Bell pepper growth responses and soil environmental changes to humic substances and deficit irrigation in controlled environments

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Introduction

Organic matter-derived soil amendments containing humic substances (HS) have a functional role to improve plant growth and soil quality, but their response to water deficit stress is unknown, particularly in vegetable crops.

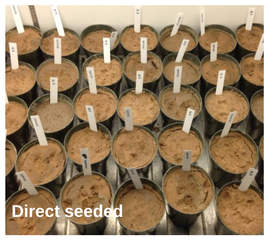
Objective

To assess the impacts of lignite-derived HS on bell pepper and soil biota growth and evaluate their potential mitigative effects under water deficit stress.

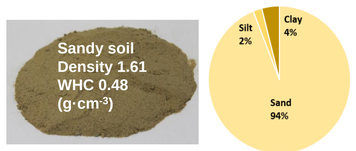
Materials and Methods

Plant material: Bell pepper (*Capsicum annuum* cv. Revolution)

Growth environments



Growth chamber (16 h/day, 8 h/night)
- Ramping temperature: 20 to 28 °C
- Ramping light intensity: 0 to 500 µmol m^{-2} s^{-1}

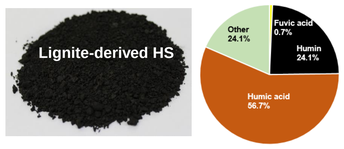


Greenhouse
- Average temperature: 29.4°C
- Average daily light integral: 11.0 mol·m^{-2}·day^{-1}

Treatments

a. Soil amendment (SA)

- Control
- HS (0.5 kg·m^{-2})



b. Irrigation (IR)

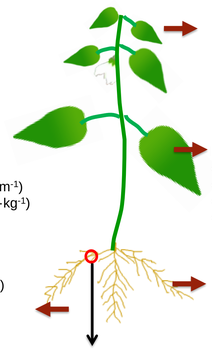
- Severe stress, 20% WHC *
- Mild stress, 40% WHC
- Moderate stress, 60% WHC
- Well-watered, 80% WHC

* WHC: water holding capacity

Growth chamber
- Start: 4 weeks after direct seeding
- End: 10 weeks after direct seeding

Greenhouse
- Start: 1 week after transplanting
- End: 4 months after transplanting

Measurements



Plant morphology
- Plant height (**PH**, cm)
- Stem diameter (**SD**, mm)
- Above-ground dry weight (**AGDW**, g)

Plant physiology
- Photosynthesis ***Pn*** (µmolCO_2·m^{-2}·s^{-1})
- Stomatal conductance g_s (molH_20·m^{-2}·s^{-1})
- Transpiration ***E*** (mmolH_20·m^{-2}·s^{-1})
- Chlorophyll content index (**SPAD**)

Root traits
- Root dry weight (**RDW**, g)
- Root length (**RL**, m)
- Root surface area (**RSA**, cm^2)
- Root average diameter (**RAD**, mm)

Soil basic analysis (cores)
- Soil pH (**pH**)
- Electrical conductivity (**EC**, µmhos·cm^{-1})
- Nitrate-nitrogen content (**NO_3-N**, mg·kg^{-1})
- Available phosphorus (**P**, mg·kg^{-1})
- Available potassium (**K**, mg·kg^{-1})

Soil microbial analysis (cores)
- Soil respiration (**SR**, CO_2-C, mg·kg^{-1})
- Active bacteria (**AB**, µg·g^{-1})
- Total bacteria (**TB**, µg·g^{-1})
- Active fungi (**AF**, µg·g^{-1})
- Total fungi (**TF**, µg·g^{-1})

Data analysis: ANOVA; multiple comparisons of means: LSD under α = 0.05 in SAS

Results

Table 1: Time-course effects (*P*-values) of HS on bell pepper **morpho-physiological traits** in two controlled environments

Environment	Time	PH	SD	SPAD	*Pn*	g_s	*E*
GC sandy	Week 2	< 0.001 +	< 0.001 +	< 0.001 +	0.742	**0.047 -**	0.059
	Week 4	< 0.001 +	< 0.001 +	0.092	0.811	0.079	0.309
GH sandy	Month 1	0.002 +	0.015 +	0.353	**0.001 -**	**< 0.001 -**	**0.006 -**
	Month 2	0.696	0.193	0.284	0.767	0.755	0.522
	Month 3	0.725	0.021 +	0.738	0.710	0.283	0.704
GH clay	Month 1	0.071	0.027 -	0.008 -	**0.011 -**	**0.037 -**	0.077
	Month 2	0.065	0.633	0.223	**0.016 -**	**0.036 -**	**0.030 -**
	Month 3	0.336	0.576	0.843	0.537	0.679	0.864

Time shown as biweekly intervals in the growth chamber (GC) and monthly in the greenhouse (GH) after imposing irrigation levels; + indicates significantly increased, - indicates significantly decreased of HS compared to control at α = 0.05, according to LSD test.

Stomatal conductance (g_s)					
		GC sandy	GH sandy	GH clay	GH clay
SA	**IR**	Week-2	Month-1	Month-1	Month-2
Control	20%	0.38	0.07	0.22	0.34
HS	20%	0.28	0.05	0.13	0.63
Control	40%	0.24	0.42	0.16	0.76
HS	40%	0.12	0.24	0.12	0.37

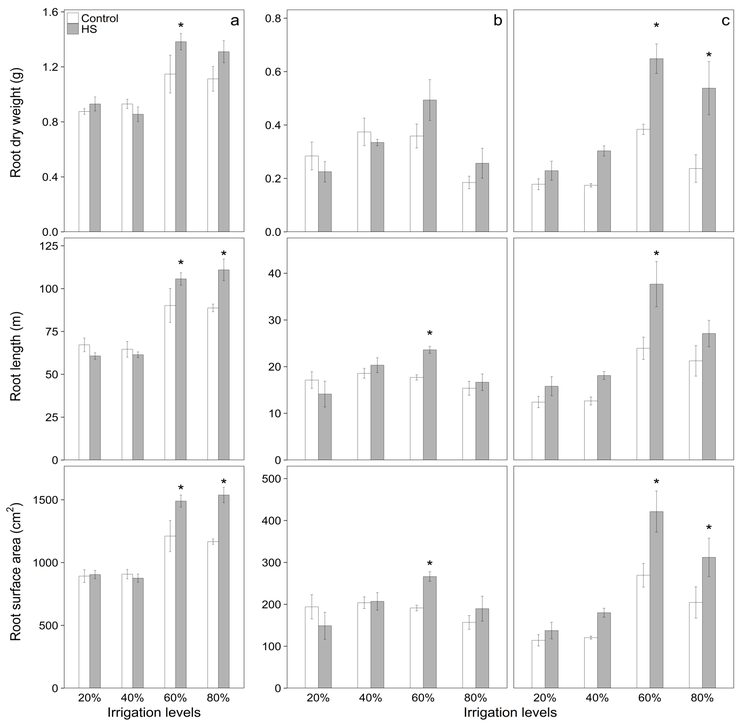


Figure 1: Bell pepper **root traits** (± standard error) in the growth chamber with sandy soil (a), and greenhouse with sandy (b) and clay soil (c) in response to soil amendment and irrigation levels. * indicates significantly differences between HS and control at α = 0.05, according to LSD test.

Table 2: Final **chemical and microbial properties of sandy and clay soils** as affected by soil amendment (SA) and irrigation (IR) treatments in greenhouse (GH) environment.

Environment			EC	NO_3-N	SR	AB	TB	AF	TF
GH sandy	SA	Control	271	15.0	4.17	27.12	**1020 b ***	6.71	433
		HS	265	10.2	4.86	28.68	**1140 a**	7.56	388
	P	SA	0.796	0.263	0.357	0.565	0.046	0.577	0.483
		IR	< 0.001	< 0.001	0.007	0.580	0.881	0.082	0.299
		SA × IR	0.019	0.062	0.104	0.197	0.202	0.869	0.649
GH clay	SA	Control	**941 b**	**57.2 b**	82.72	35.95	**828 b**	13.71	243 a
		HS	**1182 a**	**96.5 a**	80.01	33.33	**1191 a**	13.22	168 b
	P	SA	0.004	0.015	0.849	0.261	0.005	0.880	0.014
		IR	< 0.001	< 0.001	0.031	0.035	0.513	0.177	0.260
		SA × IR	0.154	0.095	0.723	0.289	0.245	0.608	0.421

Discussion

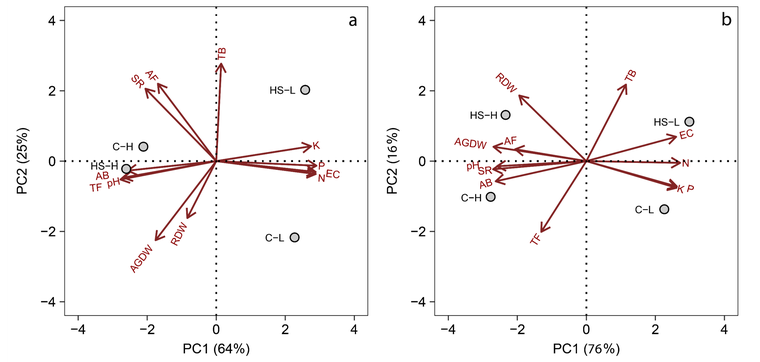
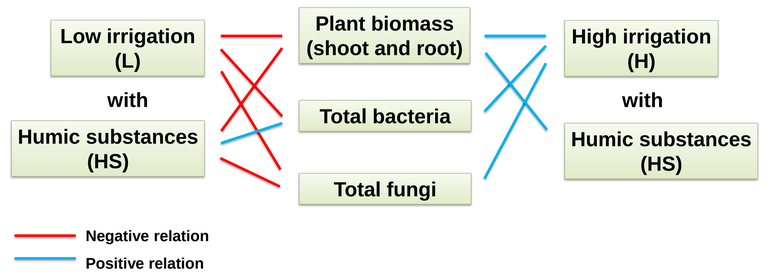
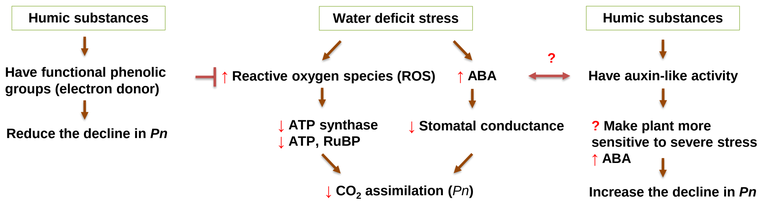


Figure 2: Principal component analysis (PCA) depicting the relationships between selected variables (plant, soil, microbial) and treatment factors in the greenhouse with sandy (a) and clay soil (b). Treatment factors were displayed by filled grey circles: the first letter corresponds to control (C) or humic substances (HS), the second letter corresponds to high irrigation level (H) or low irrigation level (L).



Leaf gas exchange hypothesis



Conclusions

Deficit irrigation
- Severe and mild stress decreased plant growth
- Moderate stress maintained or promoted plant growth

Humic substances
- Mitigated severe and mild stress by quickly reducing leaf gas exchange
- Improved plant shoot and root growth under moderate water stress
- Modulated soil bacteria and fungi population

References

Aeschbacher, M., Graf, C., Schwarzenbach, R. P., Sander, M. (2012): Antioxidant properties of humic substances. Environmental science & technology 46, 4916-4925.
Lawlor, D. W., Tezara, W. (2009): Causes of decreased photosynthetic rate and metabolic capacity in water-deficient leaf cells: a critical evaluation of mechanisms and integration of processes. Annals of botany 103, 561-579.
Tezara, W., Mitchell, V., Driscoll, S., Lawlor, D. (1999): Water stress inhibits plant photosynthesis by decreasing coupling factor and ATP. Nature 401, 914.

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