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THE INFLUENCE OF BIOLOGICAL ADDITIVES ON THE MOISTURE RETENTION OF SOIL

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With the onset of climate change, dry periods are more frequent, and therefore the rational use of naturally accumulating soil moisture can be a tool to regulate the unfavourable soil moisture regime. Demand for new biological materials is increasing rapidly with the development of biotechnological science. Superabsorbent or water retaining material is considered promising material that is widely used in the fields of industry and agriculture. These can both absorb large amounts of water, as much as hundreds of times their own mass.
The use of biological environmentally friendly additives to the cultivation of agricultural products, particularly germination and rooting periods, can ensure the required moisture content of the soil. The use of additives is more economical growing relatively more expensive raw materials, so in most cases it is related to vegetable and berry crops. The aim is to investigate the extent to which biological additives can absorb and give back moisture, assessing the different incorporation relations, as well as different biological additives. Soil moisture variation for samples with embedded biological additives ended after 24 and 26 days under laboratory conditions at 17 and 19 °C; it ended after 15 days in an environmental chamber at 20 °C. On average, soil moisture retention increases by 14 days more than the control without additives. The results showed that at low temperatures all the biological additives considered help to keep the moisture available to the plants longer in the soil for approximately the same number of days. In assessing these results, it should be emphasized that the conditions in the nature are different from the simulated critical temperatures and without the addition of moisture, in the natural conditions the impact of biological additives will be longer.

Keywords: evaporation, soil moisture, biological additives

INTRODUCTION

Plant productivity depends on many factors, including local soil properties and climatic conditions, soil moisture regime, precipitation, carbon dioxide concentration in the air, plant species and variety of genetic characteristics, growth stage, pests, diseases, etc. (Abd El-Rahim, 2006; Kramer and Boyer, 1995).

With the onset of climate change dry periods are more frequent, and therefore the rational use of naturally accumulating soil moisture can be a tool to regulate the unfavourable soil moisture regime. Water and air treatment depend on soil texture, its structurality, density, topsoil layer thickness, and other factors. According to the HadCM3-A1B climate change scenario, considerable decrease in soil moisture in May-August is foreseen in Lithuania in the future. Compared with 1971-2000, soil moisture for as soon as 2001-2030 is projected to decline 15-18%. The greatest changes are expected in western, as well as north-eastern Lithuania, with the average change nationwide at 15.9%. It is projected to dry up most on the soil surface layer formed on the light surface layer of rock (sand and sandy loam). It is believed that in the second half of the 21st century the 200 mm thick layer of soil will already be characterized by less than the current moisture content at the beginning of the active vegetation period (Stonevičius et al., 2008).

Due to unfavourable weather, Lithuanian farmers suffered losses in 2000-2014, which amounted to an average of about 5% of total crop production.

As temperatures rise, precipitation and the number of rainy days during the warm season decrease, and we witness problems causing adverse soil moisture regimes, we have to look for different solutions based on scientific research methods. The use of various biological additives can help us safely use productive soil moisture reserves, which in the spring compose 80 mm (sandy loam soils) to 130 mm (clay soils) of Lithuanian land.

Biological additives potentially influence infiltration rates, density, soil structure, compaction, soil texture, aggregate stability, crust hardness (Helalia and Letey, 1989), and evaporation rates. They increase the water in the soil available to the plant, which prolongs plant survival under water stress (Huttermann et al, 2009; Jobin et al., 2004; Agaba et al., 2010). Biological additives can hold or accumulate hundreds of times more water than they weigh themselves: 400-1500 grams of water per gram of additives, reducing watering frequency (Agaba et al., 2011; Bowman and Evans, 1991). Agrovermiculite, agroperlite, and hydrogel are used to hold soil moisture in agriculture most often.

Agroperlite, agrovermiculite, and hydrogel are widely preferred as they encourage faster root development, reduce the risk of damping off, avoid water logging, and provide an optimum balance of air and water. The optimum moisture level can be maintained around the root, and this is a significant advantage over rockwool, which has less apillary action. They have been widely used in horticulture, including growing tomatoes, cucumbers, melons, peppers, lettuce, and roses (Hochmuth and Hochmuth, 2003; Rodriguez et al., 2006; Orikiriza et al., 2013; Fascella and Zizzo, 2005; Dorajji et al, 2010). All of these absorbent benefits lead to increased plant growth. Most of the articles cited here focus on how these additives affect yield, crop quality, and plant engraftment, and only a few analyse additive ability to bind moisture. The objective is to investigate mineral soil moisture change using various agricultural biological additives.

MATERIALS AND METHODS

The study was carried out in two stages: the first stage was carried out under laboratory conditions, the second at the Water Resource Engineering Institute’s water balance research site, but in this article only first stage results are presented.

Soil moisture change samples were assessed under laboratory conditions with these biological additives: Stockosorb®, agroperlite, vermiculite, as well as universal hydro-granules. Biological additives, in accordance with the manufacturers recommendations, were mixed with mineral soil mixture (substrate) and poured into equal-sized containers (Ø 12 cm).

The containers were saturated with water up to the maximum water susceptibility. This was done once at the beginning of the experiment using 200 ml water. The observed water runoff is likely to be zero, so it is assumed that evaporation under laboratory conditions is the difference between the weight at the beginning and end of the observation. Excess moisture is collected during the moisture saturation stage.

Accrued soil moisture change is recorded every 24 hours by weight. Laboratory test conditions were also carried out by means of environmental chambers monitored 24 hours a day set at 17 °C, 19 °C, and 20 °C.

Each measurement was carried out three times. Weighing was stopped when soil moisture change was no longer recorded.

Soil water content (*SWC*) calculated (Fenta et al., 2012):

$$SWC = \left[\left(m_p - m_s\right) \cdot m_s^{-1}\right] \cdot 100, \tag{1}$$

m_p – initial mass of soil samp;
m_s – mass of dry soil.

The amount of water that percolated through the soil monolith is determined by volume. This is the water evaporation calculation formula:

$$E = H + m\,(A_1 - A_2) - N, \text{ mm} \tag{2}$$

E – evapotranspiration, mm
H – precipitation, mm
m – watering rate, cm^3
A_1 – A_2 evaporator mass at the beginning and end of research
N – the amount of water percolated through the soil monolith and permeated, mm

RESEARCH RESULTS

Laboratory tests for moisture retention were carried out with *Stockosorb*®, agroperlite, vermiculite and universal hydrogels at 17°C in the laboratory (under natural conditions). It was found that in the first 7 days the moisture change was $3.5\% \cdot p^{-1}$ in all mixtures (Fig. 1.), a more intense change in soil moisture was recorded on the 11 th day of the experiment, on average, from 4 to $6\% \cdot p^{-1}$, by analogy more intensive evaporation was fixed at 20–24 days (at that time the additives yield a larger amount of accumulated water), and later the soil moisture change stabilized. From the 12th day and to the end of the experiment, the moisture change was on average $1.3\% \cdot p^{-1}$.

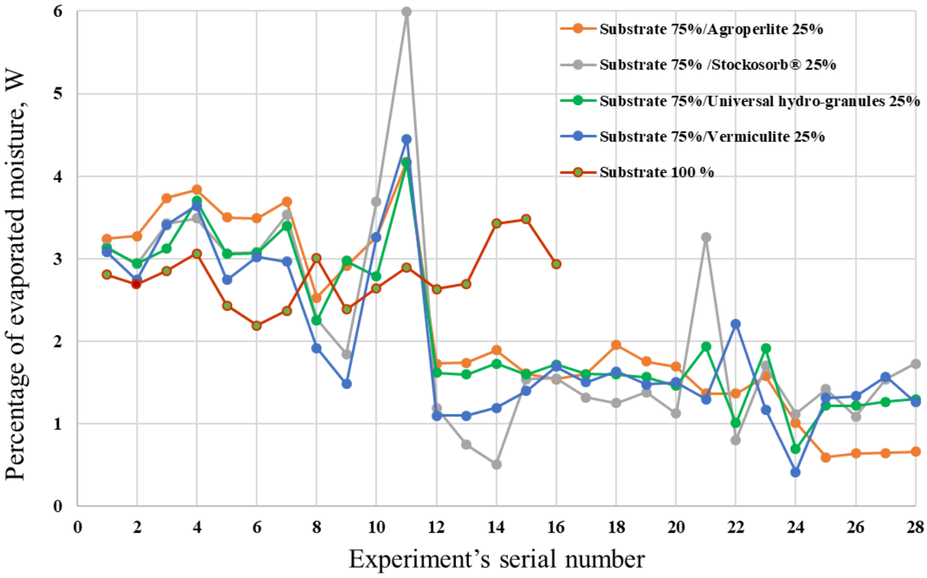

Figure 1. The dynamics of soil moisture change in the laboratory under natural conditions (17°C)

In the experiment, the most intense change (throughout the study period) was fixed in a sample where the substrate was mixed with *Stockosorb®* (11th day) additive, which accumulates the highest amount of moisture (during saturation) 6%·p^{-1}. The change in the moisture content of the control variant is no longer fixed after 16 days, and the test additive – after 29 days. It can be stated that at 17ºC all additives are equally effective for soil moisture retention when using a mixture of substrates and bio additives in a ratio of 75:25.

The soil moisture dynamics is not uniform (Fig. 2) and at an average temperature of 19°C, after 7 days, a decrease in moisture content is recorded on average by 2.6%·p^{-1}, after which the moisture change increases to 3.5%·p^{-1} (17th day) and stabilizes on the 21st day and averages 1.5%·p^{-1}.

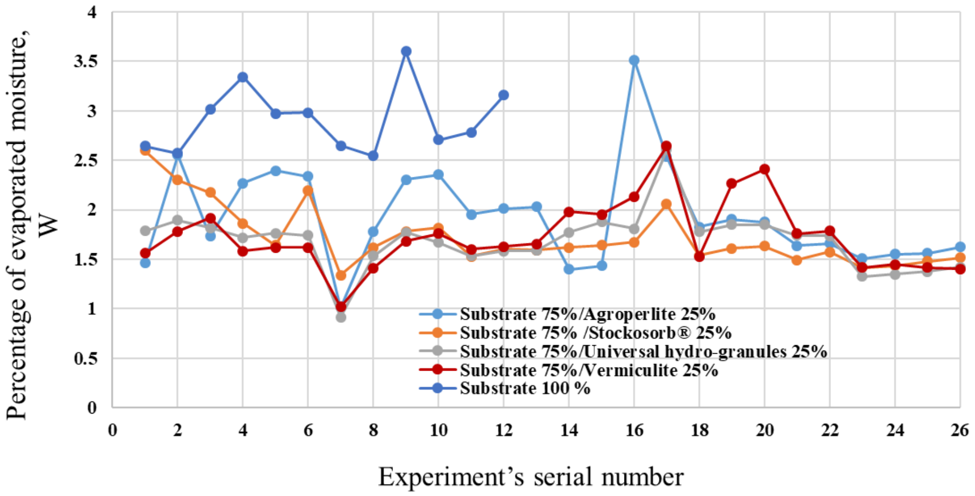

Figure 2. The dynamics of soil moisture change in the laboratory at 19°C

Comparing the results of moisture dynamics in the samples when only substrate and other four biological additives were used, it was found that the soil moisture change stabilizes after 12 and 26 days, with added biological additives the moisture is maintained longer (+14 days). The difference in total evaporated water content in all samples varies slightly at 19ºC and from the 21st day the moisture change stabilizes.

In a sample with a substrate at 17°C, the soil moisture change is not fixed after 15 days, at 19°C after 12 days, the soil moisture change in the samples with biological additives at 17°C is no longer fixed after 28 days, at 19°C – after 26 days. Biological additives suspended soil moisture in the samples longer by an average of 13 days. The results showed that at low temperatures all the biological additives considered help to keep the moisture available to the plants longer in the soil for approximately the same number of days.

It has been determined in the experiments that using agroperlite granules in various proportions (Fig. 3), in a climatic cabinet at 20°C it was found that during the first 7 days, evaporation of moisture varied from 12 to 2%·p^{-1}, then stabilized and decreased by about 2%·p^{-1}. Using only a substrate and substrate mixed with agroperlite in a ratio of 50:50, the evaporation stabilizes after 13 days, and the daily moisture change is 2–11 percent. In the sample, where the substrate and agroperlite were mixed at 75:25, the evaporation of moisture changed from 3 to 7%·p^{-1}, this trend was observed for

13 days, from the14th day until the end of the experiment, the moisture change was 0–3%·p^{-1}. After mixing the substrate and agroperlite in a ratio of 25:75, it was found that the evaporation of moisture in the first 4 days of experiment increased from 9 to 10% per day, then evaporation (on the 4th day of the experiment) began to decrease, followed by 4 to 9 %·p^{-1}, which lasted 6 days, after which the moisture change stabilized and varied by 1–3%·p^{-1}. Analysis of the data obtained in the research shows that the maximum moisture evaporation rate in the samples is about 12%·p^{-1}, during 1–3 days when agroperlite was used.

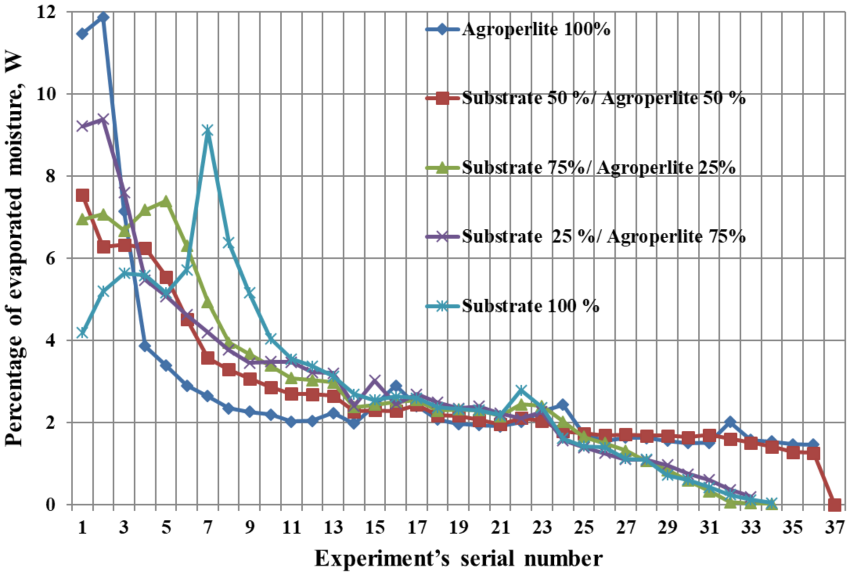

Figure 3. General diagram of soil moisture change by mixing samples in different proportions (20°C)

During the experiment, using only vermiculite granules, it was determined that evaporation of moisture for the first 7 days varied from 6 to 2.7%·p^{-1}, later (from 16th to 20th day) increased to 4% and only on 21st day it stabilized and decreased by an average of 1–2%·p^{-1}. Using a substrate mixed with vermiculite in a ratio of 50:50, it was found that the evaporation change was 2.5% p^{-1}, and lasted up to the 20th day (Fig. 4).

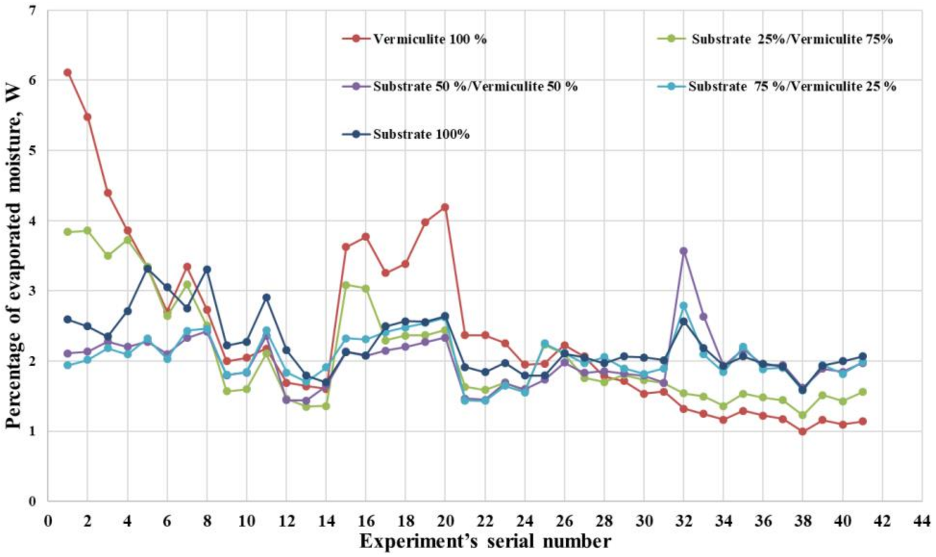

Figure 4. Total diagram of changes in soil moisture content by mixing samples in different proportions (20 °C)

By mixing the substrate and vermiculite with a ratio of 75:25; the evaporation of moisture was determined on average by 3%·p^{-1}, this trend was observed for 8 days; from the 8th day until the end of the experiment, the moisture change was on average 1.5%·p^{-1}. After mixing the substrate and vermiculite in a ratio of 25:75, the evaporation of moisture throughout the experiment was on average 2%·p^{-1}. It can be argued that using vermiculite granules in various proportions, the evaporation of moisture intensively took place for the first 4 days at 2–6%·p^{-1}, then the intensity decreased to 1–2%·p^{-1}.

When analyzing the dynamics of the moisture change of the substrate mixtures with vermiculite, it was found that at 20°C, the retention of absorbed moisture content is dependent on the amount of vermiculite in the mixture. The higher the amount of vermiculite in the mixture, the better absorption of moisture is retained (results vary from 11.8 g to 40.7 g).

The results showed that at low temperatures all the biological additives considered help to keep the moisture available to the plants longer in the soil for approximately the same number of days. In assessing these results, it should be emphasized that the conditions in the nature are different from the simulated critical temperatures and without the addition of moisture, in the natural conditions the impact of biological additives will be longer.

CONCLUSIONS

- Experimenting with mixing substrate in different proportions with vermiculite it was found that, at 20°C, the retention of absorbed moisture content is dependent on the amount of vermiculite in the mixture. The higher the amount of vermiculite in the mixture, the better absorption of moisture is retained (results vary from 11.8 g to 40.7 g). Vermiculite, as a moisture retainer, is only effective at temperatures close to 20°C. Based on the results obtained, it is stated that using vermiculite for the retention of moisture reserve effect is +9 days. Agroperlite was the most effective at 20°C with 50:50 ratio of substrate and agroperlite, all soil moisture reserves evaporated after 36 days, the same results were obtained for 75:25 and 25:75 substrate and agroperlite samples.
- By comparing the results of the experiments with the results of the moisture change at temperatures of 17-19°C, in the control version (substrate only) and in versions with vermiculite, agroperlite, hydrogel and *Stockosorb*® (25:75) it was found that in the first 7 days similar amounts of water evaporate on average 3.5 and 2.5%$\cdot$p^{-1}. The soil moisture change is stabilized at 12 and 26 days, and with added biological additives, moisture is maintained longer (+13 days).

REFERENCES

1. Abd El-Rahim, H.A. 2006. Characterisiation and possible agricultural application of polyacrylamide/sodium alginate crosslinked hydrogels prepared by ionizing radiation. *Journal of Applied Polymer Science*, Vol. 101, pp.3572–3580, https://doi.org/10.1002/app.22487
2. Agaba, H., Lawrence J. B. Orikiriza, Obua, J., Kabasa, J.D., Worbes, M., Hüttermann, A. 2011. Hydrogel amendment to sandy soil reduces irrigation frequency and improves the biomass of Agrostis stolonifera. *Agricultural Science*, Vol. 2, No. 4, pp. 544–550, https://doi.org/10.4236/as.2011.24071
3. Agaba, H., Lawrence J. B. Orikiriza, Esegu, J.F.O., Obua, J., Kabasa, J.D., Hüttermann, A. 2010. Effects of hydrogel amendment to different soils on plant available water and survival of trees under drought conditions. *Clean Soil Air Water*, Vol. 38, pp. 328–335, https://doi.org/10.1002/clen.200900245
4. Bowman, D.C., Evans, R.Y. 1991. Calcium inhibition of polyarcylamide gel hydration is partially reversible by potassium. *HortScience*, Vol. 26, No. 8, pp. 1063–1065.
5. Dorajji, S.S., Golchin A., Ahmadi, S. 2010. The effects of hydrophilic polymer and soil salinity on corn growth in sandy and loamy soils. *Clean Soil Air Water*, Vol. 38, pp. 584–591. https://doi.org/10.1002/clen.201000017
6. Fascella, G., Zizzo, G.V., 2005. Effect of growing media on yield and quality of soilless cultivated rose. *Acta Horticulturae*, Vol. 697, pp. 133–138. https://doi.org/10.17660/ActaHortic.2005.697.15
7. Fenta, B. A., Driscoll, S. P., Kunert, K. J., Foyer, C. H. 2012. Characterization of drought tolerance traits in nodulated soya beans: the importance of maintaining photosynthesis and shoot biomass under drought induced limitations on nitrogen metabolism. *Journal of Agronomy and Crop Science*, Vol. 198, pp. 92–103.
8. Helalia, A.M. and Letey, J. 1989. Effects of different polymers on seedling emergence, aggregate stability and crust hardness. *Soil Science*, Vol. 148, pp. 199–203. https://doi.org/10.1097/00010694-198909000-00007
9. Hochmuth, G.J., Hochmuth, R.C. 2003. *Keys to Successful Tomato and Cucumber Production in Perlite Media*. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, 5 May 2004.
10. Jobin, P., Caron J., Bernier, P.Y., Dansereau, B. 2004. Impact of two hydrophilic acrylic-based polymers on the physical properties of three substrates and the growth of Petunia hybrida “Brilliant Pink”. *Journal of the American Society for Horticultural Science*, Vol. 129, pp. 449–457.
11. Kramer, P.J. and Boyer, J.S. 1995. Water relations of plants and soils. Academic Press, London.
12. Orikiriza, L.J. B.; Agaba, H., Eilu, G., Kabasa, K. J., Worbes, M., Hüttermann, A. 2013. Effects of Hydrogels on Tree Seedling Performance in Temperate Soils before and after Water Stress. *Journal of Environmental Protection*, Vol. 04, No. 07, pp. 713–721. https://doi.org/10.4236/jep.2013.47082
13. Rodriguez, J.C., Cantliffe, D.J., Shaw, N.L., 2006. Soilless media and containers for greenhouse production of ‘Galia’ type muskmelon. *HortScience*, Vol. 41, pp. 1200–1205.
14. Stonevičius E., Štaras A., Valiuškevičius G. 2008. Dirvožemio drėgmės režimo pokyčių XXI a. prognozės pagal skirtingus klimato kaitos scenarijus. *Geografija*, Vol. 1, Book 44, pp.17–25. [In Lithuanian]