area (210 m^2/g), indicating the presence of many adsorption sites and thus showing desirable characteristics for potential use as pollutant adsorbent in wastewater treatment, or bio-fertilizer to absorb nutrient and promote plant growth and that oil palm waste is a biowaste that shows exceptional promise to be transformed into high-grade biochar rather than simply disposed by landfilling or burned as low-grade fuel in boiler.

MATERIALS AND METHODS

Biochar preparation from oil palm biomass waste

The oil palm biochars were prepared from oil palm biomass waste. Oil palm biomass (Trunk, fronds and empty fruit bunches) was manually cut to appropriate size. Fresh samples were left to sundry naturally to moisture content below 10%. Ol palm biomass wastes used as a novel feedstock for biochar production using Annual core biochar reactor of ICAR-CIAE, Bhopal. Oil palm fronds biochar (OF Biochar) oil palm trunk biochar (OT Biochar) and Oil palm empty fruit bunches biochar (OEFB Biochar), was prepared at different preparation variables *i.e* heating temperature (300-500 ^{0}C) and holding time (60- 90 min).

Biomass and Biochar Chemical Analysis

Pyrolyzed samples were ground and sieved to less than 2mm in diameter. The pH of the biochar in 1:20 suspension (w/v) was measured using a pH meter (Systronics pH system 362). The electrical conductivity (EC) of biochars was measured at room temperature after suspending biochar in deionised water for 24 h (1:10 biochar to deionised water) using a EC meter. Cation exchange capacity of the biochar was determined by saturating the biochar exchange complex with 1N sodium acetate solution (pH 8.2). One g of biochar sample was leached with sodium acetate solution (pH 8.2) for replacement of exchangeable cations by Na+ ions. The excess salts were washed down by ethanol and the adsorbed Na+ ions were released by NH4 + ions, using 1N ammonium acetate (pH 7.0) solution. The Na+ ions so released from the exchange spots were measured by using flame photometer. Total organic carbon (C) content was determined directly by dry combustion on TOC analyzer (Elementar, Germany). Total Nitrogen concentration was estimated using N distillation unit. Concentrations of total P and K in biochar were determined by digesting 0.5 g of each biochar sample in a di-acid mixture (HNO_3:$HClO_4$ in 3:1 ratio). The biochar yield was calculated as the proportion of the weight of pyrolysis product to the original material. Biochar yield from the oil palm biomass waste was calculated by the following equation (Antal and Gronil, 2003).

Biochar yield (%) = (M biochar / M biomass) x 100
Where, M biochar is the mass of biochar obtained after conversion and M biomass is the dry mass of the original oil palm biomass loaded into the reactor.

RESULTS AND DISCUSSION

Production of oil palm waste biochar and optimization of biochar production parameters

Results on biochar yield from oilpalm waste biomass viz., oil palm fronds (OF), oil palm trunk (OT), and oil palm empty fruit bunches (OEFB) at different process variables (temperature and holding time) of the annual core biochar reactor were presented in Table 1. At a temperature of 400^{0}C temperature for a period of 120 minutes oil palm empty fruit bunches turned in to torrified material, *i.e.* incomplete charring was done. Similar results were found with respect to oil palm fronds (400 ^{0}C and 120 minutes) and oil palm trunk (400 ^{0}C and 90 minutes).The optimized conditions for complete charring of OF Biomass, OT Biomass and OEFB Biomass were attained at 500 ^{0}C and holding time of 60, 60 and 90 minutes, with yield recovery of 35.5%, 34.0% and 32.0% respectively. Biochar yield tended to decrease with increase in reactor temperature and holding time (Poorna Bindu et al., 2015) Increasing temperature resulted in reduction in yield of biochar and this reduction

Table 1: Optimization of Oil Palm waste biochar production parameters

S.No	Biomass	Temperature	Time (min)	Recovery (%)	Appearance of Biochar
Exp. 1	Oil Palm Empty fruit bunch	400 ^{0}C	120	41.25	Torrified
Exp. 2	Oil Palm Empty fruit bunch	500 ^{0}C	90	35.50	Completely charred
Exp. 3	Oil Palm Fronds	400 ^{0}C	120	37.50	Torrified
Exp. 4	Oil Palm Fronds	500 ^{0}C	60	34.00	Completely charred
Exp. 5	Oil Palm Trunk	400 ^{0}C	90	36.00	80% charred
Exp. 6	Oil Palm Trunk	500 ^{0}C	60	32.00	Completely charred

Table 2: Average nutrient concentrations of feedstock (Oil palm biomass) and biochar (Oil palm waste biochar)

Parameters	OF Biomass	OF Biochar	OT Biomass	OT Biochar	OEFB Biomass	OEFB Biochar
Total organic carbon (%)	43± 0.39	68± 1.17	40± 0.75	57± 2.23	42± 0.48	67± 0.44
Nitrogen (%)	0.73± 0.04	1.10± 0.07	1.10± 0.09	2.04± 0.06	0.98± 0.07	1.60± 0.1
Phosphorus (%)	0.10± 0.03	0.19± 0.009	0.08± 0.02	0.17± 0.006	0.11± 0.01	0.23 ±0.004
Potassium (%)	1.27± 0.05	2.27± 0.006	1.44± 0.04	1.28± 0.09	2.88± 0.01	6.069± 0.05

OF: oil palm fronds; OT: oil palm trunk; OEFB: oil palm empty fruit bunch

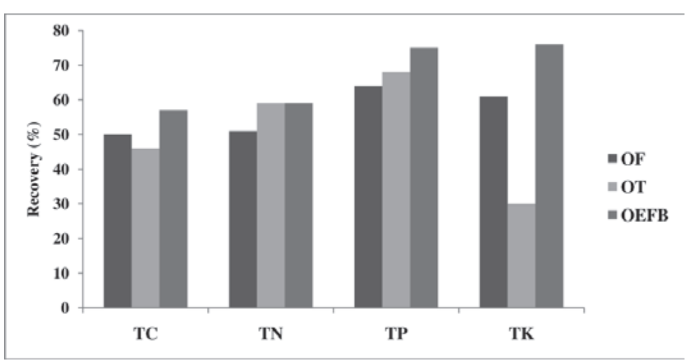

Fig.1: Percent Recovery of nutrients in Oil Palm Fronds (OF), Oil Palm Trunk (OT) and Oil Palm Empty Fruit Bunch (OEFB)

Table 3: Physico – Chemical characteristics of oil palm waste biochar

Parameter	OF Biochar	OT Biochar	OEFB Biochar
pH (1:20)	6.55	9.97	8.91
EC (dS m^{-1}) (1:20)	0.21	0.18	0.41
CEC (C mol (P^+) kg^{-1})	12.82	11.12	10.24

OF: oil palm fronds; OT: oil palm trunk; OEFB: oil palm empty fruit bunch

may be due to rapid reduction of oxygen (O), hydrogen (H) and volatiles content at high temperature 500°C (Peng *et al.,* 2011).

Carbon and nutrient composition of oil palm biomass and biochar

Pyrolysis significantly altered the carbon and other nutrient concentrations (N, P and K) of feedstock and nutrients concentration in the biochar were significantly different (Table 2). OF biomass contained 43% total organic carbon (TOC), 0.73 % nitrogen (N), 0.1 % phosphorus (P) and 1.23 % potassium (K). The OF biomass contained 40 % TOC, 1.1 %N. 0.08 % P, 1.44 %K. Whereas, the OEFB biomass contained 42 %TOC, 0.98 %N, 0.11 % P and 2.88 % K. The pyrolysis process giving 34 %, 32 % and 36 % biochar yield in case of OF, OT and OEFB respectively, lead to enrichment of the carbon and nutrients in the end product. The OF Biochar contained 68 % TOC, 1.1 % N, 0.19 % P and 2.27 %K. The OT Biochar contained 57 % TOC, 2.04 % N, 0.17 % P, and 1.27 % K. Whereas, OEFB Biochar contained 67 % TOC, 1.6 % N, 0.23 % P and 6.069 % K. It was clear from the results depicted in Fig. 1 that the amount of carbon conserved from biomass to biochar (% recovery) in OF, OT & OEFB was 50, 46 & 57 % respectively. During the pyrolysis or oxidation process biochar production under higher temperature, voltalization of nutrients esspecially from the surface of the biochar occurs, while other nutrients become concentrated in the remaining biochar. Therefore, biochar could act as a soil conditioner and could propel nutrient transformations than serving as a primary source of nutrients (Glasser *et al.,* 2002; Lehmann *et al.,* 2003).

Physico-Chemical Characteristics of Oilpalm waste biochar

The data on other physico-chemical characteristics (Table 3) indicate that the OF biochar was slighly acidic in reaction, with pH of 6.55, OT Biochar and OEFB biochar was alkaline in reaction,with pH of 9.97 & 8.91 respectively. Pyrolysis temperature is known to have an impact on biochar pH. Specifically, increasing pyrolysis temperature removes acidic functional groups and the ash content increases, causing biochar to be more basic. Biochars those produced from grass, crop residues or manures are acidic in nature. (Lehmann *et al.,* 2011; Mukherjee *et al.,* 2011). Cation exchange capacity is also an important characteristic of biochar. Similar to soils, biochar cation exchange capacity (CEC) represents its ability to electrostatically sorb or attract cations. OF Biochar, OT Biochar and OEFB Biochar had a CEC of 12.82, 11.2 and 10.24 C mol (p+) / kg and was well within the range of CEC values reported by Venkatesh *et al.,* 2013).

The oil palm biomass waste biochar (having completely charred residue) can be optimally prepared by the pyrolysis at a process temperature of 500°C and a holding time of 60-90 min. The biochar yield obtained was about 32-36% of the dry oil palm biomass. Conversion of oil palm biomass to biochar resulted in recovery of carbon and nutrients to the extent of more than 50%. Oil Palm biochars also had relatively high proportion of total organic carbon and thereby indicating its suitability as soil amendment for improving the soil physical environment.

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