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Granular organic hydrosorbents increase water retention and resistance of boxwood seedlings

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Abstract: Sufficient available water in the soil is critical for plant growth, especially soon after planting. Water absorbed by organic hydrosorbents has the potential to reduce drought stress after planting and improve seedling survival. This research evaluates the effectiveness of granular organic hydrosorbents (GOH) in increasing soil-water retention in a pot experiment with boxwood (*Buxus sempervirens* L.) seedlings. The leaf chlorophyll content was also evaluated to determine plant growth. The following fertilisers were used: GOH 1 comprised 50% biogas products and 50% wheat straw, and GOH 2 combined post-harvest grain, legume and oilseed residues. The fertilisers were applied to the bottom of the pot or mixed with the soil. Both types doubled the initial water retention compared to the control. While the control water retention dropped below zero after 18 days without watering, retention in the fertilised treatments ranged from 0.5 to 0.76 L. Re-watering part of the trial after the 18 days then induced increased retention to the initial levels in all treatments and the control. However, the fertilised plant's water retention was up to half a litre greater than in the control when the 62-day experiment ended. The effect of GOH application was also manifested in the chlorophyll content. In the no watering mode, the chlorophyll content was, on average, 20% and 13% higher in the treatments with GOH 1 and GOH 2 than in the control. In the watering regime, the application of GOH 1 and GOH 2 increased the chlorophyll content by an average of 31% and 26%, respectively. Finally, these trials established that the GOH applications significantly delayed boxwood-seedling drying and increased their water retention and chlorophyll content in unwatered and re-watered plants.

Keywords: chlorophyll content; organic fertilisers; pot experiment; seedling survival; water stress

Global warming is the most important manifestation of climate change worldwide (IPCC 2018). Concurrently, rainfall levels are significantly decreasing, and dry periods and desert formation are increasing (IPCC 2019). This combination negatively affects agricultural plant production and the growth of other cultivated and wild plant species (Allakonon, Akponikpè 2022). One method of reducing the negative effects of global warming is to retain a sufficient amount of water in the soil, especially in plant

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root systems. The application of organic matter, such as compost, is the most widespread way of increasing soil water-holding capacity and retention (Minasny, McBratney 2018; Bondì et al. 2022). For example, de Sosa et al. (2023) reported that composted olive residues increased water retention and olive production by 30% to 41%. The application of different amounts of compost was tested on three different soil textures. Results suggested that soil texture influenced compost's hydrology benefits and that compacted soils had limited beneficial effects (Kranz et al. 2023). Water retention benefits also depend on the mulching materials applied and their depth in the soil. The moisture content under green waste compost surpassed that of bark. The deeper this mulch, the greater the moisture retention beneath it (Pickering et al. 1998).

Many researchers also examined hydrogels. These are super-absorbent synthetic polymers employed to improve the hydro-physical soil properties and water filtration through the soil. Those used in agriculture are composed of polysaccharides, polyacrylic acid and polyacrylamide or potassium acrylate (Crous 2016). It was demonstrated that the addition of acrylamide and acrylic acid hydrogels improved soil water retention in sandy loam and clay soils. These also delayed the wilting of cultivated seedlings by 4–5 days compared to controls (Akhter et al. 2004). Moreover, the addition of biochar enhanced hydrogel water retention (Doğaroğlu 2023).

However, the greatest disadvantage of synthetic hydrogels is their prolonged or zero biodegradation. It is, therefore, appropriate to use additives that decompose more easily in the soil. These include hydrogels based on starch, cellulose and pectin polysaccharides (Guilherme et al. 2015). Many studies have illustrated the effectiveness of hydrogels based on natural materials. For example, a hydrogel based on alkaline lignin showed a swelling ratio of 1.092% and a significant increase in soil water retention, while plant available water capacity was unaffected (Adjuik et al. 2023). The application of 4 g/m^2 starch-based hydrogel increased wheat yield by 41% at 75% irrigation compared to the control with 100% irrigation (El-karamany et al. 2019). Cellulose-based hydrogel increased the germination percentage and the average number of wheat leaves by 22%. The germination percentage increased to 100% after 21 days, and the water uptake improved by 95% (Qin et al. 2022). Further improvement incorporated residual wheat straw and wood sawdust into the hydrogel, which increased the swelling ratio by 300% and water retention by 10% (Cruz Fabian et al. 2023).

Finally, and importantly, including wood-derived biochar improved hydrology in the bio-retention systems and enhanced plant root growth (Akpinar et al. 2023), leading to an increase in saturated hydraulic conductivity and water retention over time. The most pronounced effects were in high-percentage sand media without mulch or compost. Thus, biochar has similar effects to compost without the risk of undesired nutrient leaching. Researchers further identified that biochar pellets were superior to biochar powder in retention efficiency. The pellets increased water retention by 20% in sandy soil compared to the control, but the increase was only approximately 4% more than in the control with biochar powder form (Bartocci et al. 2017). Therefore, pelletising organic materials increases benefits to soil conditions and water retention in the plant root zone because the pellet structure improves soil water retention and drainage.

Organic hydrosorbents are promising and poorly-researched water retention agents. These are based on dry digestate from a biogas plant and plant residues. Their granular form provides simple application during planting and allows for easy logistics and storage. However, these have less than 10% water content and must be stored in dry-covered storage areas (Šulc et al. 2020).

Herein, we examined the effects of special granular hydrosorbents on water retention in soil and chlorophyll content in leaves of common boxwood (*Buxus sempervirens* L.) seedlings, which was chosen as an experimental plant. This is a slow-growing evergreen shrub or small tree up to 9 m in height. It originates in the Mediterranean, where it occurs mainly in drier locations on limestone substrate and in the undergrowth of mixed forests. It is often cultivated in the Czech Republic as an ornamental shrub and used for hedges. The boxwood species was chosen based on a requirement from horticulture practice due to its popularity with growers and moderate growing conditions. Due to its resistance to pollution, boxwood is also recommended as suitable for urban and industrial areas (Hillier, Coombes 2007).

We hypothesise that (*i*) adding a hydrosorbent to the soil increases water retention, (*ii*) the water retention ability will be repeated after drying and re-watering, and (*iii*) the hydrosorbents will support plant seedling survival during drought.

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MATERIAL AND METHODS

Pot growing experiment. The following two types of granular organic hydrosorbent (GOH) were used for testing in the pot cultivation trial. GOH 1 pellets combined 50% biogas products and 50% wheat straw, and the GOH 2 pellets comprised post-harvest residues of grains, oilseeds and legumes. Both GOH pellets were manufactured in 400 kg lots, and each pellet was 10 mm in diameter (Figures 1 and 2). The basic elements content is highlighted in Table 1.

The GOH experiment was conducted in a vegetation hall without controlled temperature conditions from March 13th to May 15th. The experimental plants were cultivated in five-litre pots with holes in the bottom. A substrate consisting of garden soil and coarse-grained sand was mixed into the pots in a ratio of 1 : 1. The garden soil used was heavy, clay-loamy soil. The final mixed substrate was classified as medium-heavy loam soil, and its soil characteristics are shown in Table 2.

Figure 1. Pellets made from biogas products and wheat straw (GOH 1 – granular organic hydrosorbent number 1)

Figure 2. Pellets made from crop residues (GOH 2 – granular organic hydrosorbent number 2)

The experiment comprised the following GOH 1 and GOH 2 treatments:
1. controls without GOH;
2. application of GOH mixed with substrate (mix);
3. pot-bottom application of GOH (bottom).

The experiment proceeded with 500 g of GOH added to the pots. The bottom pots had pellets poured onto approximately 5 cm of substrate. The mix pots contained a third of the 400 g pellets on the pot base, covered with substrate and then poured twice into the substrate profile. The top layer comprised only the substrate. Each treatment was performed in 10 repetitions. The treatments of the experiment were as follows: control – had only substrate; GOH 1_mix; GOH 1_bottom; GOH 2_mix; GOH 2_bottom.

Table 1. The main characteristics of granular organic hydrosorbents used in the pot experiment

Parameter	GOH 1	GOH 2
Dry matter (%)	91.7	90.8
C	43.9	41.1
N	0.97	2.14
P	0.16	0.36
K	2.06	1.92
Mg	0.17	0.25
Ca	0.73	1.85
S	0.18	0.36

Element contents are stated in % in dry matter
GOH 1 – granular organic hydrosorbent number 1; GOH 2 – granular organic hydrosorbent number 2; C – carbon; N – nitrogen; P – phosphorus; K – potassium; Mg – magnesium; Ca – calcium; S – sulphur

Table 2. Soil characteristics of the substrate used

Soil characteristics	
Clay separate (< 0.002 mm) (%)	22.65
Silt separate (0.002–0.05 mm) (%)	37.62
Sand separate (0.05–2.0 mm) (%)	39.74
Textural class of the soil texture triangle	loam
Dry matter (%)	93.6
C_{tot} (%) in dry matter	2.72
N_{tot} (%) in dry matter	0.12
pH (H_2O)	6.87

C_{tot} – total organic carbon; N_{tot} – total organic nitrogen

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The 20–30 cm high boxwood seedlings of the 'Pyramidalis' variety were pre-grown in planting pots and then transplanted to the experimental pots according to individual treatments. The seedlings for the experiment had the same genotype, i.e. they were obtained from vegetative propagation from one mother plant by cuttings.

Water retention measurement. The pots were weighed immediately after seedling-planting and placed in a water bath for 30 minutes. They were then placed on wooden grates, left to drain for 2 h, and weighed. The initial water retention was calculated from the before-and-after watering weights.

The planted pots were left on the grids in the vegetation hall for 18 days without watering, and ongoing weights were taken on days 10 and 18. The residual water retention was calculated from the weight differences during the pots' drying and before watering. After 18 days, when the pots without added GOH had reached the predetermined 8.4% experimental humidity, half the planted pots were replaced in the water bath to monitor water retention. Water retention was measured by weighing the pots on days 8, 15, 24, 28, 35, 40 and 44 after re-watering. The conditions for growing pot plants were the same for all treatments throughout the experiment, and sensors monitored air temperature (data logger TMS 4, TOMST, Czech Republic). The radiation data were taken from the agrometeorological station of the Crop Research Institute in Prague – Ruzyně, approximately 300 m from the experiment. The temperature and radiation records for the entire experiment are shown in Figure 3.

Chlorophyll content measurement. Leaf chlorophyll content provided an indicator of the vitality of the plants under stress and was monitored at certain cultivation intervals. Chlorophyll content was determined by the non-destructive CCM-300 Chlorophyll Content Meter (Opti-Science Inc., USA). The instrument assesses the fluorescence ratio at 735/700 nm wavelength and determines chlorophyll content (Gitelson et al. 1999). The result is presented as chlorophyll fluorescence ratio (CFR) or as the relative chlorophyll content in mg/m^2.

Our chlorophyll content evaluation was performed as follows: (*i*) twice before re-watering, on the 10th and 18th experimental days, and (*ii*) five times after re-watering, on the 8th, 15th, 28th, 38th, and 44th days. This content was measured on 5–6 leaves on each seedling from different sides of the plant.

Statistical analyses. The basic statistical values and analysis of variance (ANOVA) were performed with Statistica version 14.0.0.14 software (TIBCO Software Inc., USA). Tukey HSD tests at $\alpha = 0.05$ were then employed to determine homogeneous groups.

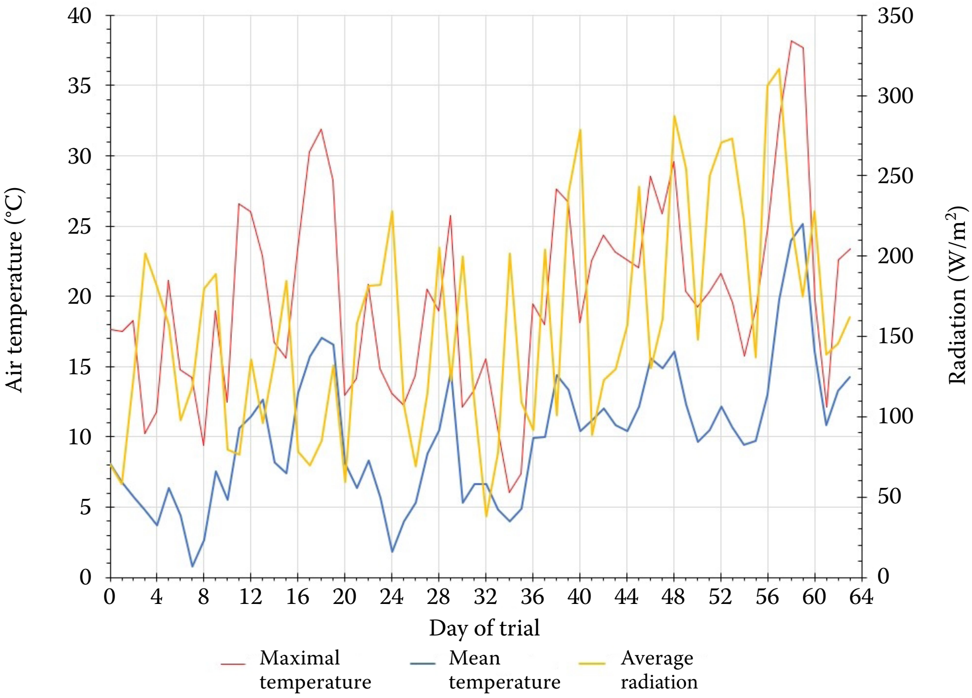

Figure 3. Air temperatures during the experiment in the vegetation hall and average daily radiation measured in the agrometeorological station Prague – Ruzyně

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RESULTS AND DISCUSSION

Water retention. The unfertilised control had 0.74 L initial water retention, ranging from 1.25 L for GOH 1_bottom to 1.56 L for GOH 2_mix. Significant differences between the treatments were evident after 18 days without watering. While the retention dropped to –0.01 L in the control, it ranged from 0.51 L in GOH 1_bottom to 0.76 L in GOH_2 mix in the fertilised treatments. Water retention values returned to the initial level after re-watering for all treatments, including the control, which registered 0.72 L. The retention values even increased slightly for some fertilised treatments. This was greatest for GOH 1_mix, where retention after re-watering increased by 0.26 L compared to the initial retention. The highest retention was recorded for GOH 2_mix at 1.68 L (Figure 4). The effectiveness of the GOH application on water retention is comparable to the effect of compochar, which mixes compost and biochar. This mix increased the volumetric water content 2-to-3 times more than the control value (Soudek et al. 2024).

Figures 5 and 6 show the course of water retention during the experiment, and Figure 5 depicts the non-watered part of the experiment. A gradual decrease is evident in all treatments, the most in the control, and the decrease is greatest in the control, where the water retention attained negative values following 18 days without watering (Figure 5). This decrease ceased at –0.61 L at the end of the experiment. In contrast, water retention in the fertilised treatments only fell below zero after 53 days, and this was even longer for GOH 2_bottom at 58 days. The retention values for fertilised treatments ranged from –0.13 L for GOH 2_bottom to –0.22 L for GOH 2_mix after 62 days without watering.

Despite re-watering, a sharp drop in water retention to 0.04 L was recorded for the control after 8 days of watering, corresponding to the 26th day after the experiment commenced. This decrease then continued until –0.52 L at the end of the experiment. Therefore, the final retention of the re-watered control was comparable to the unwatered one. A slight gradual decrease also followed an initial steep retention decrease in the fertilised treatments. In contrast

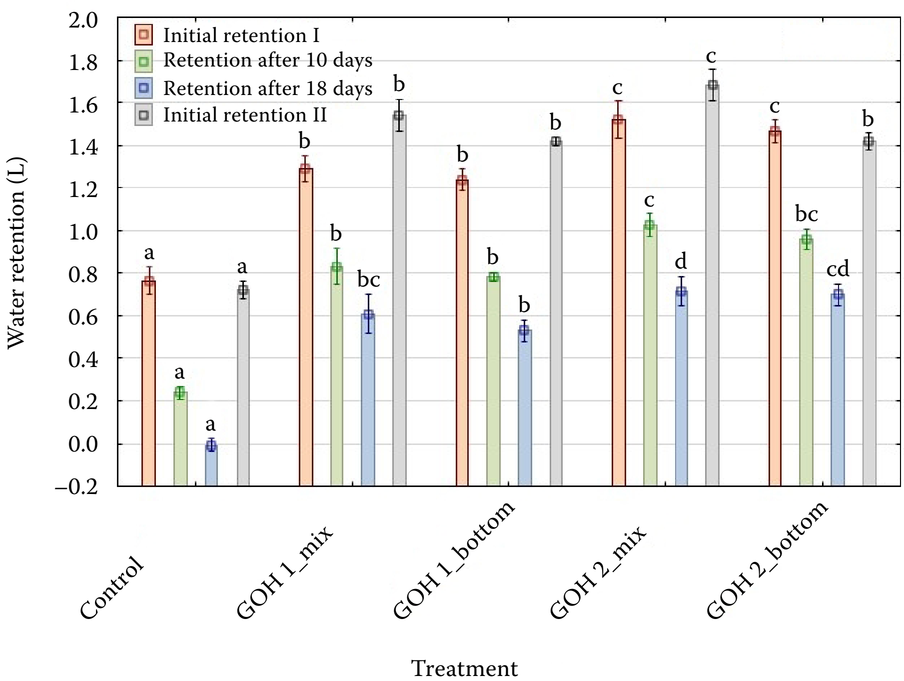

Figure 4. Water retention at the beginning of the experiment (initial retention I), after 10, 18 days and after re-watering (initial retention II)

GOH 1_mix – granular organic hydrosorbent number 1 mixed with substrate; GOH 1_bottom – granular organic hydrosorbent number 1 applied to the pot bottom; GOH 2_mix – granular organic hydrosorbent number 2 mixed with substrate; GOH 2_bottom – granular organic hydrosorbent number 2 applied to the pot bottom

[a–d]different lowercase letters indicate significant differences between treatments at α = 0.05 for each measurement separately (Tukey HSD test); mean ± standard deviation

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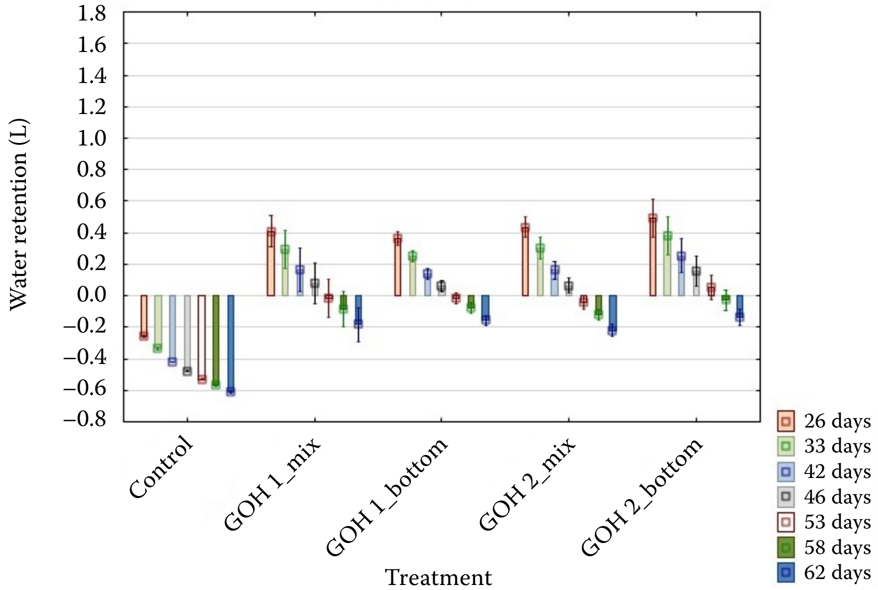

Figure 5. Water retention course during the no watering mode

GOH 1_mix – granular organic hydrosorbent number 1 mixed with substrate; GOH 1_bottom – granular organic hydrosorbent number 1 applied to the pot bottom; GOH 2_mix – granular organic hydrosorbent number 2 mixed with substrate; GOH 2_bottom – granular organic hydrosorbent number 2 applied to the pot bottom; mean ± standard deviation

to the no watering mode, the retention dropped below zero only at the end of the experiment and ranged from –0.01 L for GOH 1_mix to –0.12 L for GOH 2_bottom (Figure 6).

The GOH potential to increase water retention and chlorophyll content is comparable to biochar application (Sattar et al. 2019). In addition, GOH has a significant fertilising impact due to its carbon and gen-

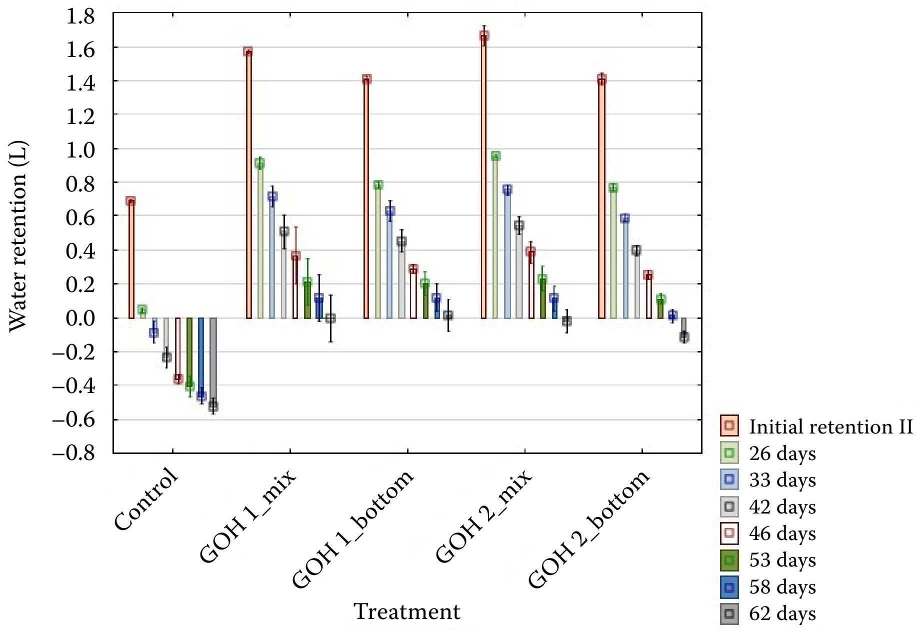

Figure 6. Water retention course in the re-watering period

GOH 1_mix – granular organic hydrosorbent number 1 mixed with substrate; GOH 1_bottom – granular organic hydrosorbent number 1 applied to the pot bottom; GOH 2_mix – granular organic hydrosorbent number 2 mixed with substrate; GOH 2_bottom – granular organic hydrosorbent number 2 applied to the pot bottom; initial retention II – water retention after re-watering; mean ± standard deviation

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eral nutrient content. The enhanced water retention benefits of pelleted fertilisers are confirmed (Bartocci et al. 2017). Moreover, their easier handling and storage provide significant advantages over powder biochar. The organic hydrosorbent properties could be boosted by adding biochar to the post-harvest residues and biogas products during pelletisation. The potential of GOH 1 to improve soil properties was investigated in a 3-year field trial. It was found that the application of GOH 1 at a dose of 40 t/ha increased the stability of soil aggregates (SAS) by 14.8% compared to the untreated plots. In contrast, the positive effect of powder biochar application on SAS and other soil physical properties was not proven in this field trial (Mayerová et al. 2023).

Chlorophyll content. Measurement of chlorophyll fluorescence provides a rapid, non-destructive method of assessing plant survival in drought (Nemeskéri, Helyes 2019), and a methodology study confirmed the correlation between chlorophyll fluorescence and relative plant water content (Woo et al. 2008). It was confirmed that the stress level of cultivated crops can be determined by measuring the chlorophyll content (Mafakheri et al. 2010).

The chlorophyll content in the boxwood plants was significantly influenced by the treatments, irrigation regimes and their interactions (Table 3). The average chlorophyll content in the control plant was lower than in all the fertilised bushes. This was evident in both control watering regimes, with 253.2 mg/m^2 chlorophyll content in the re-watering regime and 264.4 mg/m^2 in the no watering mode (Figure 7). In contrast, the greatest difference between irrigation modes was recorded for the GOH 2_mix treatment, which had the highest 384.6 mg/m^2 average chlorophyll content in the re-watering re-

Table 3. Significance of the effects of treatment and irrigation regimes and their interaction on chlorophyll content (mg/m^2) revealed by multi-factorial ANOVA

Statistic	Treatment	Irrigation mode	Treatment × mode
P-value	0.00000	0.00118	0.00000
F-value	14.517	10.59	8.3029

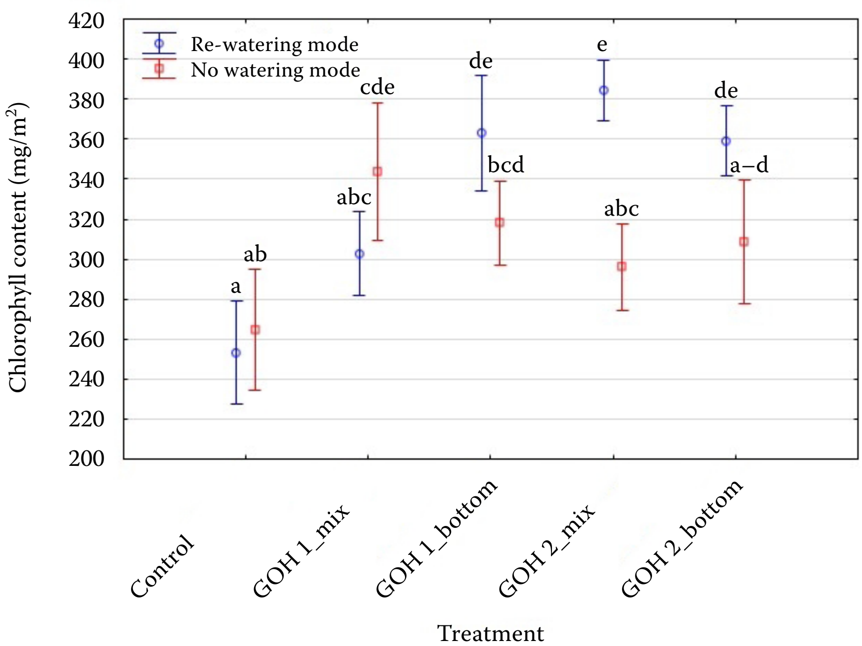

Figure 7. The average chlorophyll content values for all measurements

GOH 1_mix – granular organic hydrosorbent number 1 mixed with substrate; GOH 1_bottom – granular organic hydrosorbent number 1 applied to the pot bottom; GOH 2_mix – granular organic hydrosorbent number 2 mixed with substrate; GOH 2_bottom – granular organic hydrosorbent number 2 applied to the pot bottom

[a–e]different lowercase letters indicate significant differences between treatments and watering modes at α = 0.05 (Tukey HSD test); mean ± confidence interval

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gime and the lowest 296.1 mg/m^2 chlorophyll content without watering. The GOH 1_mix treatment is further interesting because the 343.8 mg/m^2 chlorophyll recorded content in the no watering mode is greater than the 302.8 mg/m^2 registered in the re-watered treatment. This difference, however, was not statistically significant.

Significant correlation between chlorophyll content and water retention was confirmed only for values at the end of the experiment, with r = 0.498 correlation coefficient at P = 0.011.

Figures 8 and 9 depict that the individual fertilised treatments differed in response to the irrigation regime and in response to the course of veg-

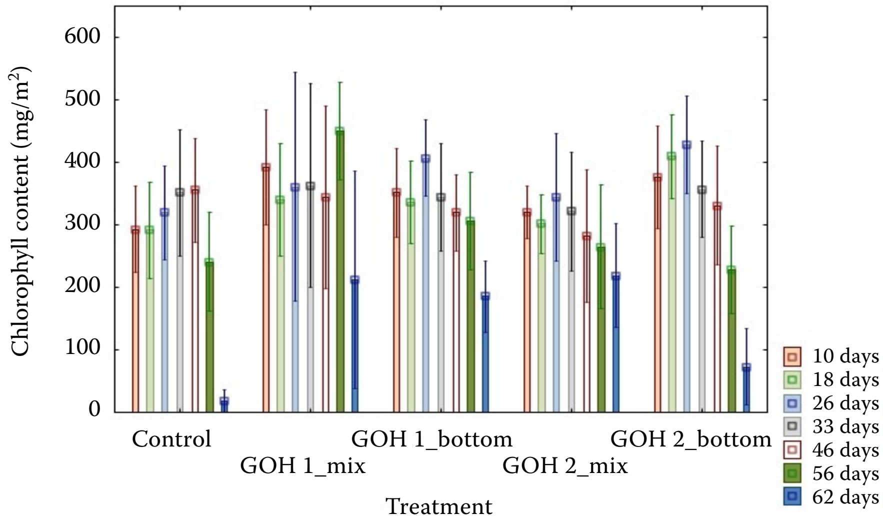

Figure 8. Average chlorophyll content values (± 95% confidence intervals) for individual treatments after 10, 18, 26, 33, 46, 56 and 62 days from the start of the experiment in the no watering mode

GOH 1_mix – granular organic hydrosorbent number 1 mixed with substrate; GOH 1_bottom – granular organic hydrosorbent number 1 applied to the pot bottom; GOH 2_mix – granular organic hydrosorbent number 2 mixed with substrate; GOH 2_bottom – granular organic hydrosorbent number 2 applied to the pot bottom; mean ± standard deviation

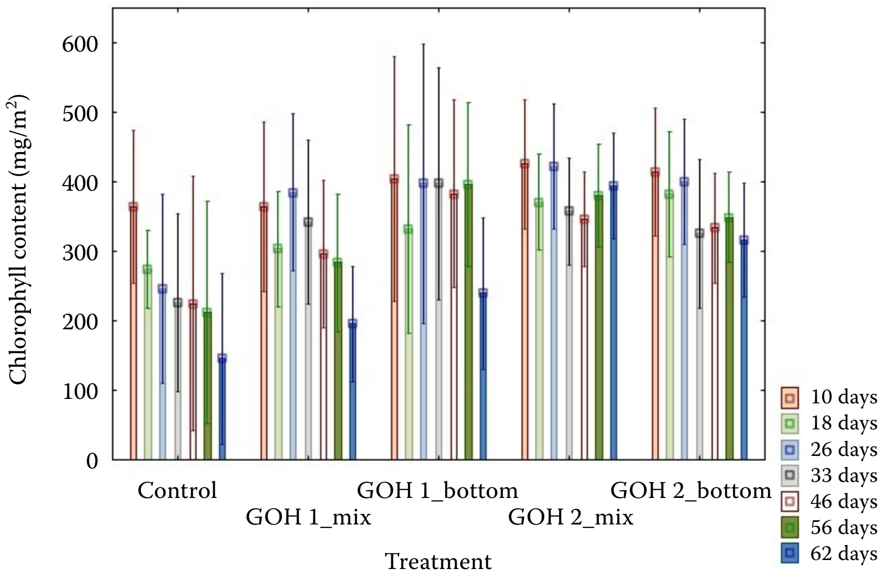

Figure 9. Average chlorophyll content values (± 95% confidence intervals) for individual treatments after 10, 18, 26, 33, 46, 56 and 62 days from the start of the experiment in the re-watering mode

GOH 1_mix – granular organic hydrosorbent number 1 mixed with substrate; GOH 1_bottom – granular organic hydrosorbent number 1 applied to the pot bottom; GOH 2_mix – granular organic hydrosorbent number 2 mixed with substrate; GOH 2_bottom – granular organic hydrosorbent number 2 applied to the pot bottom; mean ± standard deviation

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etation hall temperatures during the experiment (Figure 3). Figure 8 highlights the no watering mode, where both the control chlorophyll content and the content for all treatment modes remained at similar values for a certain period. The values 10 days after the experiment commencement ranged from 292.3 mg/m^2 in the control to 392.4 mg/m^2 in GOH 1_mix. While in the control group, chlorophyll content did not decrease significantly until 46 days, all treatments except GOH 1_mix maintained chlorophyll values until a decrease after 56 days of the experiment.

This trend is partly attributed to the relatively low temperatures in the first half of April 2021 and the significant increase by the end of the month (Figure 3). A reduced chlorophyll content due to high temperatures has been confirmed (Jumrani, Bhatia 2019). Figures 5 and 8 herein show that increased temperatures promoted decreased water retention and contributed to decreased chlorophyll content in all treatments in the no watering mode.

The highest chlorophyll content decrease was recorded at 17.8 mg/m^2 in the control after 62 days without watering. This decrease corresponds to the low water retention values. Decreased chlorophyll content was also identified in fertilised treatments, and this was especially evident in the 73 mg/m^2 GOH 2_bottom. This finding contrasts with the measured retention values, which recorded the lowest decrease for this treatment. In addition, the low chlorophyll values were due to the beginning yellowing of the leaves, which cannot be satisfactorily explained. However, the remaining fertilised treatments had significantly higher chlorophyll content than the control, even at the end of the experiment.

Figure 9 reveals that the control's average chlorophyll content did not return to the initial value even after re-watering on the 18th day. Chlorophyll content in the control reflects the decrease in control water retention below zero 26 days after the start of the experiment. In direct contrast, chlorophyll contents increased in all fertilised treatments, with GOH 2 values generally more significant than GOH 1. However, the GOH_bottom and GOH_mix application values exhibited no significantly different chlorophyll content. While chlorophyll content decreased by 219.3 mg/m^2 in the control, the lowest decreases were 31 mg/m^2 for GOH 2_mix and 97.5 mg/m^2 for GOH 2_bottom. Soil GOH treatments significantly increased the chlorophyll content of both unwatered and re-watered plants, and this was a similar effect to biochar application (Hoang et al. 2021; Gharred et al. 2022). For example, both chlorophyll a and b content increased with an increasing ratio of biochar in the compost under drought stress (Bashir et al. 2020).

The effectiveness of the tested organic hydrosorbents is comparable to other amendments used to improve water retention and increase plant resistance to drought, such as biochar or hydrogels. Very few scientific papers deal specifically with organic hydrosorbents on a similar basis as the one tested here. The use of unconventional organic residues to improve soil hydrophysical properties, such as lactobionate (Kallenbach et al. 2019), coffee waste (Kasongo et al. 2010), or water treatment residuals (Stone et al. 2024) is also a discussed topic. The principle of action of these amendments on soil and plants is different from that of GOH due to the different chemical composition.

In addition to the pot experiment, testing of the use of organic hydrosorbents in field conditions in planting woods is underway. The study has not yet been completed, so the results have not been published. However, a patent for the production of hydrosorbent has already been accepted (Šulc et al. 2020).

CONCLUSION

Herein, we assessed the efficiency of granular organic hydrosorbent fertilisers in seedling survival and reducing drought stress by increasing soil water retention and leaf chlorophyll content. The benefits of these fertilisers with two distinct origins were compared – those comprising half biogas production and half wheat straw and those from post-harvest grain and legume and oilseed residues. Both fertilisers were pelletised.

No significant difference was found between the effectiveness of these granular organic hydrosorbent fertilisers and treatment methods. Both improved the boxwood plant's water retention and delayed soil drying compared to the control. As a result, the chlorophyll content of the fertilised treatments is significantly higher than that of the control, regardless of the watering regime.

Although this is still a preliminary study, the use of tested organic hydrosorbents in tree plantings appears promising. The main benefits are easy applicability in practice and environmental friendliness

https://doi.org/10.17221/72/2024-HORTSCI

because, thanks to its organic composition, it naturally returns organic matter back to the soil. However, it is necessary to continue the study and focus especially on the influence of hydrosorbents on soil properties and soil fertility. Further testing in field conditions is also important.

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REFERENCES

Adjuik T.A., Nokes S.E., Montross M., Wendroth O., Walton R. (2023): Alkali lignin-based hydrogel: Synthesis, characterization, and impact on soil water retention from near saturation to dryness. Journal of the American Society of Agricultural and Biological Engineers, 66: 85–98.

Akhter J., Mahmood K., Malik K.A., Mardan A., Ahmad M., Iqbal M.M. (2004): Effects of hydrogel amendment on water storage of sandy loam and loam soils and seedling growth of barley, wheat and chickpea. Plant, Soil and Environment, 50: 463–469.

Akpinar D., Tian J., Shepherd E., Imhoff P.T. (2023): Impact of wood-derived biochar on the hydrologic performance of bioretention media: Effects on aggregation, root growth, and water retention. Journal of Environmental Management, 339: 117864.

Bartocci P., Vaccari F.P., Valagussa M., Pozzi A., Baronti S., Liberti F., Bidini G., Fantozzi F. (2017): Effect of biochar on water retention in soil, a comparison between two forms: Powder and pellet. In: Proceedings of the 25th European Biomass Conference and Exhibition, Stockholm, June 12–15, 2017: 1732–1736.

Bashir A., Rizwan M., Zia ur Rehman M., Zubair M., Riaz M., Qayyum M.F., Alharby H.F., Bamagoos A.A., Ali S. (2020): Application of co-composted farm manure and biochar increased the wheat growth and decreased cadmium accumulation in plants under different water regimes. Chemosphere, 246: 125809.

Bondì C., Castellini M., Iovino M. (2022): Compost amendment impact on soil physical quality estimated from hysteretic water retention curve. Water, 14: 1002.

Crous J.W. (2016): Use of hydrogels in the planting of industrial wood plantations. Southern Forests: A Journal of Forest Science, 79: 197–213.

Cruz Fabian D.R., Durpekova S., Dusankova M., Cisar J., Drohsler P., Elich O., Borkova M., Cechmankova J., Sedlarik V. (2023): Renewable poly(lactic acid)lignocellulose biocomposites for the enhancement of the water retention capacity of the soil. Polymers, 15: 2243.

de Sosa L.L., Sánchez-Piñero M., Girón I., Corell M., Madejón E. (2023): Addition of compost changed responses of soil-tree system in olive groves in relation to the irrigation strategy. Agricultural Water Management, 284: 108328.

Doğaroğlu Z.G. (2023): Two different biochar-doped hydrogels affect the growth of arugula (*Eruca vesicaria*) under different irrigation period. Journal of Soils and Sediments, 23: 232–245.

Gharred J., Derbali W., Derbali I., Badri M., Abdelly C., Slama I., Koyro H.-W. (2022): Impact of biochar application at water shortage on biochemical and physiological processes in *Medicago ciliaris*. Plants, 11: 2411.

Gitelson A.A., Buschmann C., Lichtenthaler H.K. (1999): The chlorophyll fluorescence ratio F_{735}/F_{700} as an accurate measure of the chlorophyll content in plants. Remote Sensing of Environment, 69: 296–302.

Allakonon M.G.B., Akponikpè P.B.I. (2022): Relationship of maize yield to climatic and environmental factors under deficit irrigation: A quantitative review. International Journal of Agronomy, 2022: 2408439.

Guilherme M.R., Aouada F.A., Fajardo A.R., Martins A.F., Paulino A.T., Davi M.F.T., Rubira A.F., Muniz E.C. (2015): Superabsorbent hydrogels based on polysaccharides for application in agriculture as soil conditioner and nutrient carrier: A review. European Polymer Journal, 72: 365–385.

Hillier J.E., Coombes A.J. (2007): The Hillier Manual of Trees and Shrubs. 3rd Ed. Newton Abbot, David & Charles Publishers.

Hoang T.-L.-H., Jang D.-C., Nguyen Q.-T., Na W.-H., Kim I.-S., Vu N.-T. (2021): Biochar-improved growth and physiology of *Ehretia asperula* under water-deficit condition. Applied Sciences, 11: 10685.

IPCC (2018): The IPCC Special Report on Global Warming of 1.5°C. Cambridge and New York, Cambridge University Press.

IPCC (2019): The IPCC Special Report on Climate change and Land. Cambridge and New York, Cambridge University Press.

Jumrani K., Bhatia V.S. (2019): Interactive effect of temperature and water stress on physiological and biochemical processes in soybean. Physiology and Molecular Biology of Plants, 25: 667–681.

Kallenbach C.M., Conant R.T., Calderón F., Wallenstein M.D. (2019): A novel soil amendment for enhancing soil moisture retention and soil carbon in drought-prone soils. Geoderma, 337: 256–265.

El-karamany M.F., Waly A.I., Shaban A.M., Bakry A.B. (2019): Utilization of hydrogel for reducing water irrigation quantities on two wheat cultivars grown under sandy soil conditions. International Journal of Water Resources and Arid Environments, 8: 15–22.

https://doi.org/10.17221/72/2024-HORTSCI

Kasongo R.K., Verdoodt A., Kanyankagote P., Baert G., Van Ranst E. (2010): Coffee waste as an alternative fertilizer with soil improving properties for sandy soils in humid tropical environments. Soil Use and Management, 27: 94–102.

Kranz C.N., McLaughlin R.A., Amoozegar A., Heitman J.L. (2023): Influence of compost amendment rate and level of compaction on the hydraulic functioning of soils. JAWRA Journal of the American Water Resources Association, 59: 1115–1127.

Mafakheri A., Siosemardeh A., Bahramnejad B., Struik P.C., Sohrabi Y. (2010): Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. Australian Journal of Crop Science, 4: 580–585.

Mayerová M., Šimon T., Stehlík M., Madaras M. (2023): Improving the stability of soil aggregates using soil additives and revegetation by grassland. Plant, Soil and Environment, 69: 282–290.

Minasny B., McBratney A.B. (2018): Limited effect of organic matter on soil available water capacity. European Journal of Soil Science, 69: 39–47.

Nemeskéri E., Helyes L. (2019): Physiological responses of selected vegetable crop species to water stress. Agronomy, 9: 447.

Pickering J.S., Kendle A.D., Hadley P. (1998): The suitability of composted green waste as an organic mulch: Effects on soil moisture retention and surface temperature. Acta Horticulturae (ISHS), 469: 319–324.

Qin C.-C., Abdalkarim S.Y.H., Zhou Y., Yu H.-Y., He X. (2022): Ultrahigh water-retention cellulose hydrogels as soil amendments for early seed germination under harsh conditions. Journal of Cleaner Production, 370: 133602.

Sattar A., Sher A., Ijaz M., Irfan M., Butt M, Abbas T., Hussain S., Abbas A., Ullah S., Cheema A. (2019): Biochar application improves the drought tolerance in maize seedlings. Phyton, International Journal of Experimental Botany, 88: 379–388.

Soudek P., Langhansová L., Dvořáková M., Revutska A., Petrová Š., Hirnerová A., Bouček J., Trakal L., Hošek P., Soukupová M. (2024): The impact of the application of compochar on soil moisture, stress, yield and nutritional properties of legumes under drought stress. Science of the Total Environment, 914: 169914.

Stone W., Steytler J., de Jager L., Hardie A., Clarke C.E. (2024): Improving crop growing conditions with water treatment residual and compost co-amendments: Soil-water dynamics. Journal of Environmental Quality, 53: 174–186.

Šulc R., Kolaříková M., Stehlík M., Hutla P. (2020): Reverzibilní hydrosorbent na bázi separátu z bioplynové stanice a způsob jeho výroby. CZ308487B6, 5 August 2020. (in Czech)

Woo N.S., Badger M.R., Pogson B.J. (2008): A rapid, non-invasive procedure for quantitative assessment of drought survival using chlorophyll fluorescence. Plant Methods, 4: 27.

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