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Short Communication

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Biochar for the control of plant pathogens

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ABSTRACT

Biochar, the solid product of pyrolysis of biomass at thermal degradation temperatures, is useful in agriculture as manure for enhancing plant growth through the supply of nutrients. It is used in protected cultivation practices of vegetables and flower crops in the pot culture and grow bags especially to improve soil physicochemical properties, and in hydroponics to remove pollutants like heavy metals in the water. The usage of biochar as a potential soil amendment for plant growth promotion, improving soil fertility and plant disease suppression are being explored in recent years. Biochar made from many of the agro waste materials was found to suppress the plant pathogens in the soil and also effective in controlling the pathogens affecting aerial parts of the plants. Although direct antifungal or antibacterial effects and metabolites of biochar are poorly understood, induced systemic resistance in plants through signal transduction and expression of defence chemicals and metabolites have been studied. In addition, microbiome analyses through metagenome sequencing revealed an increase in the population of beneficial microbes (antagonistic to plant pathogens) in the rhizosphere soils applied with biochar.

KEYWORDS: Biochar, Disease resistance, Induced systemic resistance, Plant growth, Pyrolysis

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INTRODUCTION

Biochar is a product obtained from biological waste, particularly agricultural biomass waste which is thermally degraded using a process called pyrolysis, in the absence of oxygen. Biochar is useful i) as a fuel source (charcoal) for renewable energy ii) for carbon sequestering to the soil preventing the release of carbon dioxide to the atmosphere iii) as a waste recycling method iv) as a soil amendment to improve the soil structure, texture, water holding capacity and other physicochemical properties thus improving the soil fertility v) plant growth promotion due to the nutrients supplied by biochar when used as manure and vi) plant disease management by either directly (antagonism) or indirectly (induced systemic resistance) in plants. Although biochar usage in agriculture is at the beginning stage, the great potential in agriculture and multi-purpose utility in agriculture and environment domains makes biochar an important product to be explored further.

BIOCHAR FOR AGRICULTURE

Biomass undergoes thermal degradation under no-oxygen conditions when heated to a temperature of 300°C and above and the process is called pyrolysis. Solid (biochar), liquid (bio-oil) and gaseous products (hydrogen, carbon dioxide, carbon monoxide, methane and ethylene), organic acids and hydrocarbons are produced (Hou *et al*., 2022). Paddy straw, wood, shells, sugarcane trash, algae, coconut fonds, sewage sludge, poultry waste, animal manure and any other agro waste can be used as raw material for the production of biochar.

Application of biochar to soil has been proven to have a positive effect on crop productivity in cereals like wheat, vegetables like beans, cucumber, sweet pepper and tomato, and fruits like strawberry. In all these observations, biochar was used as manure either directly or after composting with other organic manures. Biochar is beginning to be utilized in agriculture due to the lack of understanding on how it works and the technical issues related to the optimization of pyrolysis for each source material, the cost involved in biochar production and the quality of the feedstock required. At present, it is used in controlled cultivation technology like greenhouses and poly houses for vegetable and floriculture. The application of biochar as soil amendment in agricultural fields on a large scale is limited.

BIOCHAR IN PLANT DISEASE MANAGEMENT

The first observation of the effect of biochar application to control plant pathogens was made in 2010 (Elad *et al*., 2010), where the biochar obtained from citrus tree wood was found to protect tomato and pepper plants from the pathogens *Leveillula taurica* (powdery mildew disease) and *Botrytis cinerea* (grey mould disease), respectively.

Biochar obtained from eucalyptus wood was known to suppress disease caused by *Rhizoctonia solani* in cucumber and bean plants. In tomatoes, against crown rot disease caused by *Fusarium oxysporum* f.sp. *radices lycopersici*, the application of biochar has been proven to improve plant growth by 63% and prime the expression of genes of tomato that are related to plant resistance and growth, including the hormones (auxins and cytokinins), brassinosteroids, phenylpropanoid pathway and jasmonic acid pathway (Jaiswal *et al.*, 2020). On the other hand, the application of biochar to tomatoes increased the population of beneficial bacteria like *Pseudomonas* sp., against the *Fusarium* wilt pathogen (Jin *et al.*, 2022). This was proved by metagenomic analysis of the 16s rRNA gene in the rhizosphere metagenome of biochar-applied and non-applied tomato plants. In the presence of biochar, the tomato was also found to release chemoattractants that could have attracted the beneficial bacterial communities near the root vicinity. Thus, biochar helps to improve the population of soil beneficial microbial communities which in turn help in the suppression of soil-borne plant pathogens.

Tender *et al.* (2021) reported the attraction of plant beneficial rhizobacteria and fungi as the mechanism behind the role of biochar in plant disease suppression, based on the studies using the strawberry – *Botrytis cinerea* plant pathogen system. Botrytis cinerea is a pathogen that affects both fruits and leaves of strawberry plants. Interestingly, the application of biochar in the soil was found to control the fruit infection more than the leaf infection. A trade-off of defence or resistance-related metabolites between plant parts is hypothesized.

Biochar has been used to treat bacterial wilt in tomatoes caused by *Ralstonia solanacearum* (Choudhary *et al.* 2018). Improved soil physicochemical qualities, an increase in bacteria and actinomycetes in the rhizosphere, and decreased *Ralstonia solanacearum* swarming motility and root colonisation capacity are some of the processes underlying biochar's protective effects. The advantages of combining compost and green waste biochar (at concentrations of 0 to 3%) for lowering *Fusarium oxysporum* f. sp. *lycopersici* wilt-inducing chlamydospores in tomatoes resulted in an enrichment of beneficial bacteria, which may work either through direct competition or indirectly by causing the plant to develop systemic resistance (Akhter *et al.*, 2016).

However, the biocontrol effect of biochar on plant diseases was found to vary with the source material (biomass or agro waste) used for making the biochar, the pyrolysis process and the quantity applied to the soil/crops. A recent meta-analysis of the available literature about biochar and its influence on plant pathogen/disease revealed that biochar made with temperatures ranging from 350-600°C was found to have better disease suppression and growth promotion in plants (Yang *et al.*, 2022). Application of 3-5% of biochar was found to decrease diseases by 59%. The effect was more in cash crops than cereals and trees. Comparing soil-borne and air-borne pathogens, biochar application was known to be more effective in controlling air-borne pathogens attributed mainly to the induced systemic resistance stimulated by biochar applied to the root zone.

MECHANISM OF ACTION OF BIOCHAR

To some extent, the mechanisms by which biochar suppresses plant diseases can be categorized into i) modification of soil properties that enhance beneficial microbial activity ii) nutrient availability for antagonistic microbes iii) growth promotion of plants and influence of root exudates that could attract beneficial and antagonistic microbes and iv) induced systemic resistance involving induction of defense metabolites, enzymes and other proteins via jasmonic acid and phenylpropanoid pathways. In addition to fungal and bacterial pathogens of crop plants, the application of biochar also helps in controlling insect pests and nematodes. This is due to improvement in the beneficial microbial community in the soil and the induction of insecticidal and nematicidal metabolites in plants.

FUTURE PROSPECTS

Biochar is an excellent soil amendment to explore further for plant growth promotion, soil fertility improvement, plant disease and pest control. The uniqueness of biochar is that it contributes to waste recycling and carbon sequestering, among other global environmental issues. However, optimization of biochar preparation with different crop residues has to be experimented. In addition, nutrient profiling of the biochar developed at different pyrolysis temperatures would reveal which biomass or agro waste requires which type of thermal degradation process to yield better biochar. Since biochar alone may not be sufficient to provide all the required nutrients to the crops, the right combination of biochar with other organic manures must be derived crop-wise to supply the required nutrients to the plants. Nutrient release studies over the crop growth period are also essential to design the package of practices for crops and the recommendation of organic manure and biochar combinations. Soil and plant microbiome analysis at different crop growth stages,and gene expression studies to fully understand the molecular mechanism behind the effect of biochar and to optimize the dose to achieve its disease control effects in all plant parts are indispensable. The value addition of biochar based on the aforesaid experimental results will make it a celebrated organic product in organic farming in the future.

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