# Analysis of biochar and digestate as biofertilizers in lettuce cultivation

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## Introduction

Compared to conventional chemical fertilizers, biofertilizers derived from biodegradable waste reduce greenhouse gas emissions, recover essential nutrients, and support sustainable agriculture (Sharma et al., 2023). Biofertilizers derived from biowaste are aligned with circular economy principles and provide long-term environmental and economic benefits (Foughal et al., 2023). In this study, the effect of biochar and digestate on the growth of lettuce (*Lactuca sativa*) plants was explored. Biochar and digestate applied as biofertilizers in agriculture enhance soil fertility providing essential nutrients as nitrogen and phosphorus. Additionally, biochar enhances the aeration and water-retention capacity of the soil.

## Methodology

The biofertilizers considered in this study were i) digestate coming from the anaerobic digestion at 35°C of *Opuntia ficus-indica* waste, and ii) two biochars derived from the pyrolysis at 550°C of soft wood (SW) and of sewage sludge (SS). Lettuce plants (*Lactuca sativa*) were cultivated in 1 L pots for 5 weeks in two adjacent laboratory-scale greenhouses equipped with automatic sprinklers. Three replicates were considered for each biofertilizer, and control pots (i.e. without biofertilizer) were included in the tests. Digestate and biochar were mixed with commercial potting soil according to the doses reported by literature: 2 and 12 tons/ha for biochar (samples SS2, SS15, SW2 and SW15), and 5, 25 and 50 kg N/ha for digestate (samples C1, C2 and C3). A commercial mineral fertilizer (15-9-11 NPK + 3 Mg, Landscaper Pro, ICL, Italy) applied at 50 kg N/ha was compared to the digestate (sample CM). An automated low-cost proximal sensor system was installed in each greenhouse to monitor the micro-climate and the plants growth. Each system consisted of a MAPIR Survey 3W multispectral camera, a DHT22 sensor, to measure temperature and humidity. All sensors were integrated using a Raspberry Pi 4 computer board for automatic data collection and storage. The camera had a 12 MP sensor, collecting data in three spectral bands (550, 660 and 850 nm) with an 87° field of view. The camera allowed to capture all the plants placed in a greenhouse in a single image. Nadir images were collected hourly, and they included spectral response values in the red, green, and near-infrared (RGN) portions of the electromagnetic spectrum. Calibrated images were then used to calculate the normalized difference vegetation index (NDVI) for each lettuce plant (Zhihao & Wei, 2024). After 5 weeks, the lettuce plants were harvested, and the fresh weight of leaf biomass was measured.

## Results and discussions

In overall, the biofertilizers caused an increase of the fresh weight of lettuce plants (Figure 1). The fresh biomass of lettuce plants treated with biochar (Figure 1a) was consistently larger compared to the control pots (C): +32% for SS2, +87% for SS15, +46% for SW2, and +19% for SW15. The fresh biomass of lettuce plants treated with digestate (Figure 1b) highlighted that C1 dose (5 kg N/ha) performed analogously to the control pots, while C2 dose (25 kg N/ha) achieved better results compared to C3 (50 kg N/ha), and C2 and C3 doses performed similarly to the mineral fertilizer (CM).

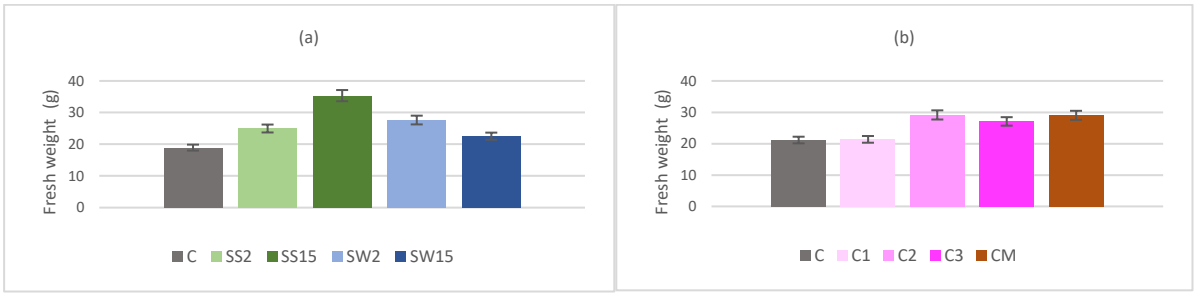


**Figure 1**: Fresh weight of lettuce treated with biochar (SS2, SS15, SW2, SW15), digestate (C1, C2, C3) and mineral fertilizer (CM) measured after 5 weeks

NDVI index values calculated for the plants treated with the biofertilizers and the control pots were alike for the first 3 weeks (Figure 2). Considering biochar, from the fourth week SW2 and SS2 treatments displayed higher NDVI values, consistently with the results in Figure 1a. SW15 and SS15 did not show NDVI values higher than the control pots. Similarly, the NDVI values calculated for the plants treated with digestate (Figure 2b) were alike to the control pots for the first three weeks. The NDVI trends in weeks 4 and 5 in both the biofertilizer trials may be attributed to uncorrected effects inherent to the sensor and exacerbated by the structure of mature lettuce plants, which were notably more complex in the digestate trial due to spatial constraints.

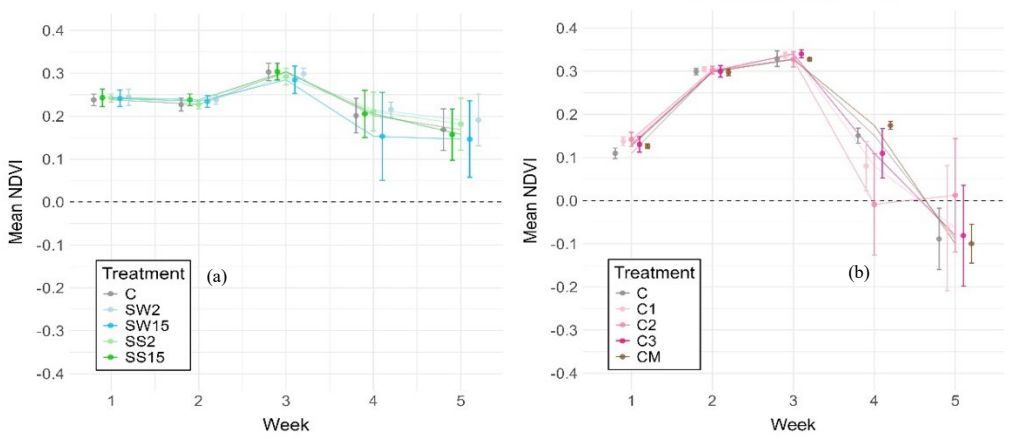


**Figure 2**: NDVI over the experiment period of lettuce treated with biochar (SS2, SS15, SW2, SW15), digestate (C1, C2, C3) and mineral fertilizer (CM).

## Conclusions

In conclusion, both biochar and digestate led to an increase of fresh weight of the lettuce plants. However, a higher dose of biofertilizer did not necessarily correspond to greater biomass production. Future research should involve tests in larger greenhouses with a greater number of plants to strengthen and validate the presented results.

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