**Combined Application of Biochar and Micorrhizal Fungi to Enhances Wheat (*Triticum aestivum L*.) Growth and Yield**

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1. **Abstract**

The objective of this study is to investigate the combined application of biochar and mycorrhizal fungi on wheat (*Triticum aestivum*) growth and yield in calcareous soil. In this study, 14 treatments were used, including to mycorrhiza, two different manures, and four levels of biochar. The experiment was carried out using a factorial complete randomized design (CRD) with four replicates. Biochar doses were 0, 1, 2, and 3 tons/hectare. The soil was collected from the research field experiment in College of Agriculture engineering sciences / Sulaimani University. The results revealed that

**Introduction**

The effect of biochar (biomass-derived black carbon) on crop growth and nutrient uptake varies depending on the amount of biochar used in conjunction with fertilizer (Solaiman, Blackwell et al. 2010). Phosphorus is one of the most important essential macronutrients for plants, which contributes in numerous vital functions in plants like photosynthesis, energy transfer, srespiration and cell division. The soils of Iraq are rich in calcium carbonate. having a slightly alkaline pH, which causes 70-90% of applied phosphorus fertilizers to be chemically and physically fixed (Esmail 2012). One of the major yield limiting factors in alkaline calcareous soil is phosphorous (P) availability. Although calcareous soils contain a lot of P, it's mostly unavailable, so farmers have to use chemical fertilizers to make up for it.

Chemical fertilizers are expensive, and most farmers cannot afford to buy the required amount of P fertilizer. As a result, the soils remain unfertilized, and the crops suffer from P deficiency. Under stress, arbuscular mycorrhizal fungi (AMF) are known to increase P availability to plants. As a result, strategies to improve the efficiency of AMF are required to increase the availability of P. Mycorrhizal fungi are commonly used as soil inoculums to improve phosphorus availability, soil properties, and crop yields(Malik, Shah et al. 2019).

Biochars are byproducts of the pyrolysis process, which is an irreversible thermochemical conversion of biomass from either plant or animal origin heated at very high temperatures (250 C) in an oxygen-free or oxygen-limited environment(Solaiman, Shafi et al. 2020). Biochar properties such as pH, specific surface area, pore volume, cation exchange capacity (CEC), other nutrients, volatile matter, ash, and carbon content are largely determined by the type and source of feedstock used in its production, as well as the temperature and pyrolysis activation treatments (Tomczyk, Sokołowska et al. 2020). Different feedstocks produce biochar with varying properties due to differences in lignin, cellulose, and moisture content. When compared to crop residue and wood biomass biochar, animal litter and solid waste biochars have a lower surface area, carbon content, and volatile matter, but a higher CEC. The application of biochar to soil has been shown to increase soil fertility and, as a result, agricultural productivity (Chan, Van Zwieten et al. 2008). Soil enhancements such as biochar (BC) are gaining popularity as tools for both mitigating climate change and promoting crop growth. However, the use of biochar can disrupt soil ecosystems by changing the physical, chemical, and biological properties of the soil (Barna, Makó et al. 2020). Biochar addition to soils has the potential to reduce climate change, sequester carbon in soils, and improve crop production. As a result, recent research has focused on biochar production and application, particularly in agricultural settings. Biochar production from discarded organic materials can also help to reduce waste generation (Ye, Zeng et al. 2019). The surface area of all particles in a sample is defined as the specific surface area (SSA), which is usually expressed per unit of mass. When it comes to processes that occur at solid-gas phase boundaries, the specific surface area can be defined as the surface accessible to gas molecules and includes both the external and internal surfaces of a solid body. The size, shape, porosity, layer composition, or molecular structure of the solid particles primarily determine the surfaces (Sokolowska, Jamroz et al. 2008). Plants and soil microbiome, including arbuscular mycorrhizal fungi (AMF), contribute to soil carbon storage, and when roots exert pressure on soil particles, they secrete exudates that influence aggregate formation significantly (Pal and Pandey 2014).

1. **Materials and Methods**

This study was conducted on the region of Sulaimani; the sampling sites were located in Bakrajo (Vertisol) (35032’15.47” N, 45021’52.25” E), soil orders was determined by morphological, physical, and chemical soil parameters (Abdulla 2015).

**Pot Experiment**

The pot experiment was conducted at the plastic house in College of Agriculture engineering sciences / Sulaimani University. The experiment was carried out using a factorial complete randomized design (CRD) and in Triplicate during November 24th, 2021 and May 31th, 2022. Soil samples were taken in (30 cm) soil surface and passed through (4 mm) sieve. Each plastic pot was filled with 0.5 kg gravel and 5.0 kg air-dried soil on top of the gravel. Two different types of Biochar (Cattle Manure Biochar, Poultry Manure Biochar) were applied to the soil before 14 days of seeding. Wheat (*Triticum aestivum L*.) were planted in each pot at 5 cm depth. Each plastic pot was added 5 seeds. Three (3g) of Mycorrhiza (*Glomus* *intraradices*) were applied to the soils of each plastic pot before seeding. Four plants were left in each pot after germination. The water content of the pots was adjusted to 75% of field capacity throughout the experimental period, depending of gravimetric method. At harvesting time, wheat shoots were harvested, measured some yield parameters, weighted, and dried at 65°C for 72 hr. to determine the dry matter yields. The soil samples were air dried and passed through a 2-mm sieve and stored in plastic bottles prior to physical and chemical analysis. Soil particle size distribution was determined by the pipette method according to (Black 1965), Electrical conductivity (Ec) and pH were measured for the soil dilution extract with using the Ec-meter according to (Rhoades 1996), and pH meter, as mentioned by (Ryan, Estefan et al. 2001). Organic matter was determined by using the (Walkley and Black 1934), method, as described by (Loeppert and Suarez 1996). The total calcium carbonate equivalent was determined method as mentioned by (Loeppert and Suarez 1996). Total N was determined by Kjeldahl method as described in (Antoniadis and Alloway 2001). Available phosphorus using Olsen method as described in (Javid and Rowell 2002). and spectrophotometer at Wave length of 882 nm (Spectro UV-VIS RS spectrophotometer). Sodium and Potassium (Na+, K+): were measured by using (JENWAY, PFP 7 Flame photometer). Zinc was developed by (Lindsay and Norvell 1978).

**STATISTICAL ANALYSIS:** The analysis of variation (ANOVA) and Duncan multiple range tests (DMRT) at p ≤ 0.05 was used to separate the means.

**RESULTS AND DISCUSSIONS**

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