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Importance of bio-char in climate change mitigation and stress crop production

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Abstract
The major limiting factors effecting crop productivity are climate change and abiotic stress mainly drought. Abiotic stress persistently checks the crop selection, crop production worldwide and reduces yield, under extreme conditions it leads to entire crop failure. Under these adverse conditions a shift from traditional agricultural practices like on-farm burning of crop residues to new technologies which can reduce green house gas (GHG) emissions and stress effect on crop production is mandatory. Bio-char incorporation into soil is the probable justification for alleviating drought and GHG emissions. The porous nature of bio-char helps in improving the water holding capacity of soil, thus reducing the effect of drought on crop production. Bio-char incorporation not only alleviates stress but also improves physical, physico-chemical and chemical properties of soil. It is a trending technology which is economical, eco friendly and feasible to farmers for getting stable production under stress conditions and is suitable to any adverse conditions.

Keywords: Human ailments, medicinal plants, documented wealth, Tamil Nadu

1. Introduction

Agriculture is the backbone for India's economy which constituently produce considerable amount of crop residue. On farm burning of this produced residue releases GHGs and the heat generated during burning hampers the growth of flora and fauna in soil. To deal with this situation conversion of this remained crop residue into an asset to the soil is necessary. In current conditions climate change through different means became a big constraint for agriculture. Along with this another considerable issue is abiotic stress such as drought under non irrigated areas and unfavourable soil conditions. By keeping these problems in view the profitable way of converting crop residue to mitigate climate change and stress into bio-char is strongly suggested.

Mostly agriculture dependent on the inputs produced through non-renewable energy which costs more. Bio-char can replace some of these requirements by improving nutrient holding capacity and by supplying some of the nutrients. It is the best way of carbon sequestration in the soil and its longuivity also more as recalcitrant carbon pool. Bio-char improves the soil physical, chemical, physico-chemical and biological properties of soil. Hence, the assured mitigation option for stress as well as climate change and also for getting sustainable yields with less inputs is incorporation of bio-char.

2. BIO-Char Production

Bio-char is a fine-grained, carbon-rich, porous product remaining after plant biomass has been subjected to thermo-chemical conversion process (pyrolysis) at low temperatures (~350–600°C) in an environment with little or no oxygen (Amonette and Joseph, 2009) [1]. Bio-char is not a pure carbon, but rather mix of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions (Masek, 2009) [2]. Bio-char can be produces by several processes, but all involve the burning of crop residue with little or no oxygen conditions to enrich the carbon in the char. The simple process is thermal decomposition generally achieved through the process of pyrolysis at low temperatures

1. Kiln: These are utilized in traditional bio-char preparation.
2. Retorts and converters: Industrial reactors capable of extracting and refining not only biochar, but also volatile fractional products (liquid condensates and syngas) are called retorts or converters
3. Retort: It is a reactor that has the ability to pyrolyze pile-wood, or wood log over 30 cm long and over 18 cm in diameter.

4. Converters: Produce biochar by carbonizing small particles of biomass such as chipped or pelletized wood.
5. Slow pyrolysis: refers to a process in which large biomass particles are heated slowly in the absence of oxygen to produce biochar.

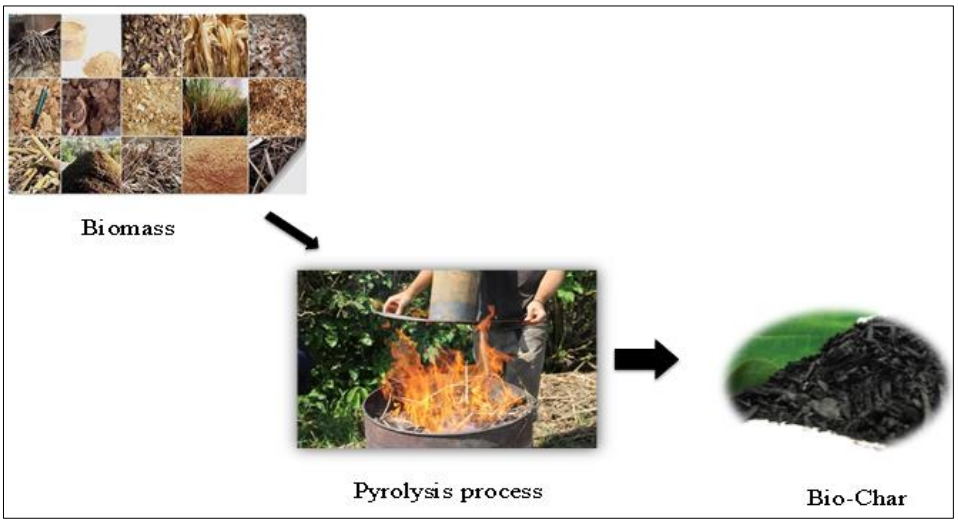

Fig 1: Conversion of Biomass into Bio-Char through pyrolysis process Bio-char can be prepared by a variety of means as following.

3. Characterization of Biochar

Properties of bio-char are governed by the type and composition of material used in its preparation. Chemical composition and physical properties of bio-char depends on the quality of feed stock used and on the pyrolysis temperature. Properties of bio-char can be studied under physical and chemical characterization separately.

3.1. Physical Characterization

Surface area of bio-char is mainly regulated by pyrolysis temperature. Day *et al*., 2005 [3] revealed that increase in temperature from 400 to 900 ^{0}C increased surface area of biochar from 120 to 460 m^2/g and bio-char produced at low temperatures suitable for controlling release of nutrients. As it is in powder form its bulk density is very low which could reduce the bulk density of soil. Micro porosity of bio-char is more which would helps in enhancing water and nutrient holding capacity. It acts as conditioner to the soil and improves soil structure, thus maintains healthy count of microbes. Purakayastha *et al*. (2013) [4] reported that the bulk density of rice and wheat biochar prepared at 400ºC was comparatively lower than the maize and pearl millet biochar. The water holding capacity of wheat biochar was highest (561%) followed by maize biochar (456%).

3.2. Chemical Characterization

Chemical properties of bio-char differ with feed stock. Its pH is in alkaline range (8.2 - 13) as the alkaline salts *viz*., Ca and Mg content is more in bio-char, hence suitable for acid soils. Cation exchange capacity of bio-char is high because of presence of cations, ranged upto 300 cmol (+) kg^{-1}.Total carbon and nitrogen ranged from 33-82.4 % and 0.18 – 2% respectively. C: N ranged between 19 and 221. Nitrogen and sulphur volatalize even at low temperatures i.e., at 300º C. Properties of bio-char produced from different sources (tab 1)

Table 1: Chemical characteristics of bio-char produced from different biomass

S. No.	Soil properties	Paddy straw	Maize stock	Coconut shell	Groundnut shell
1	pH	9.7	9.4	9.2	9.3
2	EC (dSm^{-1})	2.4	4.2	0.7	0.4
3	Total organic carbon (g kg^{-1})	540	830	910	770
4	Total nitrogen (g kg^{-1})	10.5	9.2	9.4	11
5	C : N ratio	51.4	90.2	96.8	70
6	Total phosphorus (g kg^{-1})	1.2	2.9	3.2	0.6
7	Total potassium (g kg^{-1})	2.4	6.7	10.4	6.2
8	Calcium (g kg^{-1})	4.5	5.6	8.5	3.2
9	Magnesium (g kg^{-1})	6.2	4.3	5.8	2.1

Source: S. Shenbagavalli *et al*., 2012 [5]

4. Bio-Char in Climate Change Mitigation

4.1 Carbon Sequestration

Carbon sequestration is the capture and long-term storage of atmospheric carbon dioxide (CO_2) and may refer specifically to: "The process of removing carbon from the atmosphere and depositing it in a reservoir." In order to decrease carbon in the atmosphere, it is necessary to move it into a passive pool containing stable or inert carbon. Bio-char provides a facile flow of carbon from the active pool to the passive pool (Srinivasarao *et al*., 2013) [6]. The conversion of biomass carbon to biochar leads to sequestration of about 50% of the initial carbon compared to the low amounts retained after burning (3%) and biological decomposition (less than 10-20% after 5-10 years) (Lehmann *et al.* 2006) [7].

4.2 Mitigation of Ghgs

Crop residue burning emits significant amount of GHGs. For example burning of paddy straw caused the release of 70, 7

and 0.66% of C as CO_2, CO and CH_4, respectively, while 2.09% of N in straw is emitted as N_2O (Srinivasarao *et al*., 2013) [6]. Besides the advantage of carbon sequestration, other eco advantage of bio-char is reduction of non CO_2 GHGs emission by soil. Biochar addition induces microbial immobilization of available N in soil, thereby decreasing N2O source capacity of soil. As per the estimates in 2009, the greenhouse gas emission in India was 1,900 million t CO_2 per annum, hence it can be seen that biochar could contribute between 2-4% reduction (Priyadarshini and Prabhune, 2009) [8].

5. Role of Bio-Char in Stress Alleviation

Bio-char acts as an amendment as well as drought alleviator. Bio- char successfully reclaimed saline – sodic soil with and without sterilization leached with reclaimed water (Chaganti and Crohn, 2015) [9]. Bio-char produced with Fagus grandifolia sawdust pyrolyzed at 378 ^{0}C incorporated @ 50 t ha^{-1} as topdressing alleviated salt stress and stress induced mortality in *Abutilon theophrasti* and prolonged survival of *Prunella vulgaris* even under salt stress (Thomas *et al*., 2013) [10]. The application of bio-char reduced the uptake of Cd, Pb and Zn by plants with the jack bean translocating high proportions of metals (especially Cd) to shoots (Puga *et al*., 2015) [11]. In a green house experiment incorporation of bio-char reduced the wheat sodium uptake under salt stress and reduced osmotic stress by improving water content (Akhtar *et al*., 2015) [13, 16] and alleviated salt stress in beans by regulating osmotic adjustment (Abriz *et al*., 2017) [15]. Under maize- wheat cropping system grown in nutrient poor alkaline calcarious soil, addition of bio-char enhanced plant nutrition, crop productivity and soil quality (Arif *et al*., 2017) [14]. Bio-char mitigated the sodium stress in salf effected soil in potato crop and improved the quality and yield (Akhtar *et al*., 2015) [13, 16].

Bio-char acts as an amendment during drought stress as it having tremendous capacity to store water because of its high surface area and porous nature. Akhtar *et al*., 2014 [12] conducted an experiment on yield and quality of tomato under different irrigation regimes and revealed that application of bio-char under deficit irrigation and partial root zone drying irrigation improved water productivity and quality of tomato. Mulcahy *et al*. (2013) [17] reported that biochar application increased tomato seedling resistance to wilting in sandy soil. Application of 1% straw gasification biochar increased the shoot and root growth of barley grown in the coarse sandy subsoil under water. However, there was no effect of gasification biochar on barley growth under water stress in sandy loam soil (Hansen *et al*. 2016) [18].

6. Potentials and Constraints of Bio-Char Utilization in India

In India nearly 500-550 Mt of crop residue is produced every year which is a major opportunity for bio-char production. Most of the produced residue is subjected to burning because of lack of awareness and leading to environmental pollution by the release of GHGs. Production of bio-char and its incorporation in soil offers ample benefits ecologically and nutritionally. This novel technology is the promising technique for getting sustainability in agriculture and for mitigation of climate change. The availability of huge quantity of biomass in our country is the biggest potential for bio-char production.

In rural areas women cook the food by using biomass which causes environmental pollution with the release of GHGs. This process also leads to deforestation by collection of wood, burning the biomass causing impact to the environment. Farmers will not show interest for producing and incorporating bio-char, as the collection of residue in the field is not feasible and lack of awareness of benefits offered by bio-char. The above mentioned are the major constraints in on-farm production of bio-char.

7. Conclusions and Future Prospects

In agriculture dependent countries like India, sustainable production technologies with minimum impact on environment is necessary. Conventional practices like burning of residue and utilization of biomass for cooking releases huge quantity of GHGs leading to the environmental damage which became a major concern to the agricultural scientists. Hence invention of new technologies for productive utilization of biomass is required, which could be achieved through bio-char. Bio-char mitigates stress conditions, climate change and also improves soil health and productivity. It enhances the soil quality by improving physical, chemical and biological properties of soil.

Currently agriculture mostly depended on renewable resources for energy, so in near future requirement of ecofriendly, economical and feasible techniques are essential. In this respect bio-char has tremendous utilization in near future. For mitigating the bio-char use constraints further research on bio-char, and demonstration of its uses and utilization to the farmers is required.

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