Effect of biochar type and dose in cultivation tests at lab and pilot scale

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Introduction

The conversion of biodegradable waste into biofertilizers supports sustainable agriculture and circular economy, recovers vital nutrients, and decreases greenhouse gas emissions associated to agricultural operations. Biochar applied as a biofertilizer improves soil aeration, water retention, and nutrient availability while sequestering carbon and reducing the use of chemical fertilizers. This study explored the impact of biochar types and doses on the growth of lettuce (*Lactuca Sativa*) plants. The tests were performed in parallel for 5 weeks in a lab-scale greenhouse and in a pilot-scale greenhouse. A low-cost automated proximate sensor system was installed in the lab-scale greenhouse for the remote monitoring of plants growth and microclimate.

Methodology

Commercial garden soil mixed with biochar derived from the pyrolysis at 550°C of soft wood (SW) and sewage sludge (SS) was used to grow lettuce sprouts. The tests involved two groups operated in parallel: thirty 1-L pots in a lab-scale greenhouse and twenty-one 2-L pots in a pilot-scale greenhouse. Both groups were irrigated via automatic sprinklers for 35 days. Biochar was dosed according to literature (2 and 12 tons/ha) and was applied unaltered and after physical activation with CO_2 at 900°C in the 1-L pots and unaltered in the 2-L pots. Three replicates of each treatment (i.e., type and dose of biochar) and control pots (i.e. no biochar) were considered. The lettuce plants' growth was assessed by counting the leaves weekly in each pot and measuring their fresh and dry weight (after drying at 80°C for 20 hours) at the end of the tests.

A low-cost automated proximate sensor system was installed in the lab-scale greenhouse to monitor plant growth and microclimate (air temperature and soil moisture). The system included a MAPIR Survey 3W multispectral camera with an 87° field of view; the camera's 12 MP sensor acquired information in three spectral bands (550, 660 and 850 nm). The camera was positioned on the roof of the greenhouse to capture all the plants in a single frame, and nadir images were collected every hour. Spectral response values in the red, green, and near-infrared (RGN) regions of the electromagnetic spectrum were included in the pictures. A Raspberry Pi 4 computer board integrated the sensors and the camera to gather and store data automatically. The normalized difference vegetation index (NDVI) was calculated for each pot based on calibrated pictures.

Results and discussions

Figure 1 summarizes the results obtained about the leaves' weight in 1-L pots. Compared to control pots (C), biochar addition led to higher leaves' mass in all doses and types tested. In overall, activation and greater dose seem to enhance the leaves' weight. Considering the types and compared to control pots, SS biochar performed better than SW, as follows. SS applied at lower dose enhanced the biomass compared to C, both as unaltered (SS2, +28.7% fresh, +42.3% dry) and as activated biochar (SS2a, +35.0% fresh, +31.6% dry). SS applied at higher dose had even greater effect as unaltered (SS15, +67.3% fresh and +81.3% dry) and as activated (SS15a, +106.0% fresh and +110.4% dry). SW improved growth at lower dose as unaltered biochar (SW2, +21.4% fresh and +28.5% dry) and as activated (SW2a, +70.6% fresh and +83.4% dry), and at higher dose as unaltered (SW15, +22.0% fresh and +30.2% dry) and as activated (SW15a, +16.1% fresh and +22.6% dry). The results obtained in 2-L pots mostly confirmed the ones achieved in 1-L pots. In 2-L pots, compared to C, the leaves' mass increased with SW applied at both doses (SW2 +28.6% fresh, +2.7% dry; SW15 +67.2% fresh and +5.9% dry) and when unaltered SS was applied at lower dose (SS2, +28.6% fresh, +2.7% dry), while it decreased when SS was applied at higher dose (SS15, -13.2% fresh and -7.7% dry).

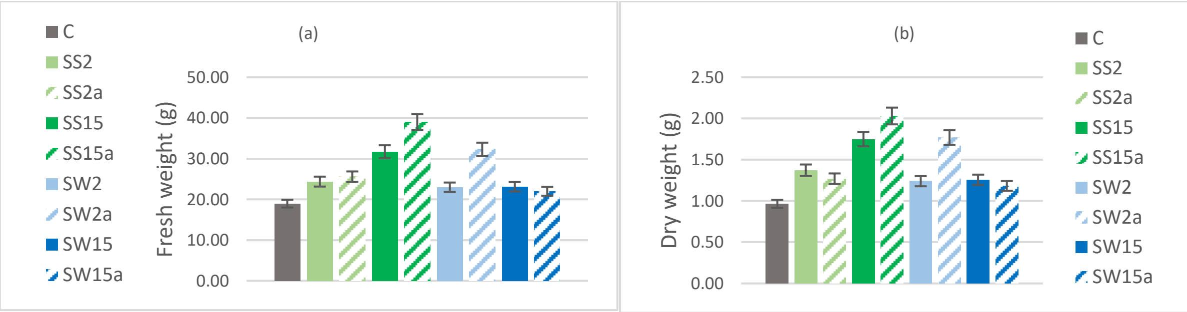

Figure 1: Fresh (Figure1a) and Dry (Figure 1b) weight of lettuce treated with Soft Wood biochar (SS2, SS2a, SS15, SS15a) and Sewage Sludge biochar (SW2, SW2a, SW15, SW15a).

Considering the NDVI trends recorded in the 1-L pots (Figure 2), after 3 weeks the values decreased and variability increased across all groups, probably because the geometry of mature lettuce plants affected the quality of the acquired data. In weeks 4 and 5 the leaves of mature plants were less uniform in shape, height and size compared to the first three weeks. Under bright sunlight, the edges of some leaves appeared oversaturated, particularly in centrally-located plants due to the sensor's vignette effect. This resulted in high red band reflectance, low near-infrared reflectance, and thus low and negative NDVI values, reducing the average NDVI per plant.

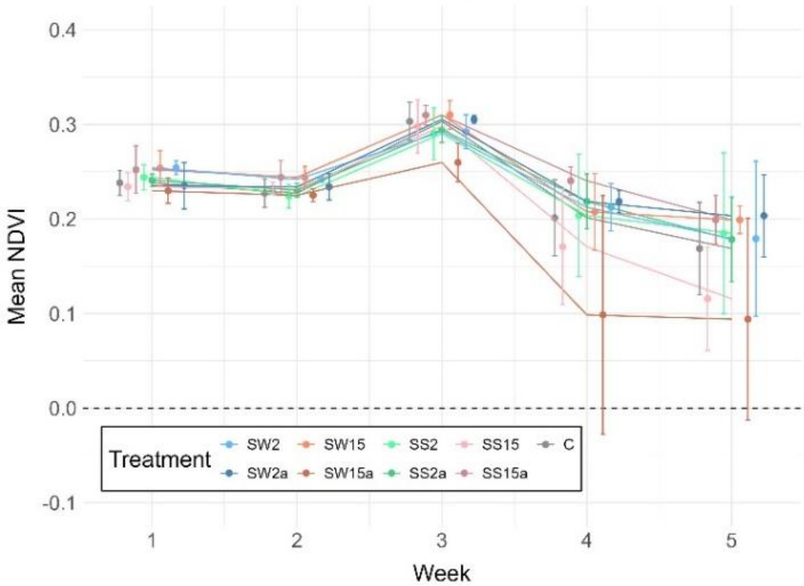

Figure 2: Normalized difference vegetation index (NDVI) trends recorded in the 1-L pots.

Conclusions

In overall, supplementing biochar to the soil enhanced lettuce leaves' weight compared to control pots. Activated biochar showed superior outputs, while applying higher dose of biochar didn't led to an improvement in all the tested experimental conditions. Further research is needed to validate the results achieved scaling-up the setup and to optimize the remote sensing system, such as testing sensors corrections and alternative calibration approaches.

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