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Effects of biochar addition into intensive-olive orchard soils under deficit irrigation

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Introduction

Agriculture challenge

- Growing population

Cultivation of olives

- Mediterranean region (7.7 million hectares)
- Spain (2.5 million hectares)

Olive sector concerns

- Super-intensive cultivation
- High requirement of irrigation
- Huge amounts of residual biomass

Valorisation of residual biomass → Biochar and compost → Which are the impacts on...?

- crop productivity
- soil properties
- plant physiology

Materials and methods

Organic amendments

Olive pomace biochar (OB)

Slow pyrolysis (15 min, 500 °C)
pH: 9.90±0.05
WHC: 78±15%
C and N contents: 56.3±1.7% and 1.73±0.03%
EC: 13,700±389 µS cm^{-1}

Green compost (GC)

Mixture of garden pruning wastes and pine wood shavings
pH: 8.30±0.20
WHC: 66±20%
C and N contents: 149±2% and 6.8±0.2%
EC: 1,184±177 µS cm^{-1}

Experimental setup

"La Hampa" experimental farm (Coria del Río, Spain, 37°17′ N, 6°3′ W)
2021
Total precipitation: 443.40 mm
Total irrigation: 752.39 mm

Materials and methods

Four treatments:

- Control plots with no amendment (**C; control**)
- Olive pomace biochar at dose of 40 t ha^{-1} (**OB**)
- Green compost at a dose of 40 t ha^{-1} (**GC**)
- OB+GC at a dose of 20 t ha^{-1} each (**OB+GC**)

Analysis performed

❑ Soil properties
pH, EC, WHC

❑ Soil humidity and resistance to penetrability at field

❑ Physiological status of olive trees
Midday stomatal conductance (g_s), net photosynthesis rate (A_N) and maximum rate of electron transport (ETRmax)

❑ Olive and oil productivity per tree

Results and discussion

(no differences below 10-20 cm, data not shown)

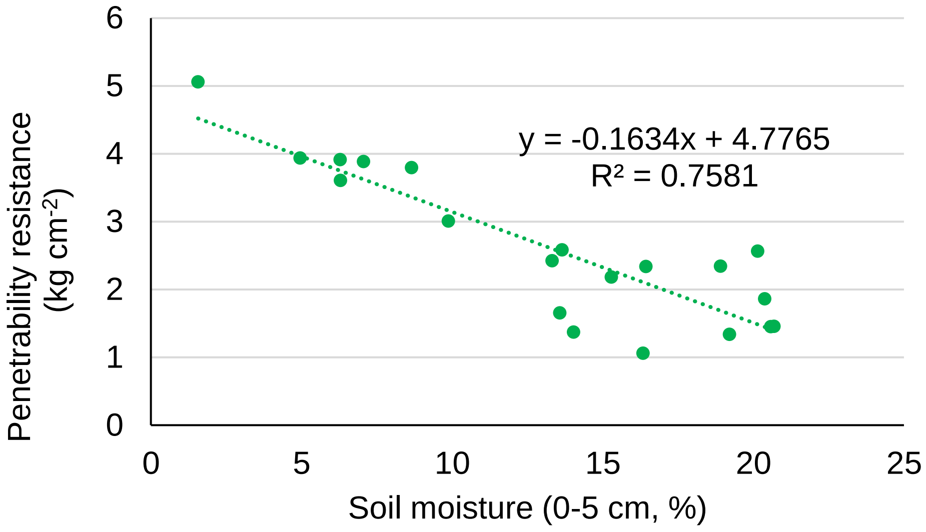
Effects on soil properties

	Sample depth	Day of year	Month	Treatments C	OB+GC	GC	OB
pH (1:5)	0-5 cm	118	April	7.6±0.5^{c}	9.4±0.1^{b}	8.1±0.2^{c}	9.7±0.4^{a}
		159	June	7.7±0.1^{c}	9.4±0.0^{b}	7.4±0.0^{d}	9.9±0.0^{a}
		251	September	8.2±0.0^{c}	9.5±0.0^{a}	8.3±0.0^{c}	9.3±0.0^{b}
		287	October	8.9±0.1^{b}	10.1±0.1^{a}	8.6±0.0^{c}	9.1±0.0^{b}
	5-10 cm	118	April	8.1±0.2^{b}	9.1±0.2^{a}	8.2±0.2^{b}	9.3±0.4^{a}
		159	June	7.7±0.1^{d}	8.1±0.1^{c}	8.3±0.1^{b}	9.7±0.0^{a}
		287	October	9.1±0.1^{c}	10.1±0.1^{a}	9.4±0.0^{b}	9.0±0.0^{c}
EC [μS cm^{-1}] (1:5)	0-5 cm	118	April	191±56^{c}	743±330^{ab}	450±167^{b}	754±211^{a}
		159	June	227±81^{d}	475±39^{c}	1242±22^{a}	789±33^{b}
		251	September	1343±12^{c}	1798±102^{b}	2330±42^{a}	1185±49^{c}
		287	October	904±13^{c}	1964±12^{a}	1193±6^{b}	473±30^{d}
	5-10 cm	118	April	167±32^{c}	307±109^{ab}	276±112^{b}	353±110^{a}
		159	June	431±21^{a}	180±10^{b}	309±85^{ab}	435±26^{a}
		287	October	305±25^{b}	478±2^{a}	274±7^{b}	217±4^{c}
WHC (%)	0-5 cm	118	April	66.9±5.0^{a}	50.6±4.6^{b}	62.6±6.2^{a}	57.0±9.0^{ab}
		159	June	27.1±3.1^{b}	67.9±11.0^{a}	55.5±23.8^{ab}	59.6±14.8^{ab}
		251	September	64.8±11.6^{a}	61.9±5.3^{a}	83.5±9.4^{a}	52.7±2.5^{a}
		287	October	53.4±0.5^{ab}	84.0±21.5^{a}	45.6±4.9^{b}	71.8±8.6^{ab}
	5-10 cm	118	April	63.6±10.3^{a}	49.6±5.0^{a}	52.7±8.9^{a}	59.8±4.8^{a}
		159	June	62.9±10.4^{a}	41.7±8.9^{a}	55.9±14.5^{a}	57.0±14.1^{a}
		287	October	53.8±9.0^{b}	78.5±5.3^{a}	48.6±1.8^{b}	67.8±13.2^{ab}

Different letters indicate significant differences between treatments in the same sampling ($p<0.05$).

Results and discussion

Effects on soil properties



Soil moisture and penetrability (in situ parameters) of unamended and amended soils

	Sample depth	Season	Treatments			
			C	OB+GC	GC	OB
Soil moisture (%)	0-5 cm	Spring	7.1 ± 6.5^{c}	13.6 ± 6.0^{b}	13.4 ± 6.7^{b}	15.5 ± 5.4^{a}
		Summer	11.6 ± 7.8^{b}	20.3 ± 0.3^{a}	19.9 ± 1.8^{a}	20.1 ± 1.7^{a}
		Autumn	16.7 ± 5.5^{a}	19.9 ± 1.2^{a}	18.6 ± 3.3^{a}	19.0 ± 2.6^{a}
		Winter	11.2 ± 7.9^{c}	12.2 ± 6.9^{bc}	17.5 ± 5.3^{ab}	18.7 ± 2.6^{a}
	5-10 cm	Spring	11.5 ± 6.2^{b}	17.0 ± 3.3^{a}	17.3 ± 2.9^{a}	18.0 ± 2.3^{a}
		Summer	17.1 ± 4.8^{b}	20.6 ± 0.1^{a}	20.6 ± 0.2^{a}	20.2 ± 3.0^{a}
		Autumn	19.5 ± 2.2^{a}	$20.5.\pm0.2^{a}$	20.1 ± 1.3^{a}	20.5 ± 0.2^{a}
		Winter	17.3 ± 3.8^{a}	16.1 ± 4.0^{a}	20.4 ± 0.3^{a}	20.4 ± 0.2^{a}
Penetrability (kg cm^{-2})		Spring	3.8 ± 1.5^{a}	2.5 ± 1.5^{b}	2.6 ± 1.5^{b}	2.0 ± 1.1^{c}
		Summer	4.0 ± 1.9^{a}	1.7 ± 1.1^{b}	1.8 ± 1.0^{b}	1.3 ± 0.8^{b}
		Autumn	3.5 ± 1.7^{a}	1.2 ± 0.3^{c}	1.8 ± 0.9^{b}	1.5 ± 0.9^{b}
		Winter	4.7 ± 1.6^{a}	2.0 ± 1.0^{c}	3.7 ± 1.7^{b}	2.6 ± 1.2^{c}

Different letters indicate significant differences between treatments in the same sampling ($p<0.05$).

The higher the moisture, the lower the resistance to penetrability.

Biochar (40 T ha^{-1}) was the most effective in increasing soil moisture.

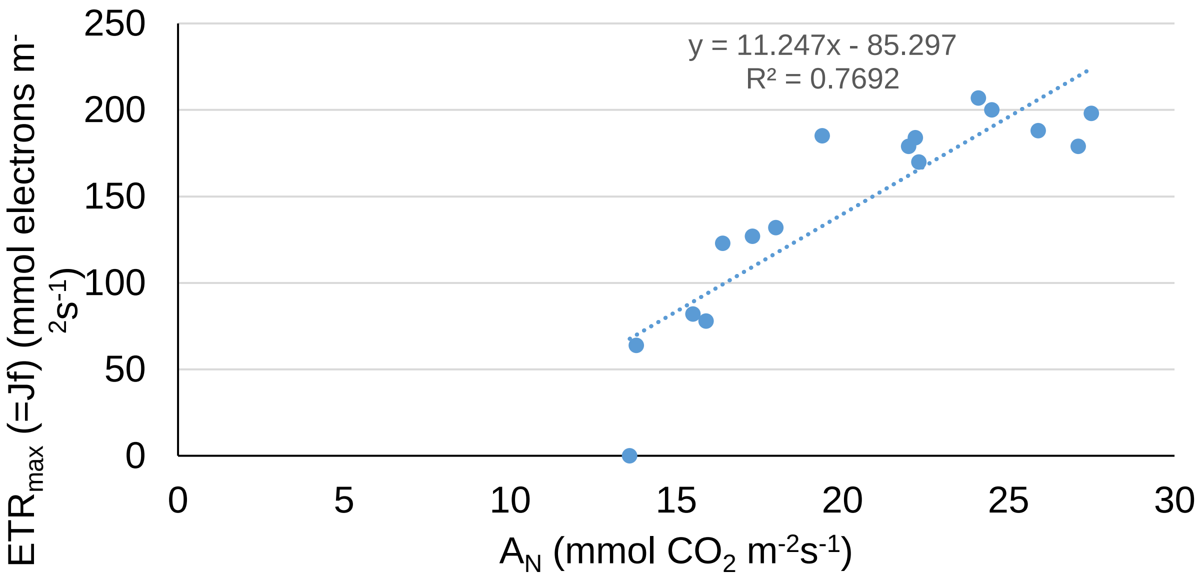
Soil moisture of amended soils increased during the low irrigated periods.

Results and discussion

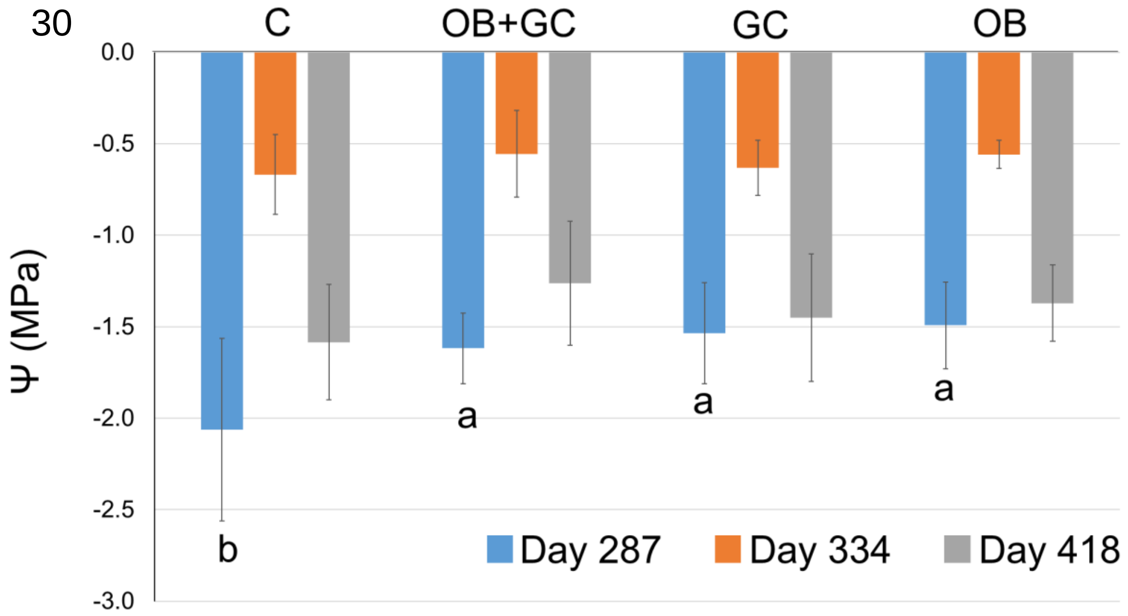
Effects on plant physiology

Maximum rate of electron transport (ETR_{max}) was positively correlated with the net photosynthesis rate (A_N).

All treatments



Physiological markers of plant stress of the olive trees from the OB plots improved at the harvesting time.



Results and discussion

Productivity: Olive yields and oil per tree

Treatment	Production of olives (kg per tree)	Humidity of olives (% w/w)	Total fat (% w/w)	Oil free acidity	Production of olive oil (kg per tree)
C	10.1±0.4a	61.7±0.3a	15.1±0.2a	0.31±0.02	1.52
GC	10.5±0.3a	61.0±0.4a	15.8±0.4a	0.35±0.03	1.66
OB+GC	10.8±0.2a	61.7±0.3a	15.2±0.2a	0.31±0.03	1.64
OB	11.9±0.3b	63.9±0.5b	14.1±0.3b	0.29±0.04	1.68

Different letters indicate significant differences between treatments for the same parameter ($p<0.05$).

Conclusions

The application of organic amendments with high porosity and water retention capacity:

- modified the soil physical properties, reducing soil compaction
- Improved the water status of olive trees in super-intensive olive trees plantations
- increased olive yields about 15%, although net olive oil production per tree was maintained

This work shows that there exists a sustainable way to significantly reduce the irrigation needs.

Thank you for your attention

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