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The biological additives as cey factor on soil moisture dynamics in the context of climate change

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ABSTRACT

In recent years, climate change trends specific to the world's regions have been observed in Lithuania. Droughts and torrential rains are increasingly being recorded, causing long-term waterlogging. As Lithuania is an agrarian country, the horticulture sector is developed. Abundant growers of potatoes, cabbage and other vegetables are counted in years. It is estimated that the consumption of potatoes in Lithuania is more than 96 kg per capita per year. However, potatoes, which are grown by the majority of crop farms, suffer most from frequent natural droughts. To lower droughts influence, farmers can install irrigation systems or use biological additives in the field, such as agroperlite and agrovermiculite. The experiment was conducted at the two experimental farms in Lithuania, growing '*Vineta*' potatoes. The aim of the study was to determine the dynamics of soil moisture in May-August, when different amounts (effects of different percentages) of biological additives are added to the soil. In 2020, the amount of precipitation varied during the research period. During the whole period in Pupasodis fields precipitation was 234 mm. During observed period, 77% of all decades were drier than perennials (DNs). In Šilavotas fields, it was found that 351.5 mm of precipitation fell during the observed period, which is 164.3 mm more than in the Pupasodis area. The distance between experiment plots was more than 70 km. The study results show that soil temperature correlates with exponential dependence with precipitation. The correlation coefficient $r = 0.69$, and when assessing the relationship between soil temperature and ambient temperature, a linear dependence and $R = 0.5649$ were found.

Keywords: volumetric water content, soil moisture, mineral additives, precipitation.

1 INTRODUCTION

Many authors note that the yield of agricultural crops is greatly influenced by meteorological conditions (Bujauskas, 2001). In Lithuanian soils, crop yields vary greatly due to meteorological factors, the yield is determined by the air temperature and atmospheric precipitation for all decades.

Potato (*Solanum tuberosum* L.) is a traditional, one of the main food products in Lithuania. They are grown by most farmers and consumed more than 96 kg per capita per year (Bujauskas, 2001). Potato is a shallow rooted crop and extremely sensitive to water stress (Jefferies & Heilbronn, 1991; Fabeiro, Martín, & Juan, 2001; Alva, Moore, & Collins, 2012). The deficit of water has great influence on commercial potato production (Bujauskas, 2001). Soil, water and temperature have been shown to be in potato plant growth and tuber production (Epstein, 1966; Singh, 1969; Wang *et al*., 2005).

In recent years, drought and soaking problems in Lithuania have become more frequent. Potatoes and maize suffer most from natural droughts, as they need moisture most in July and August (Švedas & Antanaitis, 2000). Most researchers say that the highest potato yield can be grown when the soil moisture is 80% of the field moisture capacity (FMC). When the soil is too dry (15–20% FMC) or too moist (up to 90–100% (FMC)), the potato yield is low (Bujauskas, 2001; Ražukas, 2003). For this, it is necessary that the tubers receive at least 5–6 mm of water from the soil moisture resources every day. The main indicator of the onset of irrigation is the dry top layer (up to 6 cm deep) of the soil. Potatoes are planted when the soil is already warmed to 7–8 °C at a depth of 10 cm and germinated to 6 °C.

In order to avoid droughts, farmers have several options – to install irrigation systems or to use mineral additives in the fields, which help to increase soil moisture and thus reduce the need for irrigation.

Mineral additives potentially influence infiltration rates, density, soil structure, compaction, soil texture, aggregate stability, crust hardness (Helalia & Letey, 1989), and evaporation rates (Teyel & El-Hady, 1981). They increase the water in the soil available to the plant, which prolongs plant survival under water stress (Huttermann, Orikiriza, & Agaba, 2009; Jobin *et al*., 2004; Agaba *et al*., 2011). Mineral additives can hold or accumulate hundreds of times more water than they weigh themselves. Agrovermiculite, agroperlite, and hydrogel are most often used to hold soil moisture in agriculture. Also, they 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 capillary action.

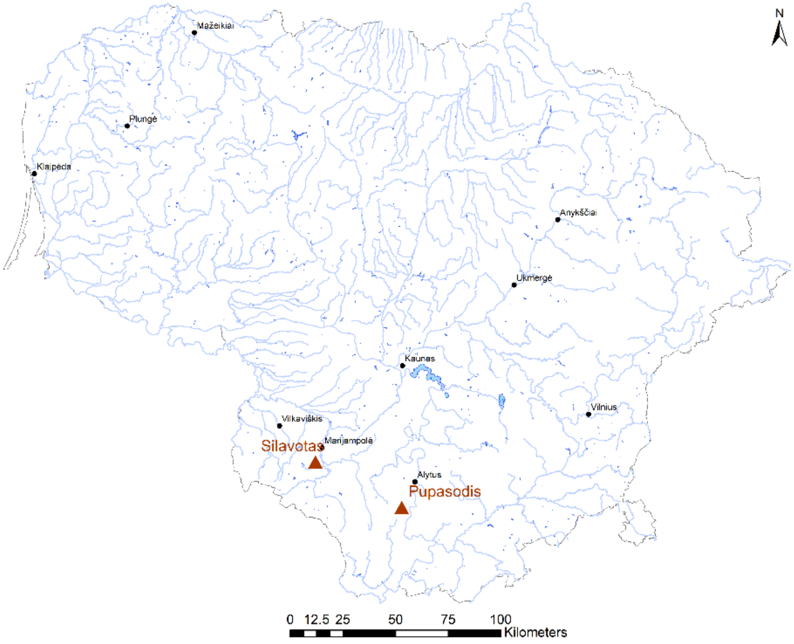
All of these benefits lead to increased plant growth. Most of the articles cited here focus on how these additives affect yield, crop quality, and plant engraftment, and only a few analyses additive ability to bind moisture.

The aim of the study was to determine the dynamics of soil moisture in May–August, when different amounts – 0.5 cm, 1 cm and 2 cm of biological additives are added to the soil.

2 MATERIALS AND METHODS

The experiment was conducted at the two experimental farms in Šilvotas (SF) and in Pupasodis (PF) villages in Lithuania (Figure 1). The aim of the study was to determine the dynamics of soil moisture in May–August, when different amounts (effects of different percentages) of biological additives are added to the soil.

Figure 1. Place of experiment.



The physical and chemical properties of the soil (Table 1) were determined, samples were taken at a depth of 0–30 cm, the tests were performed in an accredited laboratory.

Table 1 Physical and chemical properties of the soil at a 0-30 cm depth on the study sites

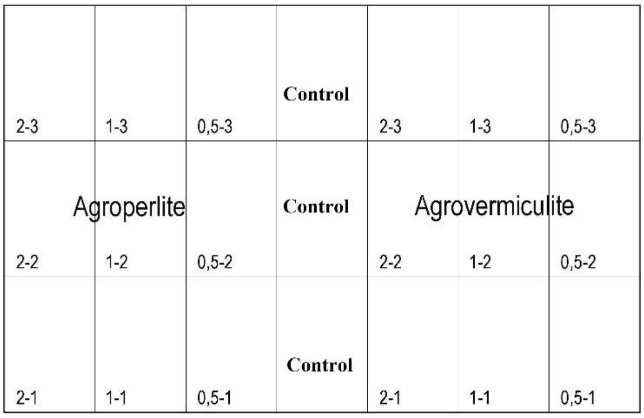
Soil property	Units	Value	
		Pupasodis	Šilavotas
Sand	2000-63 µm	90.6 ±7.1	93.2±7.1
Silt	63 - 2 µm	6 ±0.5	4 ±0.5
Clay	<2%	3.4 ±0.3	3±0.3
ph.	ph 1 mol / KCl suspension	6.2 ±0.2	5.3 ±0.2
Concentration of mobile phosphorus (P_2O_5)	mg kg^{-1}	334	300
Concentration of mobile potassium (K_2O)	mg kg^{-1}	120	140
Concentration of mobile magnesium (Mg)	mg kg^{-1}	144	150

PS. The particle size distribution was performed according to s- ISO 11277-2020 N.

It was found that at SF study site soil mechanical composition is – loamy sand, and PF study site – sandy. Low acidity or neutral reaction soils (pH 6.5–7.0) are most suitable for potatoes.

In both farms, potatoes were grown in the experimental fields. '*Vineta'* varieties of potatoes were planted on April 8 in SF and on May 6 in PF. The effectiveness of soil moisture retaining additives was studied by spreading a layer of agroperlite or agrovermiculite of different thickness (0.5 cm – 2%; 1 cm – 4%; 2 cm – 8%, as a volumetric percent of soil) on the soil surface. The Figure 2 shows how the experimental 5-acre area is arranged for different amounts of biological additives.

Figure 2. Scheme of mineral additives ratio in the soil in the experimental field (explanation: 2-1 mean -2 cm of agroperlite 1 repeat, all ratio has 3 repeats).



2-3	1-3	0,5-3	Control	2-3	1-3	0,5-3
2-2	Agroperlite 1-2	0,5-2	Control	Agrovermiculite 2-2	1-2	0,5-2
2-1	1-1	0,5-1	Control	2-1	1-1	0,5-1

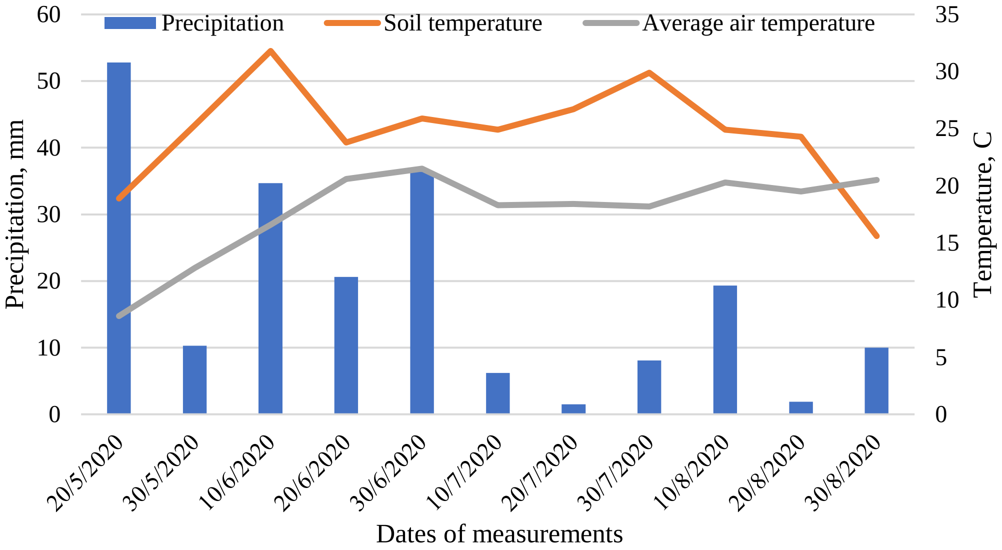
A ‘TDR 150’ device was used to measure the volume of water (%) in soil, the operation of TDR is based on the measurement of the rate of change of voltage (wave). The voltage is supplied by a wire which enters the measuring probe and is inserted into the soil. The rate of propagation of the voltage pulse in the measuring probe is a dimension that can be interpreted as soil moisture in an appropriate ratio. The smaller the pulse propagation speed, the wetter the soil. Soil moisture measurements were performed every 10 days at a depth of 0–20 cm, and soil temperature was also recorded with 3 measurements in each test field.

Meteorological data of the analyzed period were used from the nearest Alytus and Marijampolė meteorological stations.

3 RESULTS AND DISCUSSION

In 2020, the amount of precipitation changed during the research (Figure 3). During the whole period observed in 2020, in the study fields in PF precipitation was 234 mm and on May 2, the most abundant precipitation was recorded – 52.8 mm. During this short observation period, the soil moisture content was at its most optimal for potato germination conditions. During the 1st and 3rd decades of August, 34.7 mm and -21.7 mm of precipitation fell. Over the next 6 decades, less than 10 mm of precipitation was observed per decade. During this observed period, 77% of all decades were drier than perennials (DNs). Comparing the dynamics of daily average temperatures with the soil temperature that were fixed from the 1st decade of May to the 2nd of August, the soil temperature at the time of measurement (11–12 a.m.) was always at 12–16 degrees higher. Later, this difference became more even, because from the beginning of June the daily temperature did not fall below 20 °C.

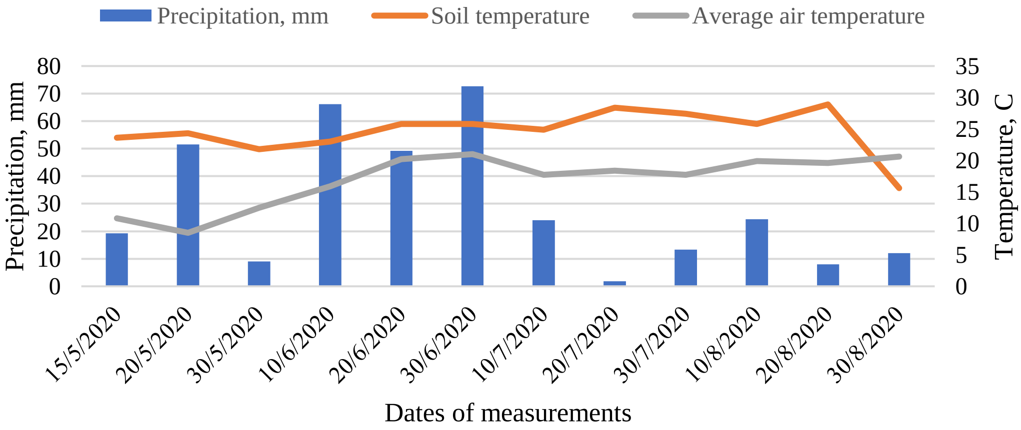
Figure 3. Dynamics of observing meteorological conditions at PF.



Analyzing the amount of precipitation in SF (Figure 4), it was found that 351.5 mm of precipitation fell during the observed period, which is 164.3 mm more than in the PF study fields. The distance between experiment plots is more than 70 km. In the 3rd decade of June, 72,7 mm of precipitation fell. Precipitation was observed below the perennial rates for the 5th observed decade (1st and 3rd decades of May, 2nd and 3rd of July, 2nd of August). It stood out for the 2nd decade of July, then it fell to 1.8 mm of precipitation. Comparing the amounts of precipitation between the two fields, we see that dry and warm weather prevailed in the second half of the vegetation period.

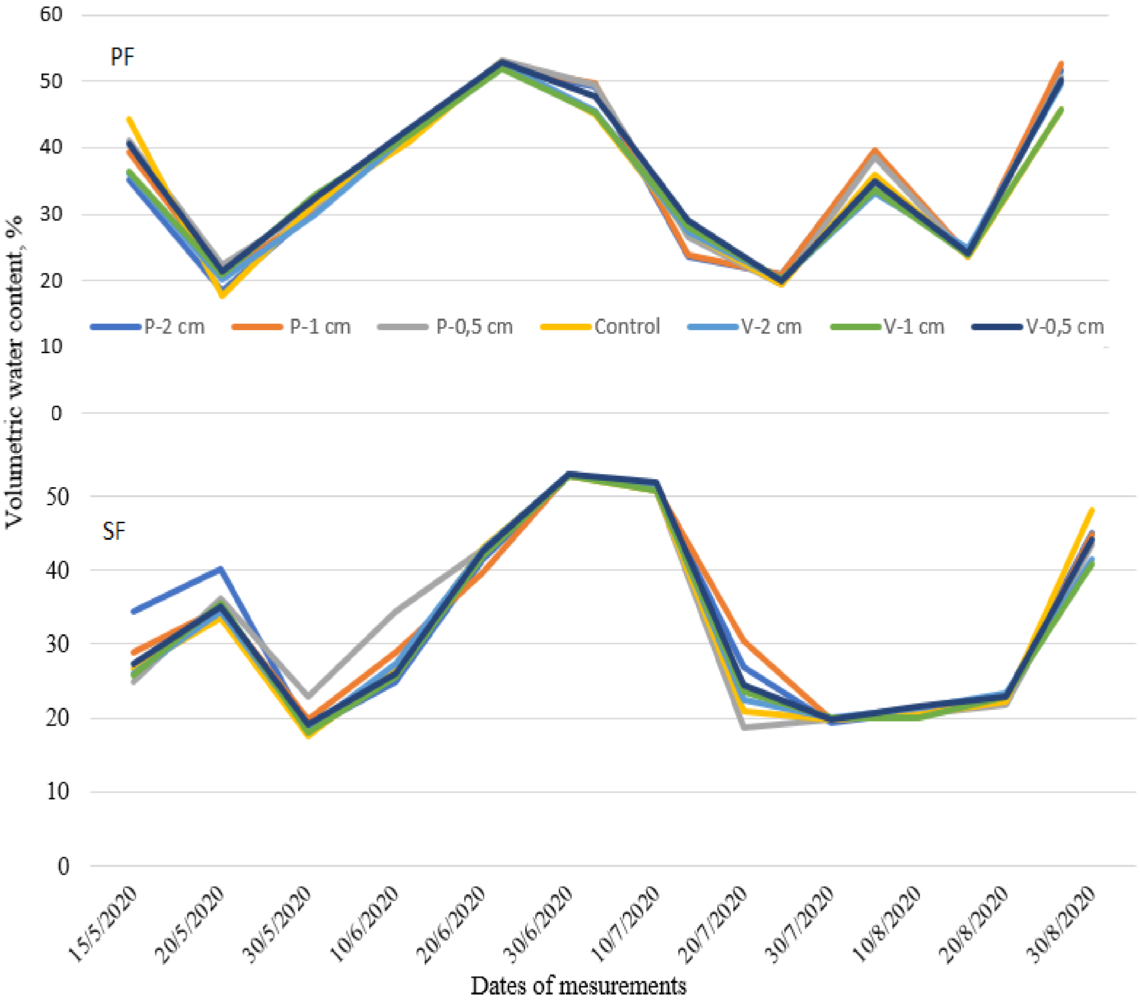
Assessing the dynamics of soil temperature (Figure 3), we observe a tendency that from the 2nd decade of May the soil layer up to 20 cm thick warms up and maintains higher than average daily temperatures up to 15 °C. In the study fields SF and PF, we see that in the 2nd and 3rd decades of August there is a change between the average ambient temperature. It becomes higher than the soil surface temperature.

Figure 4. Dynamics of observing meteorological conditions at SF.



Soil moisture measurements were performed at 10-day intervals. In Figure 5, we see that the soil moisture dynamics overlap in the same field of study even with different rates of biological additives. However, as it might be expected, soil moisture dynamics are mostly influenced by precipitation and air temperature. However, studies performed on PF show that less changes in soil moisture are observed with agrovermiculite than with agroperlite. Agroperlite additives keep soil moisture for longer. In PF fields, during the dry period from the second decade of July till the second decade of August, up to 5% difference in soil moisture dynamics compared to the control fields is observed.

Figure 5. Volumetric soil moisture dynamics in experimental fields.



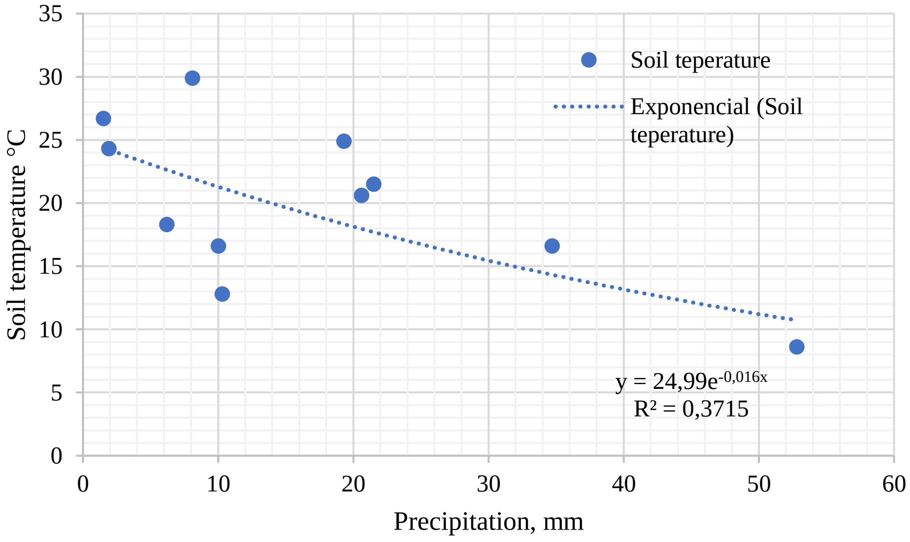
After analyzing the soil moisture dynamics in SF fields, we see that between first and second decades of July, due to high daily average temperatures and low precipitation (25.8 mm), even with the use of biological additives, soil moisture fall could not be stopped. In the control fields it dropped to – 21% (from 51%) and in the fields with 1 cm of agroperlite the soil moisture dropped from 51.1% to 30.4%. However, we record a 10% difference in volumetric water content between the fields, which means that agroperlite spreading it in a 1 cm layer when planting potatoes is able to retain soil moisture longer. The results presented in Table 2 show that the differences in volumetric water content in the experimental fields range from 2.07% to 3.66%.

Table 2 The analysis of volumetric soil moisture

Mineral additives ratio	Average volumetric soil moisture, %		Standard deviation, %		α
	PF	SF	0.05	SF	
P-2cm	35.29	33.22	12.67	12.63	0.05
P-1cm	36.01	32.89	12.63	11.99	
P-0.5cm	36.11	32.43	12.17	12.69	
Control	34.97	31.92	11.82	13.29	
V-2cm	34.71	31.85	11.53	12.38	
V-1cm	34.61	31.48	10.74	12.40	
V-0.5cm	36.00	32.30	11.72	12.53	

As climate change has a major impact on farmers ’work schedules, planting and digging deadlines are adjusted. The study found that soil temperature correlates with exponential dependence on precipitation (Figure 6).

Figure 6. Exponential relationship between soil temperature and precipitation.



The correlation coefficient r = 0.69, and when assessing the relationship between soil temperature and ambient temperature, a linear dependence and coefficient of determination R = 0.5649 were found, and the correlation between these two environmental phenomena is very strong at r =0.751.

4 CONCLUSIONS

In 2020, the amount of precipitation changed during the research. During the whole period observed in 2020, in the study fields in PF, precipitation was 234 mm. During this period, 77% of all decades were drier than perennials (DNs). In SF, it was found that 351.5 mm of precipitation fell during the observed period, which is 164.3 mm more than in the PF study fields. The distance between experiment plots was more than 70 km. Comparing the amounts of precipitation between the two fields, dry and warm weather prevailed in the second half of the vegetation period.

Average differences between volumetric water content ranged from 2.07% to 3.66% (to compare all observed data) between Pupasodis and Šilavotas villages experimental fields. A difference of 2.98% was found between the two control fields. The results explain differences in final amount of production in different regions of Lithuania.

The study found that soil temperature correlates with exponential dependence on precipitation. The correlation coefficient r = 0.69, and when assessing the relationship between soil temperature and ambient temperature, a linear dependence and coefficient of determination R = 0.5649 were found, and the correlation between these two environmental phenomena is very strong at r =0.751.

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