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EFFECTS OF CLIMATIC CONDITIONS, ORGANIC AMENDMENTS AND PLANT CULTIVATION SYSTEM ON SOIL WATER CONTENT

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Abstract

The soil water availability is essential for soil organisms activity, for the growth and development of cultivated plants as well as for soil tillage. It can affect the sustainability of agricultural production and the resilience of agro-ecosystems. This paper refers to soil water behavior during autumn-summer cropping cycle within a study conducted between October 2021 and September 2022 in a field experiment set up at Moara Domnească Teaching and Research Station of the USAMV of Bucharest, Romania. The study is part of a research topic aiming to evaluate the sustainability of agricultural production and the resilience of agro-ecosystems under the effects of climate change. The study is carried out on red preluvosoil in Sylvosteppe area of Romanian Plain. In order to achieve the study objectives monthly measurements regarding temperature and precipitation were performed. Starting with March 2022, determinations of soil moisture were made, and its evolution was followed under the effect of the mineral fertilizers, manure compost and of agricultural crops (wheat, maize, soybean and mixtures of perennial grasses).

Key words*: organic amendments, soil moisture, plant cultivation system, red preluvosoil, wilting point.*

INTRODUCTION

Water is of primary importance for the growth of plants and at the same time a limiting factor at the global level considering the climatic conditions. In many water-scarce areas, crop production is very limited (Vereecken et al., 2008). But climate change makes that even in temperate areas, where water used to be provided by rainfall, the absence of water is felt especially in the critical phenological phases of cultivated plants, and the impact on production is increasing, sometimes even compromising production.

The availability of water in the soil is important for crop production, including tillage, but also for the physico-chemical properties of the soil and for the activity of macro and micro-organisms in the soil (Mujdeci et al., 2017). Plants uptake the water for their growth and development through their root system, only a small quantity of it being taken by leaves, stem and branches (Mujdeci et al., 2017).

"During their growth, most annual plants absorb from soil in temperate climatic conditions 300 to 500 units of water for each unit dry matter formed" (Russell and Sir, 1937).

The amount of water from soils could affect the sustainability of agricultural production and the resilience of agroecosystems (Seneviratne et al., 2010).

Crop production in agricultural systems is inextricably linked to the presence of water. The impact of soil moisture in the climate system is related to its role for evapotranspiration in soil moisture-limited regimes. The soil moisture is directly linked to the soil water potential or soil suction (how tightly the water is bound to the soil matrix) (Seneviratne et al., 2010).

Through the actions undertaken for the purpose of growing plants, through the intensity and timing of certain works, man can contribute both to the improvement of soil water-holding capacity and to the degradation of its physical properties. The soil tillage methods influence the soil characteristics (pore size distribution, soil porosity, bulk density) which are related to moisture and that determines the amount of plant available water holding capacity of soil (Gao et al., 2017; Bai et al., 2016; Mujdeci et al., 2017).

There are many differences between soils regarding their water-holding capacity, which is determined by the physical properties, the content in organic matter, the climatic characteristics of the area etc. One of the most important strategies for increasing the soil water-holding capacity and for improving its

water regime is the application of organic fertilizers (Seyedsadr et al., 2022). "Fertilization has a strong influence on soil water content, because it stimulates plant growth and thus the plant use of soil water and its distributions" (Ritchie and Johnson, 1990). The organic a-mendments influence the wet range of the soil water retention characteristics differently (Zhou et al., 2020). "Organic amendments may (Zibilske et al., 2000) or may not (Gupta et al. 1977) increase available water in soil, most of this increase resulting from the water adsorbed by the organic matter" (Larney and Angers, 2012).
The influence of organic amendments on soil water content is very important in degraded sandy soils than fine-textured soils, the latter having greater intrinsic water-holding capacity (Larney and Angers, 2012). In sandy loam and clay soils, the application of organic composts had different effects on the soil moisture. For example, treatments with high rates of organic composts applied after crop harvest show a positive impact on soil water content in sandy loam soil in 0-15 cm depth but, on clay soil, various treatments with organic composts had no significant effect on soil moisture in 0- 20 cm depth (Gagnon et al., 1998). Under 8-year manure amendments, the soil water content in the 0-10 cm soil layer increased compared with the sole application of mineral fertilizer (Yang et al., 2011). Also, through the application of ammoniated straw (ammonification of crop straw through adding urea), during a 3-year period, the soil water storage and crop water productivity increased significantly in a summer maize - winter wheat rotation (Yu et al., 2017).
Again, the differences in organic amendments composition could have different effects on soil water content and crop water productivity through the changes in soil functions (Hossain et al., 2017; Barzegar et al., 2002; Yazdanpanah et al., 2016).
The main objective of this study is to assess the effect of climatic conditions, organic amend-ments applied to soil and plant cultivation system on soil water moisture during an annual crop production cycle.

MATERIALS AND METHODS

The experiments were carried out in Moara Domnească Teaching and Research Station of the University of Agronomic Sciences and Veterinary Medicine (USAMV) of Bucharest situated in a Sylvosteppe ecological area of Romanian Plain, with characteristic type of soil, which is red preluvosoil. The preceding crop was alfalfa. In the fall of 2021, due to the drought, the soil was worked with the scarifier at 40 cm depth. Before sowing period, it rained enough so that the seed bed could be prepared by two passes with the cultivator, soil having an average moisture of 19.5%. The physico-chemical characteristics of soil are presented in Table 1.

Table 1. The physico-chemical characteristics of the red preluvosoil from Moara Domneasca Experimental Field

Soil parameters	Mean values
pH	5.89
C_org. (%)	2.02
N_{total} (%)	0.216
N-NO_3 (mg/kg d.m.)*	28.67
N-NH_4 (mg/kg d.m.)	9.12
P_{AL} (mg/kg d.m.)	86.04
K_{AL} (mg/kg d.m.)	289.5

* mg kg^{-1} dry matter

The experimental field was organized into 4 blocks, and each block was organized into 8 plots (32 in total), each one with an area of 15 square meters. Eight (8) experimental variants (V_1.....V_8) in 4 replicates have been organized with the following treatments: V_1-control (soil); V_2 - fertilized only with complex chemical fertilizers (NPK); V_3 - 15 t/ha compost; V_4 - 15 t/ha compost + complex chemical fertilizers (NPK); V_5 - 30 t/ha compost; V_6 - 30 t/ha compost + complex chemical fertilizers (NPK); V_7 - 60 t/ha compost; V_8 - 60 t/ha compost + complex chemical fertilizers (NPK). The complex chemical fertilizers were applied fractionally (Table 2; Photo 1).
The experiment included the following crops: 1) winter wheat (*Triticum aestivum* L.), 2) mixture of grasses (rye grass - *Lolium perenne* L., smooth meadow-grass - *Poa pratensis* L. and orchard grass - *Festuca pratensis* L.) and perennial legumes (white clover - *Trifolium repens* L., birdsfoot trefoil - *Lotus corniculatus* L.), 3) soybean (*Glycine max* L.) and 4) maize (*Zea mays* L.).

Table 2. Fraction of mineral fertilizers applied to crops during the study

Treatment	Wheat		Mixture of grasses		Maize			Soybean		
	Fraction 1 (24-03-2022)	Fraction 2 (15-04-2022)	Fraction 1 (24-03-2022)	Fraction 2 (15-04-2022)	Fraction 1 (15-04-2022)	Fraction 2 (13-05-2022)	Fraction 3 (30-05-2022)	Fraction 1 (15-04-2022)	Fraction 2 (13-05-2022)	Fraction 3 (30-05-2022)
V1 - control (soil)	-	-	-	-	-	-	-	-	-	-
V2 - NPK	57 kg/ha N + 57 kg/ha P_2O_5 + 0 K_2O	28 kg/ha N + 28 kg/ha P_2O_5 + 0 K_2O	40 kg/ha N + 40 kg/ha P_2O_5 + 0 K_2O	40 kg/ha N + 40 kg/ha P_2O_5 + 0 K_2O	40 kg/ha N + 40 kg/ha P_2O_5 + 0 K_2O	46 kg/ha N + 46 kg/ha P_2O_5 + 0 K_2O	29 kg/ha N + 29 kg/ha P_2O_5 + 0 K_2O	18 kg/ha N + 18 kg/ha P_2O_5 + 0 K_2O	20 kg/ha N + 20 kg/ha P_2O_5 + 0 K_2O	13 kg/ha N + 13 kg/ha P_2O_5 + 0 K_2O
V3 - 15 t/ha compost	-	-	-	-	-	-	-	-	-	-
V4 - 15 t/ha compost + NPK	42 kg/ha N + 42 kg/ha P_2O_5 + 0 K_2O	21 kg/ha N + 21 kg/ha P_2O_5 + 0 K_2O	29 kg/ha N + 29 kg/ha P_2O_5 + 0 K_2O	29 kg/ha N + 29 kg/ha P_2O_5 + 0 K_2O	29 kg/ha N + 29 kg/ha P_2O_5 + 0 K_2O	34 kg/ha N + 34 kg/ha P_2O_5 + 0 K_2O	21 kg/ha N + 21 kg/ha P_2O_5 + 0 K_2O	16 kg/ha N + 16 kg/ha P_2O_5 + 0 K_2O	18 kg/ha N + 18 kg/ha P_2O_5 + 0 K_2O	11 kg/ha N + 11 kg/ha P_2O_5 + 0 K_2O
V5 - 30 t/ha compost	-	-	-	-	-	-	-	-	-	-
V6 - 30 t/ha compost + NPK	27 kg/ha N + 27 kg/ha P_2O_5 + 0 K_2O	13 kg/ha N + 13 kg/ha P_2O_5 + 0 K_2O	18 kg/ha N + 18 kg/ha P_2O_5 + 0 K_2O	18 kg/ha N + 18 kg/ha P_2O_5 + 0 K_2O	19 kg/ha N + 19 kg/ha P_2O_5 + 0 K_2O	22 kg/ha N + 22 kg/ha P_2O_5 + 0 K_2O	14 kg/ha N + 14 kg/ha P_2O_5 + 0 K_2O	13 kg/ha N + 13 kg/ha P_2O_5 + 0 K_2O	15 kg/ha N + 15 kg/ha P_2O_5 + 0 K_2O	9 kg/ha N + 9 kg/ha P_2O_5 + 0 K_2O
V7 - 30 t/ha compost	-	-	-	-	-	-	-	-	-	-
V8 - 30 t/ha compost + NPK	In V_8, for winter wheat, mixture of perennial grasses and maize, according to the calculation, the amount of manure compost should have ensured the nutrient requirements (NPK) and it was decided not to supplement it with chemical fertilizers.							8 kg/ha N + 8 kg/ha P_2O_5 + 0 K_2O	10 kg/ha N + 10 kg/ha P_2O_5 + 0 K_2O	6 kg/ha N + 6 kg/ha P_2O_5 + 0 K_2O

Photo 1. Application of different doses of manure compost in Moara Domneasca Experimental Field plots

Measurements regarding precipitation and temperature were performed monthly as well as determinations of soil moisture (Figure 1). After 20th of October 2021, the quantity of precipitation (57.2 mm) and the soil moisture allowed sowing winter wheat in the optimal time and in good conditions. Unfortunately, the prolonged drought did not allow sowing the mixture of perennial grasses and legumes during September. The delay in sowing the mixture of perennial grasses by almost a month made the sprouting of the plants to be deficient, even if the favorable climatic conditions in autumn lasted until November. The perennial grasses had a good germination but did not germinate, and the perennial legumes generally did not germinate. Thus, in the spring of 2022, an over seeding was done to obtain a more consistent vegetation cover.

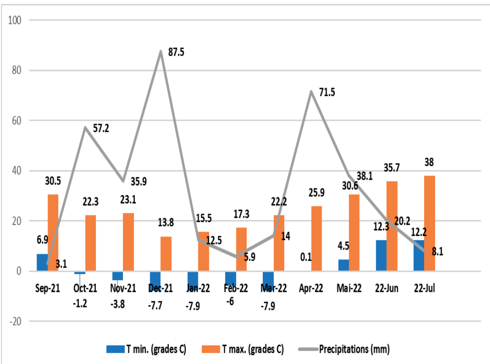

Figure 1. Climatic conditions in Moara Domnească Experimental Field, September 2021-July 2022 period

In January-July, the minimum temperatures varied between -7.9 and 12.2°C and the maximum temperatures between 15.5 and 38°C. The precipitation regime was deficient during the first three month of 2022, the amount of precipitations varying between 5.9 mm (February) and 14 mm (March). April, corresponding to the sowing period for maize and soybean, was characterized by minimum temperatures of 0.1°C and maximum temperatures of 25.9°C, and the monthly amount of precipitation was 71.5 mm.

Starting with March 2022, soil samples were taken from each plot and determinations of soil moisture and wilting point (WP) were made and their evolution was followed under the effect of organic matter (manure compost) for all crops (winter wheat, maize, soybean and mixtures of perennial grasses and legumes). Soil samples were collected at a depth of 0-20 cm. To determine soil moisture, the gravimetric method was used with the drying of soil samples in aluminum ampoules at a temperature of 105°C for 8 h. The wilting point was calculated indirectly based on hygroscopicity coefficient. This one was determined by exposing the soil in a thin layer to an atmosphere of definite humidity under conditions of constant temperature and pressure.

RESULTS AND DISCUSSIONS

Water acts as a solvent and as a medium for the transfer of nutrients from the soil to plants. As a nutrient, water becomes part of the cell contents without changing or is broken down into its elements and used in the production of new compounds. Thus, in proper amounts, soil moisture becomes one of the controlling factors in crop growth. The amount of water held within the plant is not much in comparison with the amount that is lost by evapotranspiration (Lyon and Buckman, 1922). In the conventional agriculture system, 50-60% of the water from rainfall is lost through evaporation during one year (Rusu et al., 2015).

During March-July 2022, the soil water content in 0-20 cm depth has fluctuated depending on climatic conditions and cultivated plants. Thus, in March, the lowest value of soil moisture was determined in the plots where maize and soybean were to be sown (17.11% in maize plots and 17.3% in soybean plots) and the highest values were registered in the soil cultivated with winter wheat (19.3%) followed by the soil covered by the mixture of perennial grasses and legumes (18.5%) (Figure 2). The denser the vegetation cover, the higher the degree of water conservation in the soil (Photo 2).

a) b)

Photo 2. The vegetation cover in winter wheat (a) and mixture of perennial grasses and legumes plots (b) in March, 2022

The lower values of soil water content measured in the plots where maize and soybean were to be sown were due to the dry spring but also to the absence of the vegetation cover.

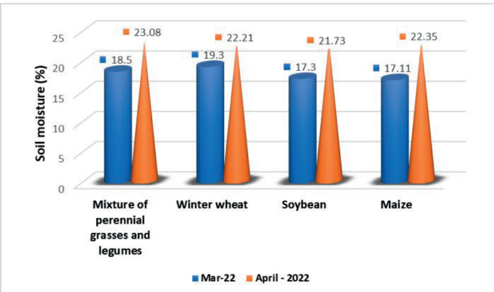

Figure 2. The soil moisture content during March-April period within soil cultivated with winter wheat, mixture of perennial grasses and legumes, soybean, and maize

In April, the amount of precipitation was good and thus the soil moisture values where higher in all plots, varying from 21.73% in soil covered by soybean to 23.08% in soil cultivated with mixture of perennial grasses and legumes.

Rational fertilizer application could facilitate sustainable and effective exploitation of available rainfall (Liu et al., 2020). Moreover, organic matter content in soil has an influence on its physico-chemical properties, being both a binder of particles and a permanent source of nutrients for plants (Carter, 2002). In this sense, our experiments show that the soil moisture content vary among crops and fertilization regime.

May 2022 was characterized by higher temperatures and a smaller quantity of precipitations (38.1 mm), which were also reflected by the soil moisture values. Thus, in winter wheat crop, the highest value of soil moisture was observed in the unfertilised variant (17.58%) followed by V3 (15 t/ha manure compost) with 16.29% and V5 (30 t/ha manure compost) with 15.59%. The lowest value was determined in V7 (60 t/ha manure compost) i.e. 12.81%.

In maize crop, the highest value of soil moisture was registered in variant V2 where only chemical fertilizer was added (21.46%) and the lowest soil moisture (18.76%) was determined in V3, with 15 t/ha compost (Figure 3).

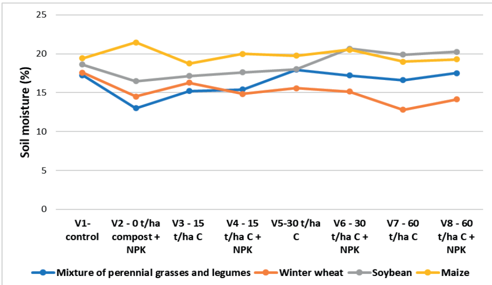

Figure 3. Soil moisture (%) under different fertilization regime and crops – May period, Moara Domneasca Experimental Field, 2022

In the mixture of perennial grasses and legumes, soil moisture had the highest values in the variants where 30 t/ha manure compost was applied, in the control and in the variant with 30 t/ha manure compost and NPK fertilizer (17.96%, 17.26% and 17.21%) and low values in the variant with chemical fertilizers only (13%). Also, in soybean plots, the lowest value of soil moisture was registered in V2 (16.48%) but the highest value in variant V6 (20.66%) (Figure 3).

In June, the pluviometric regime was deficient and the temperatures were higher than the normal registered for this period. The rising temperatures lead to an increase of evaporation at soil level and a decrease of soil moisture. However, the highest values of soil moisture were registered in soybean plots, in the variants V1 (14.89%), V8 (14.87%) and V4 (14.81%). In soil cultivated with maize, the highest soil moisture value was determined in V1 (13.95%), followed by V5 (30 t/ha compost) (13.77%) and V7 (60 t/ha compost) with 13.32% (Figure 4).

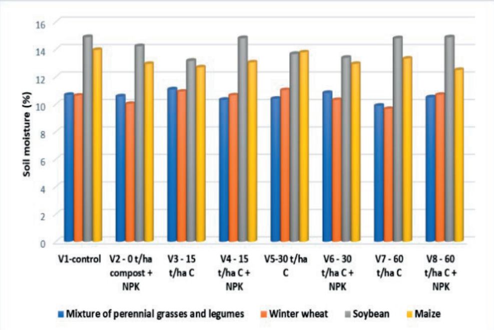

Figure 4. Soil moisture (%) under different fertilization regime and crops - June period, Moara Domneasca Experimental Field, 2022

In winter wheat and in the mixture of perennial grasses and legumes plots, soil moisture values were much lower than in soil covered by maize and soybean. Thus, in the soil cultivated with winter wheat, the moisture values varied from 11.02% (V5) to 9.65% (V7) and in the soil with mixture of perennial herbs, from 11.08% (V3) and 9.89% (V7) (Figure 4). It can be observed that in these two experiments, the lowest values for soil water content were determined in the variants where 60 t/ha compost was applied. An explanation could be that as it was the first year of compost application, the porosity of soil was higher so the bond between soil particles and organic matter was week which is in accord with Derdour et al. (1993). Thus, the effect of different doses of compost on soil water content could be better observed on long-term. Another explanation of this decrease of soil moisture could be associated with the increase of crop water demand for usage of the available nutrients from the applied fertilizers.

In July, the soil moisture fluctuated in relation with the deficient rainfall regime (8.1 mm) and registered in all experiments the lowest values from entire vegetation period. So, in drought conditions, the highest values of soil moisture were registered in soybean plots, these varying between 10.84% (V1) and 9.5% (V4). In case of soil covered by maize crop, the highest value was determined also in V1 (9.18%) and the lowest value, in variant with 15 t/ha compost (7.43%). In these two experiments it can be observed that soil moisture values are higher in variants where compost is applied in combination with mineral fertilisers.

In winter wheat plots, soil moisture was lower than in soybean plots, the highest value being determined in V8 (60 t/ha compost and NPK fertiliser treatment), i.e. 10.14%. This result can be explained by the fact that in periods with low precipitations, the increased soil organic matter content and a good vegetation cover led to an increased soil water retention. The lowest values of soil moisture in this period were registered in the soil covered by mixture of perennial grasses and legumes, i.e. between 11.08% (V3) and 9.89% (V7). This may be because the land was not covered very well by vegetation and high temperatures led to an increase of evaporation loses (Figure 5).

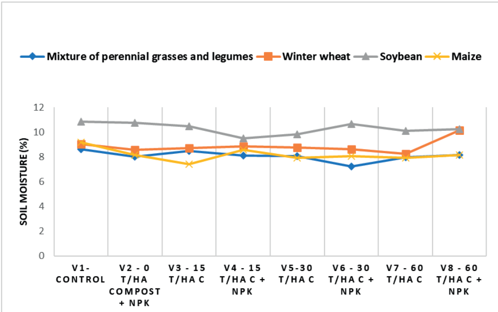

Figure 5. Soil moisture (%) under different fertilization regime and crops - July period, Moara Domneasca Experimental Field, 2022

The capacity of a soil to regulate the freshwater supply is a fundamental ecosystem service. The water percolated through soil is filtered, stored for plant utilization, and redistributed to groundwater and surface water bodies. Thus, the sustainability of water resources is directly influenced by soil (O'Geen et al., 2010).

The water from the soil is taken by the plant roots or evaporated from the topsoil into the atmosphere. If there is not an additional water supply to the soil, it gradually dries out and if the soil become very dry, the remaining water is retained more tightly, and plant roots are not capable to extract it. At a certain point, the water uptake is not sufficient to meet the plant's needs, so they are losing their freshness and wilts, they change the colour of leaves and finally the plant dies (Brower et al., 1985).

Our research showed that in plots cultivated with winter wheat, mixture of perennial grasses and legumes, soybean and maize, there was a strong correlation (R^2 was between 0.73 at winter wheat and 0.83 at soybean) between soil moisture values and the wilting point. As much as soil moisture decrease to WP, the greater the effort of the plants to absorb the water (Figure 6).

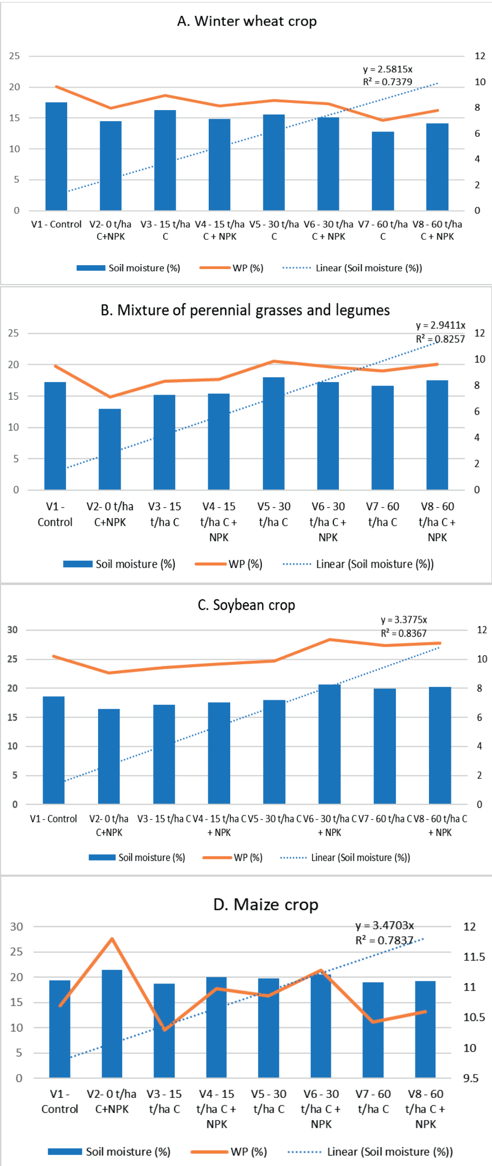

Figure 6 (A., B., C., D.). The correlation between soil moisture and wilting point in the winter wheat, mixture of perennial grasses and legumes, soybean, and maize, under different fertilization regimes, Moara Domneasca Experimental Field, May 2022

In winter wheat plots, the WP determined in May period showed a variation from 9.65% in the control and 7.78 % in V8 where 60 t/ha manure compost + NPK were applied. In the mixture of perennial grasses and legumes, the lowest value of WP was in V2 (7.14%) and the highest, in V5 (9.86%).
In soybean plots, the WP values were between 11.35% in V6 (30 t/ha C + NPK) and 9.05% in V2 (only NPK fertilizer) and in the soil cultivated with maize, the lowest value of WP was registered in V3 (10.3%) and the highest value, in V2 (11.8%).

CONCLUSIONS

The soil moisture varied under the influence of climatic conditions and crops, and with the fertilization regime. So, during the vegetation period, complex relationships are established between soil, water and plants, which are strongly influenced by the evolution of climatic conditions, especially by the rainfall regime.
Climatic factors have a strong influence on plant-water relationships, but the soil is the key for water regulation acting as a sponge to hold water against gravitational forces in forms that are available for plants. So, maintaining a good structure of the soil through organic matter addition can lead to an increase of plant available water holding capacity. Also, understanding the soil-water relation is fundamental for the most land use decisions.
In the conditions where only the water from the precipitation would ensure soil moisture and therefore the water necessary for the growth and development of plants, a good water capacity of the soil would be essential for the sustainability of the agroecosystem. At the same time, a good correlation of the natural supply of precipitation with the water needs of the cultivated plant species would be necessary and useful. The elements of cultural technology such as the distances between plant rows and between plants in a row, respectively the density of the vegetation cover, are also important for an efficient use of soil water and for achieving crop production.
Research on the effects of organic fertilization must continue in the coming years to be able to reveal the contribution of organic matter from compost in the medium term on the physical

properties of the red preluvosoil and on its water regime.

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