Validation of Biochar as a Soil-Amending Substrate

C. Partheni[1], K.M. Kakokefalou[1], E.M. Barampouti[1], S. Mai[1], D. Malamis[2], K. Moustakas[1]

[1]Unit of Environmental Science & Technology, School of Chemical Engineering, National Technical University of Athens, 9 Iroon Polytechniou Str., Zographou Campus, GR-15780 Athens, Greece

[2]Department of Civil and Environmental Engineering, Brunel University of London, London UB8 3PH, UK

Presenting author email: kalliopikakokefalou@gmail.com

Introduction

Residual biomass valorization is a central principle of circular bioeconomy systems, and biochar, produced through thermochemical conversion routes including hydrothermal processing, and has emerged as a promising value-added product for the productive reuse of biomass side-streams in agronomic and environmental applications. This concept is usually applied to olive pruning residues and wheat straw fractions generated during the production of advanced biofuels, as part of a zero-waste strategy and efficient use of resources.

Aim

This study aims to validate the effectiveness of biochar as a soil-amending substrate through greenhouse pot trials using lettuce, with emphasis on agronomic performance, environmental functionality, and carbon sequestration potential.

Materials & Methods

- **Plant used in greenhouse pot trials**: Lettuce seedlings
- **Experimental Cycles:** Two consecutive cycles - preliminary optimization and biochar validation
- **Biochar Types:** Olive Branch biochar and Wheat Straw biochar
- **Application Rates:** 0, 2, and 5 t/ha equivalent dosages
- **Duration:** Preliminary cycle → 1 month, Validation cycle → 3 months

Standard analytical methods were employed for biochar, soil and plant characterization, including measurements of pH, electrical conductivity, moisture content, total & volatile solids, total organic carbon & total nitrogen, heavy metals & nutrient content and water dynamics (soil), as well as total chlorophyll, optical and development indicators (plants). These parameters were selected to provide a detailed compositional profile of the material, capturing both its organic matrix and inorganic components.

Biochar

Lettuce in pot with soil & biochar 2 t/ha

Greenhouse with lettuce pots

Final lettuce in pots with soil & biochar

Results

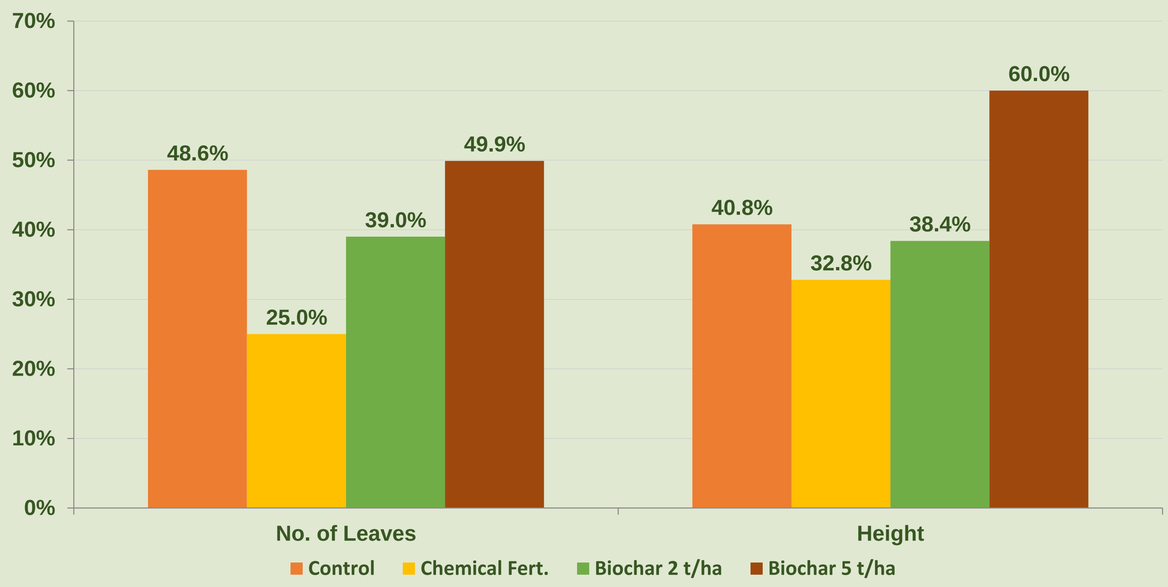

Figure 1: Growth of optical indicators for all substrates

Key Findings

- ✓ Both biochar types had low moisture content (~2.7–3.2%) and slightly acidic pH (5.10–5.66). Olive-branch biochar showed higher TOC (81.12%), higher C/N ratio, and elevated Ca (29.51 g/kg), while wheat-straw biochar had higher Mg (11.83 g/kg) and nitrogen content. Both contained elevated Ni (~423–477 mg/kg), and wheat-straw biochar also showed high Cr (106.15 mg/kg), raising environmental concerns.
- ✓ Experimental Cycle 1 revealed mild pH and EC increases across substrates, with metals accumulating preferentially in roots (Cu, Ni) and higher TOC and TN observed in leaves. Substrate type influenced growth patterns, informing Cycle 2 design.
- ✓ In Cycle 2, all substrates showed basic pH, moderate EC, and sufficient organic matter. Biochar addition increased TOC and total nitrogen. At 5 t/ha, both biochar types promoted accumulation of Cr, Ni, Mn, and Cu rather than improving nutrient availability. At 2 t/ha, nutrient availability improved in one replicate, particularly for P-PO_4, K, Ca, Mg, and Fe, though variability between samples was notable.

Conclusions

Regarding the visual indicators of plant growth, some key conclusions have emerged from the data recorded. In general, a significantly greater increase in plant height and leaf mass was observed in pots containing a substrate with biochar; more specifically, a large increase in the number of leaves, by approximately 39% for a concentration of 2 t/ha, and more significant leaf development, at approximately 60% for a concentration of 5 t/ha. The respective values for pots containing chemical fertilizer were, on average, 25% and 32.8%, respectively.

Acknowledgements

The authors of this work acknowledge that this project has received co-funding from the European Union's Horizon Europe research and innovation program under Grant Agreement No 101122151 (FUELGAE). The authors would also like to acknowledge the Centre for Research and Technology Hellas (CERTH) for supplying the biochar materials used in this study.