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Phosphorus dynamics in the soil-sunflower (*Helianthus annuus* L.) system as affected by P-enriched biochar from real treated wastewater

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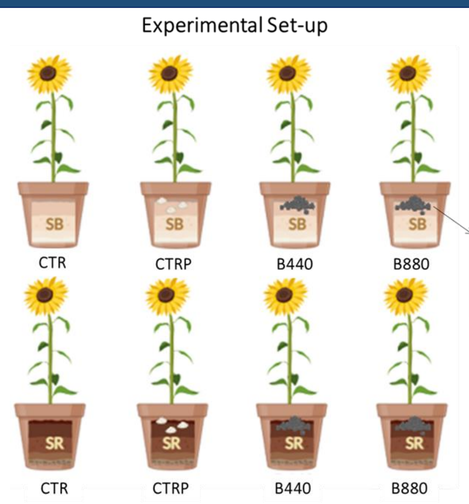
INTRODUCTION

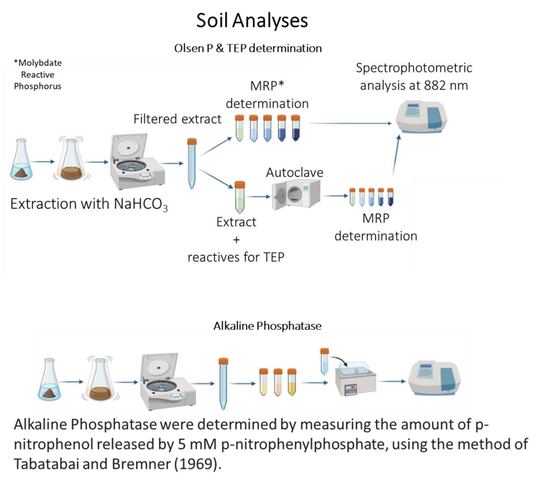
Phosphorous (P), a non-renewable resource, is an essential element for life and an irreplaceable component of modern agriculture [1]. Being a non-renewable resource, rational use of P fertilizers and P recovery from waste is desirable [2]. P can be recovered from aqueous solutions, such as municipal, industrial, and agricultural wastewater, by its adsorption onto a solid phase [3,4]. Biochar is one of the most widely used solid materials for P recovery. Biochar once enriched with P can be reused in agriculture as a slow-release fertilizer, in a circular economy perspective [5].

AIM OF THE STUDY

The aim of this study was to evaluate the effect of P-enriched biochar when used as a slow-release fertilizer in the soil-plant system. The biochars used in this study were obtained from the same biomass (wood) but with two different pyrolysis temperature, 440 and 880 °C, respectively. The B440 and B880 were previously nutrient-enriched in filter columns located in a pilot wastewater treatment plant using real wastewater from the Water Resource Recovery Facility at the University of Palermo [5]. The amount of P supplied with fertilizer or enriched biochar was 50 mg P per Kg of dry soil. The experimental test was carried out over a period of 122 days.

MATERIALS & METHODS





Alkaline Phosphatase were determined by measuring the amount of p-nitrophenol released by 5 mM p-nitrophenylphosphate, using the method of Tabatabai and Bremner (1969).

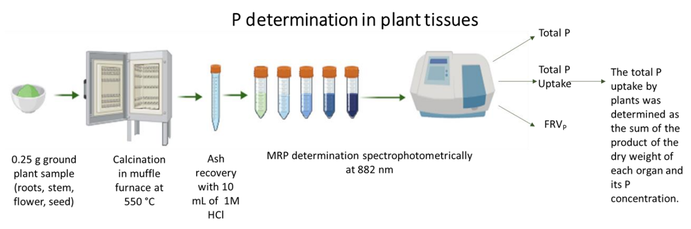


Table 1: Characteristics of the soil.

Soil	pH	Electrical Conductivity	Organic Carbon	$CaCO_3$	Active Carbonate	NO_3^-	NH_4^+	TN	Olsen P	Cation Exchange Capacity
		µS cm^{-1}		%		mg kg^{-1}		%	mg kg^{-1}	cmol kg^{-1}
SB	8.51	138.8	0.68	47.2	9.63	65.17	5.40	0.080	6.41	9.65
SR	7.61	131.3	0.51	6.8	2.28	60.20	8.68	0.078	8.54	10.33

Table 2: Physical and chemical properties of the two tested biochar. The reported results are mean ± standard deviation of four replicates.

Parameters	Unit of measurement	B440	B880
Bulk density	g L^{-1}	180 ± 14	126 ± 11
Surface area	m^2 g^{-1}	194 ± 12	247 ± 15
Total pore volume	cm^3 g^{-1}	38 ± 4	51 ± 3
Maximum water retention	%	62 ± 11	400 ± 32
Soil reaction	pH	9 ± 1	10 ± 1
Electrical conductivity	dS m^{-1}	1.3 ± 0.2	2.1 ± 0.3
Moisture	%	3.1 ± 0.3	6.7 ± 0.9
Total limestone	%	5.0 ± 0.8	2.7 ± 0.3
Total carbon	%	62 ± 2	63 ± 1
Total N	%	0.8 ± 0.1	0.23 ± 0.05
Total P	%	1.0 ± 0.1	4.3 ± 0.8
Fe	mg g^{-1}	22.0 ± 2.0	2.8 ± 0.4
Zn	mg g^{-1}	0.017 ± 0.004	0.003 ± 0.001
Ashes to 550 °C	%	3.4 ± 0.3	6.4 ± 0.6
Molar ratio H:C	///	0.7 ± 0.2	0.2 ± 0.1

Dry matter of plants was always higher in SR than in SB soil. Supply of inorganic P increased dry matter of plants, whereas P enriched biochar had no effect compared to unfertilized soils (Figure 3).

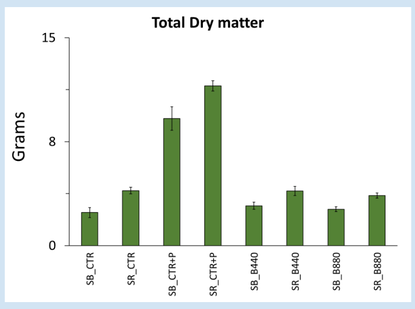


Figure 3: Effect of fertilizer treatments on total dry matter yield of sunflower plants. Values are mean ± standard deviation of four replicates.

The addition of inorganic P resulted in an increase in P uptake in both SB and SR. Interestingly, the introduction of P enriched biochar significantly increased P uptake with SB, either with B440 and B880 compared to the unfertilized control (Figure 4).

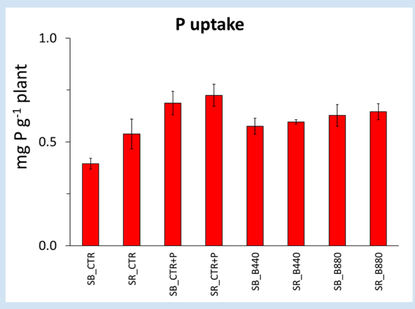


Figure 4: Effect of fertilizer treatments on P uptake of Sunflower plants. Values are mean ± standard deviation of four replicates.

Furthermore, the application of both B440 and B880 resulted in an increase in P uptake especially in SR soil compared to the unfertilized soil. The Fertilizer Replacement Value (FRV_P) showed that there were no significant differences between B440 and B880 in both SB and SR. The addition of P-enriched biochar contributed to a FRV ranging from 7 to 12% compared to the inorganic-P fertilized soils (Figure 5).

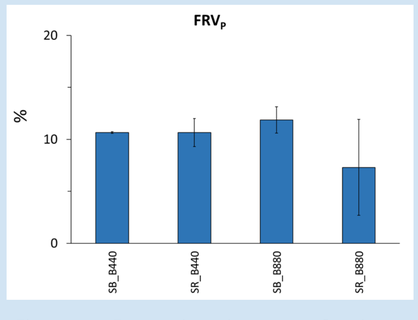


Figure 5: Phosphorus fertilizer replacement value on a P uptake basis for the two different P fertilizers. Values are mean ± standard deviation of four replicates.

RESULTS

The input of inorganic P increased the total extractable and available P (Olsen) post-harvest in both analysed soils (CTR+P). On the other hand, the input of P-enriched biochar did not influence any of the analysed P fractions compared to unfertilized soil (CTR) (Figure 1).

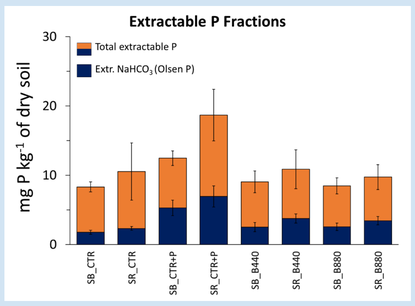


Figure 1: Effect of the different fertilizer treatments on Olsen P and Total Extractable P in soil after harvesting. Values are mean ± standard deviation of four replicates.

Alkaline phosphatase following the application of the inorganic fertilizer increased significantly only when applied to SR soil. The addition of P-enriched biochar did not influence the phosphatase activity compared to the unfertilized control (Figure 2).

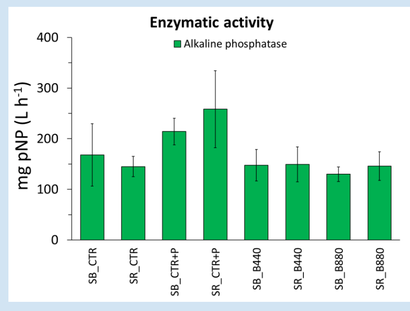


Figure 2: Effect of the different fertilizer treatments on the Alkaline Phosphatase. Values are mean ± standard deviation of four replicates.

CONCLUSIONS

- Inorganic P fertilizer increased total extractable and available P in both soils.
- P-enriched biochar had no effect on P fractions compared to unfertilized soil.
- Alkaline phosphatase increased significantly with inorganic P fertilizer in SR soil. P-enriched biochar did not influence phosphatase activity.
- Inorganic P increased plant dry matter, while P-enriched biochar had no effect.
- The introduction of P enriched biochar significantly increased P uptake with SB, compared to the unfertilized control.
- P enriched biochar contributed to a FRVP ranging from 7% to 12% compared to inorganic P-fertilized soils.

REFERENCES

1. Wang, K.; Du, M.; Wang, Z.; Liu, H.; Zhao, Y.; Wu, C.; Tian, Y. Effects of Bulking Agents on Greenhouse Gases and Related Genes in Sludge Composting. Bioresour. Technol. 2022, 344, 126270, doi:https://doi.org/10.1016/j.biortech.2021.126270.

2. Jiang, D.; Chu, B.; Amano, Y.; Machida, M.; Isiuku, B.O.; Enyoh, C.E.; Duru, C.E.; Ibe, F.C.; Jung, K.W.; Jeong, T.U.; et al. Adsorption and Desorption of Phosphate on Biochars. Rev. Environ. Sci. Biotechnol. 2020, 4, 381–395, doi:10.1016/j.biortech.2017.07.133.

3. Yang, H.; Ye, S.; Zeng, Z.; Zeng, G.; Tan, X.; Xiao, R.; Wang, J.; Song, B.; Du, L.; Qin, M.; et al. Utilization of Biochar for Resource Recovery from Water: A Review. Chem. Eng. J. 2020, 397, doi:10.1016/j.cej.2020.125502.

4. Almanassra, I.W.; Mckay, G.; Kochkodan, V.; Ali Atieh, M.; Al-Ansari, T. A State of the Art Review on Phosphate Removal from Water by Biochars. Chem. Eng. J. 2021, 409, 128211, doi:10.1016/j.cej.2020.128211.

5. Mannina, G.; Alduina, R.; Badalucco, L.; Barbara, L.; Capri, F.C.; Cosenza, A.; Di Trapani, D.; Gallo, G.; Laudicina, V.A.; Muscarella, S.M.; et al. Water Resource Recovery Facilities (Wrrfs): The Case Study of Palermo University (Italy). Water (Switzerland) 2021, 13, 1–19, doi:10.3390/w13233413.

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