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BIOCHAR PRODUCTION FROM LIGNOCELLULOSIC WASTES AND ITS USE FOR AGRICULTURAL APPROACHES

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SPOKE, WP AND TASK

Spoke 8 - Circular economy in agriculture through waste valorization and recycling.

WP 8.3 - Nutrient and organic matter recovery from wastes to reduce the use of agrochemicals and closing waste cycle.

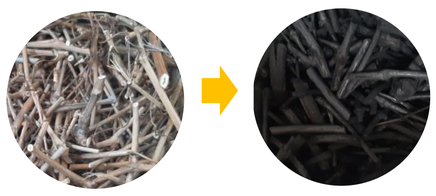
Task 8.3.2 - Valorisation and biological regeneration of wastes as resources, organic fertilizers, or amendments to improve carbon storage and soil quality.

ABSTRACT

Biochar is a carbon-rich product obtained from the pyrolysis of biomass which has numerous potential uses such as both a soil amendment and biostimulant (Palansooriya et al., 2019, Allohverdi et al., 2021, Iacomino et al., 2022). Although biochar is currently used in agriculture, its effectiveness is highly variable and depends on its chemical-physical properties, the crop on which it is used, the cultivation conditions and the soil characteristics (Basile et al., 2024).

Our research activity aimed to improve the understanding of the key factors influencing biochar efficacy in order to optimise biochar production and application. We evaluated the effect of key pyrolysis parameters on the chemical-physical properties of the biochar. A plant assay using *Medicago truncatula* was designed and implemented to test the effect of different biochar types on plant performance and plant-associated microbial communities.

MATERIALS AND METHODS



Vine prunings Biochar

Biochar physico-chemical characterization. Biochar samples produced from vine prunings applying different pyrolysis conditions, as temperature (450°C, 525°C and 600°C) and residence time (1h, 4h and 15 h), have been characterized to test the effect of the pyrolysis parameters on the qualitative parameters of the biochar. In particular, the analyses of inorganic elements (by ICP-OES Inductively Coupled Plasma Optical Emission Spectroscopy), chlorides, sulphates and phosphates (by ion chromatography) and superficial area (by iodine number assessment) were performed.

Plant assay. *Medicago truncatula* plants (genotype R108) were grown under semi-controlled conditions (greenhouse) on field soil (sandy, poor in organic matter) treated with the different types of biochar in presence of the nitrogen-fixing bacteria *Ensifer meliloti* and compared to the control untreated plants (Figure 1). Additionally, not-inoculated plants were used as control. The biomass of both aerial and root organs were measured. To investigate whether biochar influenced the root nodulation capacity of *M. truncatula*, as consequence of the symbiosis with the nitrogen-fixing bacteria, the number of root nodules was also measured.
In following assays, plants were treated with biochar, produced by pilot-scale plant (rotary kiln plant at ENEA Trisaia Research Centre) applying low temperatures (400-500°C), short residence time (15 min), and 0.1 equivalence ratio. The growth of plants was examined under two distinct irrigation regimes: normal irrigation and water deficit. Plants treated with unaged and 1 year-aged biochar were compared with untreated control plants. Aerial and root biomass, and legume number and weight were measured. Soil samples were collected to measure the effect of biochar treatment on microbial communities by metagenomics approaches (rDNA amplicon sequencing).

Figure 1. Plant assay to evaluate the effect of biochar. From left to right: *E. meliloti* inoculation of *M. truncatula* plants, plant aerial and root organs, root nodules.

RESULTS

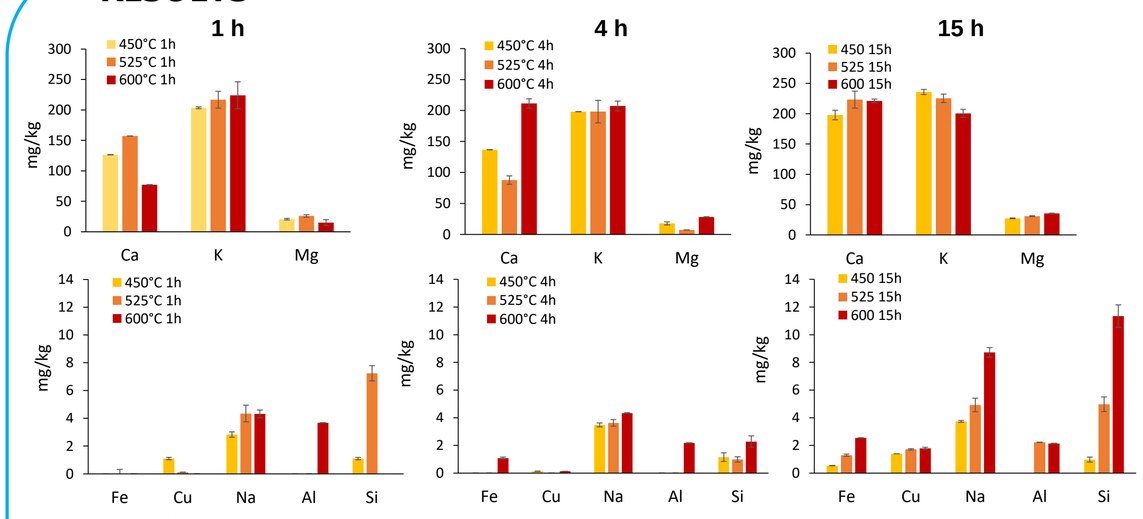


Figure 2. Analysis of inorganic elements of biochar produced by vine prunings applying different pyrolysis parameters (temperature and residence time).

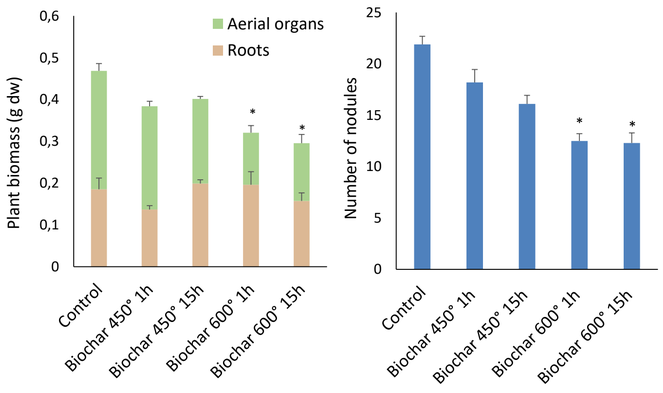


Figure 3. Plant growth and number of nodules in plants treated with different types of biochar.

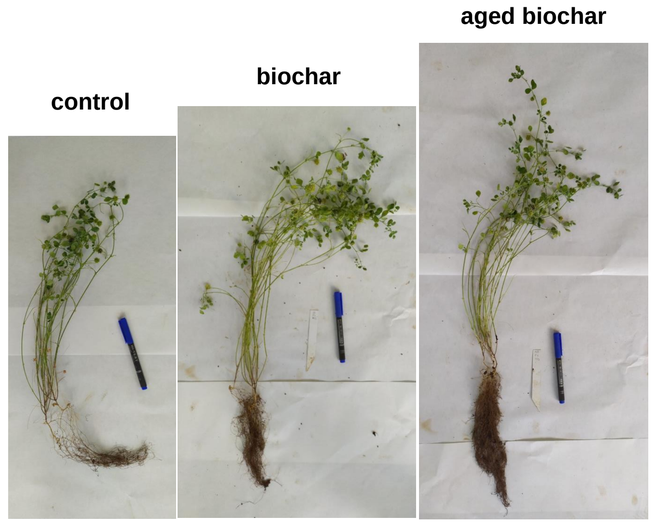
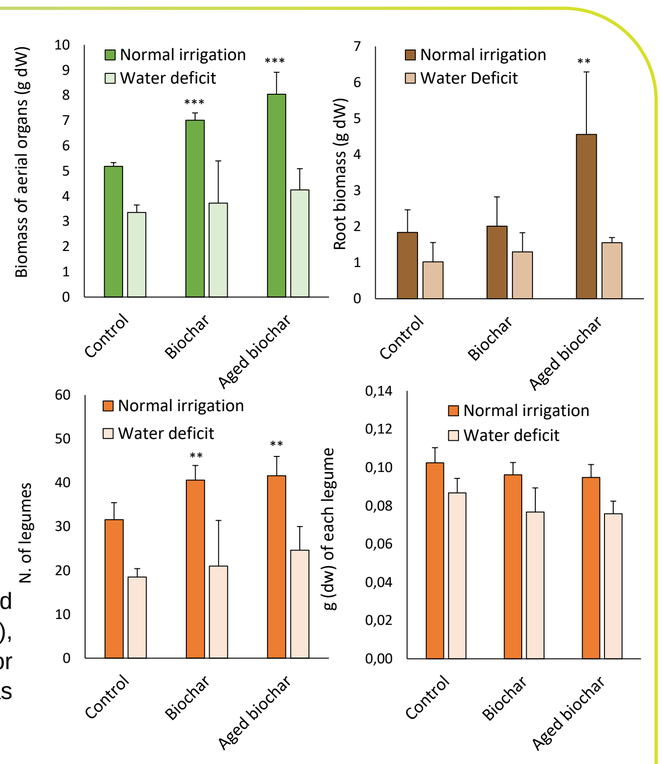


Figure 4. Effect of biochar treatment on plant biomass and number of legumes, compared to control (untreated plants), under either normal irrigation or water deficit. Biochar unaged or aged, produced by pilot-scale plant (400-500°C, 15 min) was used.



Biochar produced applying different pyrolysis parameters showed different physico-chemical properties (Figure 2). The results of the plant assays indicated that the treatments with the biochar produced at higher temperatures (600°C) had a slight negative effect on plant growth and nodulation (Figure 3). Low temperatures (T 400°-500°C) and short residence time (RT ≤ 1h) were selected for the pilot-scale biochar production.

The application of biochar (T: 400-500°C, RT: 15min) to soil resulted in the growth of *M. truncatula* plants with significantly higher aerial organ biomass and a greater number of legumes per plant, when compared to the untreated control plants (Figure 4). The benefits were enhanced when 1 year-aged biochar was used, which also enhanced root growth. No significant differences were observed in the presence of water deficit conditions.

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