The Influence of the Application of Soil Conditioners on the Temperature and Moisture of the Soil Environment

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Abstract

In cities, environmental and social impacts are increased every year due to high temperatures due to the heat island of the city. An effective struggle against the heat island of the city is the green infrastructure, where woody plants such as trees and shrubs play an irreplaceable role. Wood in the city is affected by a number of stress factors, especially high temperatures and lack of precipitation. In order for them to perform all their important functions and help reduce the negative impacts of the city's heat island, all requirements for their successful development and growth must be fulfilled. Soil conditions are an important factor affecting the condition of trees. Unsuitable soil conditions which include lack of water, compacted soil, result in insufficient development of the root system which directly affects the quality of the above-ground part of the plants. A possible treatment to improve the soil environment in the root zone of trees is the use of soil conditioners applied in the form of soil injection. The paper deals with the effect of soil conditioners (Hydrogel®, mycorrhizal mix Endomyk PROF + Trichoderma, and their combination) in the form of injection on the temperature and humidity conditions of the soil environment in a young plants of trees (species) Acer campestre L. in the city of Znojmo (South Moravia region). Plants without application of any preparation served as a Control variant. Before the actual application of conditioners MINILOG data loggers with temperature sensors and VIRRIB moisture sensors were placed in the soil which recorded changes in soil temperature and volumetric soil moisture in six-hour intervals every day in the period from February 2021 till December 2022. These changes were recorded in two profiles 0.1 - 0.4 and 0.4 - 0.7 meters. From the recorded results, it can be said that the application of soil conditioners had a significant effect on the temperature and humidity conditions of the soil environment. The variant with the soil conditioner Hydrogel® and the variant with the soil conditioner Hydrogel® in combination with the mycorrhizal mix in most cases show higher values of soil moisture and temperature compared to the Control variant. This trend is most evident in the soil profile of 0.4 - 0.7 m in the growing season.

Keywords: Analysis, Soil conditioners, Temperature, Moisture, Soil Environment

Introduction

The urban heat island is a phenomenon occurring in the urban climate where significantly higher temperatures occur in the city compared to the suburbs and the countryside. This phenomenon represents a serious problem for the environmental and social environment of cities around the world [1, 2]. Reducing the urban heat island effect can reduce the damage caused by climate change [3]. One of the most effective ways to fight against the urban heat island is green infrastructure, which lowers the higher air temperature and therefore cools the surrounding environment. Shareef states in the results that the best elements of green infrastructure are mainly mature trees [4]. The trees that shade the surrounding areas with their crowns reduce the air temperature and prevent the impact of sunlight. Thanks to this, the increase in the temperature of the surrounding air and the temperatures of the surrounding artificially built surfaces is limited [5]. The environment in the city is very stressful for all plants due to high day and night temperatures [6]. The highest risk in recent years is extreme temperatures, especially in the summer. Over the past hundred years, the average annual temperature has risen by 0.8 °C [7]. The number of heat waves and their intensity has been radically changed. This trend is likely to continue. Heat waves are very often accompanied by periods of drought. Heat wave intensity is predicted to quadruple by 2040. Heat affecting the vital functions of trees. At leaf level, photosynthesis is reduced and photooxidative stress increases. Stress from high temperatures can affect entire plants, slowing down their growth and development. If it is accompanied by high temperatures and a dry season, the attendance can lead to the death of individuals [8, 9]. With a water deficit, tree roots do not have access to mineral nutrients [10]. Intense drought causes leaf fall, slows down the growth rate, increases the thickness of the cuticle and the amount of wax [11]. Trees react to a lack of water by changing the structure of their root system. The tree lowers its metabolism, reduces the root system and initiates elongation growth [12]. The lifespan of trees in cities is reduced several times compared to trees in outdoor areas. This phenomenon is most noticeable in trees growing next to city roads and in trees growing in paved areas, as is often the case in squares [13]. The quality of the soil environment is a very important factor for the growth and development of trees in the city. Urban expansion often leads to soil degradation [14, 15], during which it undergoes physical and chemical changes such as soil removal, drying of the soil environment, lack of water caused by surface runoff, high soil temperature, lack of nutrition and pH. All the mentioned factors have a negative effect on the proper development of trees on soil microorganisms and the activity of soil enzymes [10]. These stressors, together with others, affect not only existing plantings, but also the susceptibility and development of newly planted trees. Currently, it is very important to find the right method of treating woody plants after planting, which improved their vitality and optimal development in areas plagued by prolonged heat and drought. One of the ways to improve soil conditions and increase the tolerance of tree species to stressors is the use of soil conditioners. This article deals with the influence of the application of soil conditioners in the form of injection on the temperature and humidity conditions of the soil environment when tree plantings.

Material and Methods

Characteristics of the Model Area

The model area is located in the Czech Republic in the South Moravian Region in the city of Znojmo, with a population of approximately 34,000 and an area of 65.9 km^2. The altitude of the city is around 290 m above sea level. Znojmo is located in a very warm and dry climate region with an average annual temperature of 9-10 °C and average annual precipitation of 500-600 mm with a 30-50 percent assumptions of the occurrence of a dry growing season. Experimental locations were selected in the city of Znojmo on Sokolská street, where there was a young acclimatized planting of trees of the species *Acer campestre* L. planted in a grassy strip of land approximately 1.2 m wide. According to the BPEJ catalog, there are mainly cambisol on the site with a total skeleton content of 25 %. The soils here are deep to medium deep, but due to the presence of roads on both sides, it can be assumed that there is anthropogenic soil on the model area.

Soil Conditioners Application

At the model area, all the trees in the total number of 14 were included in the experiment. These trees were divided into the following variants: Control (3 pcs), Hydrogel (4 pcs), Mycorrhiza (3 pcs), Hydrogel + Mycorrhiza (4 pcs). Individual variants were treated with soil conditioners Hydrogel® and Endomyk PROF + Tri. The Control variant was left without the application of soil conditioners. In the case of trees in variants with application of soil conditioners, their injection was carried out with a VOGT - Geo Injector device. The injection solution of Hydrogel variant was prepared by mixing 0.128 kg of Hydrogel® in 28 l of water with subsequent application using an injector. The injection solution of Hydrogel with mycorrhizal mix variant was prepared by mixing 0.128 kg of Hydrogel® in 28 l water and 40 grams of Endomyk PROF + Tri per tree dissolved in water with subsequent application using an injector. The injection itself took place by using air pressure to insert the injector to the required depth, by pushing in the air, the soil space is aerated and holes are created, into which the water-activated soil conditioner solution is then applied.

Precipitation and Temperature Recording

The evaluation used precipitation and temperature data from an automatic meteorological station located in the city of Znojmo, provides the company Amet - association Litschmann & Suchý, Velké Bílovice.

Soil Moisture and Temperature Monitoring

In years 2021 and 2022, the soil temperature was recorded using temperature sensors and the volumetric soil moisture (% vol.) was recorded using VIRRIB sensors (AMET Velké Bílovice). At each location, the sensors were placed on one test tree at two depths of 0.1–0.4 m and 0.4–0.7 m. The sensors were connected to a data logger MINILOG (Fiedler, České Budějovice), which records soil temperature and volume soil moisture at six-hour intervals. Dataloggers were downloaded using Most 2.3 software.

Data Analysis

Analysis of recorded data as well as graphs were created in MS Excel 2016 and processed in Statistica (Tibco Software Inc.), where values evaluated by analysis of variance (ANOVA) and significant differences by Tukey's (HSD) test at α significance level were recorded $\alpha=0.05$.

Results

From the recorded values of meteorological stations located in the city of Znojmo, it is obvious that both years were above average in temperature. An average annual temperature of 11.59 °C was reached in year 2021 and 11.28 °C in year 2022. The year 2021 was also significantly below average in terms of precipitation, but precipitation occurred throughout the year. In 2022, the highest precipitation totals were recorded in the growing season, as can be seen from Figure 1 and Figure 2. When evaluating the influence of the application of soil conditioners on soil temperature, it is possible to say that their application affected the soil environment both in the upper measured profile (0.1-0.4m) and in the lower one (0.4-0.7m). The most significant difference between the Control variant and the other trial variants occurred in both years in the growing season. In the month of July, the Control variant reached significantly lower soil temperature values compared to the other trial variants. The highest soil temperature values in the 0.1-0.4m profile were recorded in the months of June and July for the variants with injected Hydrogel® and mycorrhizal mix. In 2021, in the months of June, July and August, when the Control variant in the soil profile (0.4-0.7 m) had significantly lower soil temperature values compared to the other trial variants (Table 1). The highest average soil temperature values were recorded from April to September for the variant with mycorrhizal mix.

Tab. 1. Average values of soil temperature (°C) in year 2021.

Month	Average temperature (°C)[a]	Control		Hydrogel		Hydrogel + Mycorrhiza		Mycorrhiza	
		Horizon 0.1 - 0.4	Horizon 0.4 - 0.7	Horizon 0.1 - 0.4	Horizon 0.4 - 0.7	Horizon 0.1 - 0.4	Horizon 0.4 - 0.7	Horizon 0.1 - 0.4	Horizon 0.4 - 0.7
February	0.80	3.73	3.08	3.37	2.13	3.37	2.99	4.60	4.33
March	4.90	4.21	4.42	3.91	4.00	3.79	3.92	4.63	4.85
April	8.10	8.85	8.63	8.70	8.50	8.71	8.39	9.53	9.04
May	13.30	14.55	13.57	14.93	14.05	14.18	13.44	15.10	13.97
Jun	21.60	21.43	19.27	**23.61***	**21.32***	22.11	20.16	**23.56***	**21.35***
July	22.10	21.92	21.20	**24.49***	**23.50***	**23.53***	**22.84***	**24.61***	**23.09***
August	23.00	20.06	20.18	20.78	21.02	**21.45***	**21.74***	21.43	**21.39***
September	16.90	17.06	17.47	16.83	17.22	17.36	17.86	**18.52***	**18.65***
October	9.90	11.23	12.86	10.80	12.22	11.31	12.93	11.66	13.34
November	5.20	7.03	8.73	6.63	7.91	7.18	8.66	7.22	9.10
December	1.70	2.77	4.45	2.49	3.68	3.29	4.65	3.05	4.84

[a] Monthly average air temperature in 2 m height
*indicate significant differences Tukey HSD test (α=0.05) in comparison Control variant with other variants

In 2022, the temperature trend for individual variants in both profiles was similar to year 2021. Also, in 2022 significantly higher average soil temperature values were recorded for variants with soil conditioners compared to the Control variant in the growing season in the months of May to July in profile 0.4-0.7m and in the months of May till August in profile 0.1-0.4m (Table 2). In the months with lower average temperatures of February, March, October, November and December, the Hydrogel variant achieved lower average soil temperature values in both monitored years than the Control variant in both soil profiles. In the months of June and July, significantly higher average soil temperature values were recorded in both profiles compared to the Control variant (Table 2).

Tab. 2. Average values of soil temperature (°C) in year 2022.

Month	Average temperature (°C)[a]	Control		Hydrogel		Hydrogel + Mycorrhiza		Mycorrhiza	
		Horizon 0.1 - 0.4	Horizon 0.4 - 0.7	Horizon 0.1 - 0.4	Horizon 0.4 - 0.7	Horizon 0.1 - 0.4	Horizon 0.4 - 0.7	Horizon 0.1 - 0.4	Horizon 0.4 - 0.7
January	2.10	2.13	3.43	1.96	2.85	2.76	3.76	2.57	3.90
February	3.50	3.54	4.18	3.35	3.74	4.06	4.48	4.13	4.80
March	5.40	4.79	5.05	4.36	4.54	4.83	4.91	5.16	5.53
April	9.20	9.78	9.45	9.51	9.27	9.81	9.44	10.05	9.72
May	17.00	17.05	15.68	18.19	**16.70***	18.04	**16.60***	18.67	**16.76***
Jun	21.20	20.28	18.98	**22.80***	**21.14***	**22.78***	**21.16***	**23.79***	**21.48***
July	22.00	21.94	21.16	**24.52***	**23.39***	**24.18***	**23.32***	**25.02***	**23.42***
August	22.10	21.73	21.35	22.62	22.32	**23.43***	23.05	**23.50***	22.78
September	14.50	16.22	17.27	15.92	17.02	17.57	18.24	15.40	16.57
October	11.80	12.86	13.74	12.36	13.07	13.42	13.94	13.57	14.46
November	5.50	7.85	9.68	7.49	8.91	8.41	9.88	8.41	10.20
December	1.00	2.75	4.61	2.41	3.79	3.53	4.93	3.36	5.19

[a] Monthly average air temperature in 2 m height
*indicate significant differences Tukey HSD test (α=0.05) in comparison Control variant with other variants

From the recorded values of average annual precipitation in 2021, it is obvious that the year 2021 was below average in terms of precipitation. Precipitation in 2021 (220.11 mm, without precipitation in January) did not even reach half of the long-term average annual total. On the contrary, the year 2022 was an average year in terms of precipitation, the total amount of precipitation in this year was 564.63 mm. When evaluating soil moisture, it can be stated that statistically significant differences were achieved between the Control variant and the other trial variants. These differences varied depending on the depth of the soil profile. It is possible to state that the application of soil conditioners influenced the volumetric soil moisture content. From Figure 1 and Figure 2, changes during the average values of volumetric soil moisture can be observed during the monitored years. In 2021, there was more variability in the recorded values. At the beginning of year 2021, in most cases, especially for the soil profile of 0.4 - 0.7 m, significantly higher soil moisture values were recorded for variants treated with soil conditioners compared to the Control variant. In the soil profile of 0.1-0.4m, the moisture course corresponds to this only with the Hydrogel variant. In the second half of 2021, the Hydrogel + Mycorrhiza variant achieved the highest average values in both soil profiles. In the year the experiment was established, in most cases the variant with mycorrhizal mix achieved the lowest average values of volume soil moisture, these differences were evident in the soil profile of 0.1-0.4m.

In 2022, the course of volumetric soil moisture was different. Only the variant with mycorrhizal mix achieved lower average values of volumetric soil moisture compared to the Control variant, especially in the soil profile of 0.1-0.4m. In the soil profile of

0.4-0.7m, compared to the Control variant, higher average values of volumetric soil moisture were recorded for all experimental variants from the month of March. These differences were often statistically significant. In general, it can be observed that higher average values of volumetric soil moisture were achieved in variants where the Hydrogel soil conditioner was applied by injection, both in the lower (0.1-0.4m) and upper (0.4-0.7m) soil profile.

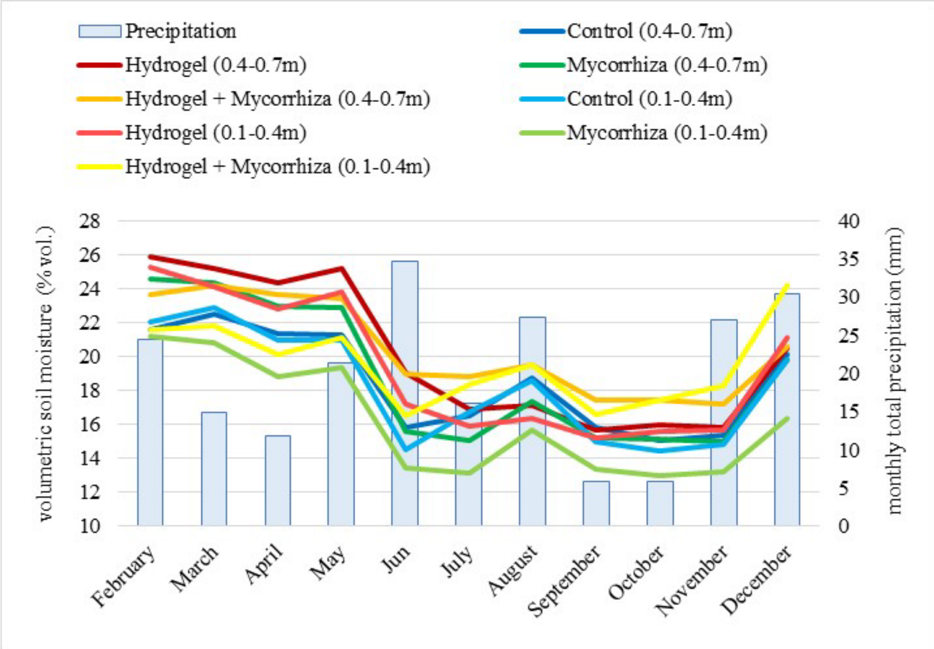

Fig. 1. Course of volumetric soil moisture in 2021.

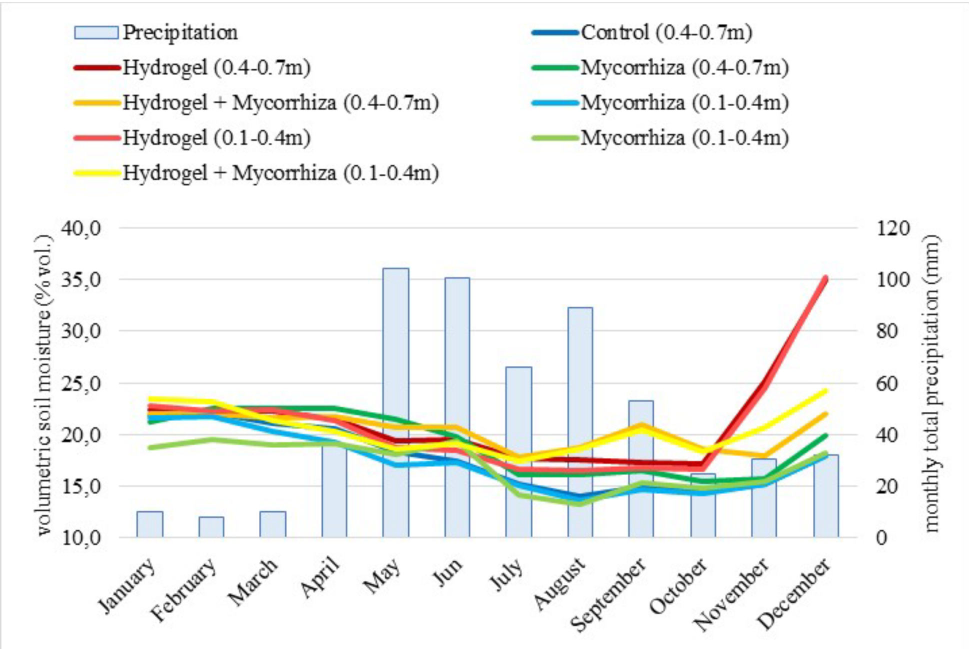

Fig. 2. Course of volumetric soil moisture in 2022.

Discussion

The experiment was carried out with the aim of improving the soil conditions of the young planting of trees, so that the water supply of the trees would be improved and they would be as little affected as possible by stress, especially from drought. Soil conditioners were applied to the soil for the existing young plantings by injection into the area of the root system of the trees. Data loggers were installed for these trees, which recorded temperature and humidity conditions in individual variants at regular intervals. Two conditioners were chosen for the experiment, namely Hydrogel® and the mycorrhizal mix Endomyk PROF + Tri. Their combination was also used in the experiment. Based on the available information, both the mycorrhizal mix and the hydroabsorbent Hydrogel® are expected to improve the properties of the soil environment [16, 17] and increase the resistance of woody plants to drought, especially in the case of mycorrhizal mix [18, 19]. Fungi primarily have the ability to make water and nutrients available to plants through their mycelium and to help plants survive a longer period of drought compared to plants without an established mycorrhizal symbiosis [20, 21], they influence the physical properties of soils, the formation of soil aggregates and their stability, as well as the content of organic matter in the soil. There is little information on the influence of soil temperature and moisture conditions after their application [22]. From a two-year observation, it is possible to say that the application of soil conditioners influenced the temperature and humidity conditions of the soil environment in the observed variants. In the case of mycorrhizal symbiosis in the first year after application, lower values of volumetric soil moisture were recorded compared to the Control variant, especially in the soil profile of 0.1-0.4m. Similar results were also reached by [23], where the authors state that mycorrhizal fungi in loamy soil can influence their drainage and conversely, increase water accumulation in sandy soils. In the second observation, the variant of application of the mycorrhizal preparation achieved higher average volume moisture values, especially in the soil profile of 0.4-0.7m, mainly in the months with higher temperatures and during the growing season. [24] noted changes in soil properties after seven months after the application of the mycorrhizal preparation (mix). [25] state that soil moisture also affects the growth and development of mycorrhizal fungi. It is therefore due to the fact that their significant development took place at the experimental location only during the next year 2022, which was an average precipitation year and overall sum of precipitation was higher compared to year 2021. The application of Hydrogel®, even in combination with its enrichment with a mycorrhizal mix, fulfilled the assumptions that their application will have a positive effect on soil moisture. These assumptions are based on many studies devoted to this issue [26, 27, 28].

In the first year (2021), approximately from the months of June and July, during full vegetation and the plants water intake needs, apparently due to very low total precipitation to reduce the soil moisture values, especially for the Hydrogel variant. The Hydrogel variant in combination with the mycorrhizal mix also achieved higher average values in the month during vegetation compared to the Control variant. In the variant with the Hydrogel®, higher soil moisture values were recorded in the second year of observation compared to the Control variant, these differences were statistically significant in most cases.

Conclusion

In conclusion, based on the results achieved, it is obvious that:

- Injection of soil conditioners Hydrogel® and mycorrhizal mix Endomyk PROF + Tri into root zone (0.1-0.7m) of young trees influenced volumetric soil moisture and soil temperature.
- Soil temperature was influenced by soil conditioners especially in conditions of higher average air temperatures, i.e. especially in the growing season.
- Both the mycorrhizal mix and Hydrogel® positively affect the volumetric soil moisture. In the case of a mycorrhizal mix, this effect is conditioned by suitable conditions for the growth of fungi mycelium.
- The effect of a one-time injection of used soil conditioners is evident even several months after application, and their long-term effect can be assumed.

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