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THE EFFECT OF MULCHING ON THE BIOLOGICAL AND PHYSICAL PROPERTIES OF SOIL IN MAIZE

MAXWELL MODIBA MAIMELA – HANAA THARWAT MOHAMED IBRAHIM – BARBARA SIMON – IGOR DEKEMATI

Abstract

To study the effect of different mulching levels on the physical and biological properties of the soil. A field experiment was conducted in Gödöllő Szárítópuszta of the Hungarian University of Agriculture and Life Sciences experimental farm (Pest county). The experiment was laid down in a random block design with five treatments, namely M0%= control, M25%= 25%, M50%= 50%, M75%= 75%, and M100%= 100% level of mulch cover. Soil moisture content (SMC), soil penetration resistance (SPR) and earthworm abundance were measured. SMC, SPR and earthworm abundance were taken at 15-day intervals unless the weather prevented sampling. The experiment was set up from May 2019 until September 2019. The statistical data was carried out using one-way variance analysis with Tukey HSD (Honestly Significant Difference) multiple comparisons post hoc tests. The significance level used in the statistical studies was 5%. Mulch treatments improved water significantly in the first two months (June and July) of crop growth at 10 and 20 cm, however, moisture was not conserved for too long. Mulch treatment did not affect penetration resistance in all treatments. SPR was high after July in all the treatments due to low SMC. The measured SPR reached 5.3 MPa in August in M25%. The highest earthworm abundance was measured at M100% in August while the lowest was measured in control treatments. The grain yield was highest at M50% (1704 kg/ha) compared to the control. Mulch treatments were assessed based on factors such as soil moisture content, biological activity and penetration resistance and mulch was partially found to be advantageous.
Keywords: *mulching, soil moisture content, soil penetration resistance, earthworm abundance, maize*

A KUKORICA MULCSOZÁSÁNAK HATÁSA A TALAJ BIOLÓGIAI ÉS FIZIKAI TULAJDONSÁGAIRA

Összefoglaló

A növényi maradványok meghagyása egy fontos talajkímélő gyakorlat, amely számos előnnyel jár, ugyanis javítja többek között a talaj vízmegtartó képességét, a szervesanyag-tartalmát és biológiai aktivitását. A kísérlet célja az volt, hogy különböző mennyiségű talajtakaró anyag hatását vizsgáljuk meg a talaj fizikai, biológiai tulajdonságaira, valamint a terméshozamra. A vizsgálatot 2019-ben végeztük a Magyar Agrár- és Élettudományi Egyetem gödöllői kísérleti gazdaságában, Szárítópusztán. A kísérletet véletlenszerű, blokk elrendezésben, egy ismétléssel és öt kezeléssel állítottuk be. A kezelések eltérő mennyiségű takaróanyagból álltak (M0% kontroll, M25%, M50%, M75% és M100%). A talajnedvesség, a giliszta egyedszám és a talajellenállás mérése a vegetációs időszakban havonta kétszer történt. Eredményeink azt mutatták, hogy a talaj nedvességtartalma június és július hónapban szignifikánsan magasabb

volt a mulcsozott parcellákban a kontroll parcellákhoz képest. A legmagasabb talajnedvesség-tartalmat az M100%-ban, a legalacsonyabbat július közepén az M0%-os parcellán kaptuk. A talajellenállás július után minden kezelésnél magas volt az alacsony talajnedvesség-tartalom miatt, a legmagasabb augusztusban az M25%-os parcellán. A legmagasabb giliszta abundanciát az M100%-nál mértük augusztusban, míg a legalacsonyabbat a kontroll kezeléseknél. A gabonatermés az M50%-nál volt a legmagasabb a kontrollhoz képest, a legalacsonyabb pedig az M0%-nál. A talajtakaró mennyiségének hatása részben előnyösnek bizonyult a talaj nedvességtartalmára, biológiai aktivitására, valamint a talajellenállására.
Kulcszavak: *mulcsozás, talajnedvesség, talajellenállás, földigiliszta darabszám, kukorica*

Introduction

Soil is critical in supporting human well-being by providing essential ecosystem services (BOGUNOVIC et al., 2017). Worldwide an estimated 2 billion hectares of land are considered degraded, that is, less productive due to deterioration of essential soil processes (GURJAR et al., 2017). Extreme climate phenomena, for instance, drought stress, water deficit or waterlogging, hailstorms, etc. have afflicted the soils of the Carpathian Basin in the last decade (BOTTLIK et al., 2013). Currently, climate change in our area is felt through extreme precipitation distribution and higher temperatures. The amount of precipitation does not change as much as its oscillation changes.

According to the scenario (IPCC, 2018), climate change is likely to have wide-ranging impacts on the water, especially in agricultural sectors. One of the most popular and key elements in global and regional climate change is water resources. VÁRALLYAY (2006) considered the increase in water use efficiency and soil moisture regulation a key issue in agricultural production in the Carpathian Basin.

In addition, from the point of view of soils, climate change affects many processes through physical properties such as soil water content, soil structure, soil penetration resistance, and through biological properties, primarily the abundance of earthworms. During the summer months, especially after the cereal harvest, the soil is heavily exposed to sunlight, which negatively affects the soil moisture content. With the aim of reducing the impact on water loss, in other words, increasing water use efficiency the wheat straw is spread on the surface of the soil. In case of maize production, the above-mentioned impacts on vegetation, in the same way, influence the characteristics of the soil, plant growth, and yield.

With the use of straw and her spreading (mulching), we can improve the micro-environment, such as retaining the soil moisture content in the soil, providing better conditions for crop growth, and controlling weeds.

In this study, our objective was to examine the impact of the different quantities of straw mulch applied to the soil surface in maize during vegetation with the aim of reducing evaporation, improving soil biological properties, and preserving the moisture within the soil and growth of maize.

Material and methods

Experimental area

The study was conducted at the Experimental and Training Farm of the Hungarian University of Agriculture and Life Sciences (MATE), Gödöllő-Szárítópuszta (47º 35 º 44 ′ N, 19 º 22 º 10 ′ E). The place is known to have a temperate climate with an average of 592.8 mm of rainfall yearly (Hungarian Meteorological Services, 2019). The study was laid on a randomized complete block design with 1 replication and five treatments.

Research design

The soil was prepared using a seedbed cultivator (autumn ploughing). After soil preparation, the field was divided into five plots each with 25 m^2 (5x5 m) measured by a measuring tape The crop planted was maize (Zea mays L.) [Limagrain 33.30 (FAO 340)]. Each plot consisted of 6 maize rows. The seeding rate of maize was 125 seeds/plot. Inter and intra-row spacing was determined by using a wooden hand marker and maize seeds were planted at a depth of 5 cm.

Straw mulch was applied at levels from 0% control, 25%, 50%, 75%, and 100% manually. Weeding was done by hand using hands and a hand hoe. Spacing between plots was 50 cm and 75 cm between rows.

Seedbed preparation and planting were done on the 3rd of May 2019. Data was collected on these dates 2019/06/24, 2019/07/20, 2019/08/03, 2019/08/17, 2019/08/31, and 2019/09/14, respectively. Soil moisture content (SMC) was measured three times per plot using a soil moisture meter (PT-I type gauge) at different soil depths of 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 cm.

A soil penetrometer (handheld Szarvas-type penetrometer) was used to measure the penetration resistance three times per plot at the same depth as moisture content.

Earthworms were sampled by hand-sorting *in situ* (25 x 25 cm, 30 cm deep) in all plots in four replicates according to the ISO Standards (ISO, 2006).

The maize harvest was carried out on 14th of September, 2019. The crop yield was weighed and the accuracy of the scale was 0.1 kg.

Rainfall and air temperature data were obtained from the meteorological station of the Száritópuszta Experimental and Training Farm of MATE.

Results and Discussion

Weather parameters

Around Gödöllő, the average rainfall for 30 years (1965-1995) is 540-580 mm. During the months of the experiment (May-Sept), precipitation became more (310.3 mm) than the long-term average (Figure1). The amount of precipitation among measurements fluctuated greatly. Therefore, their effect was taken into account when evaluating the results.

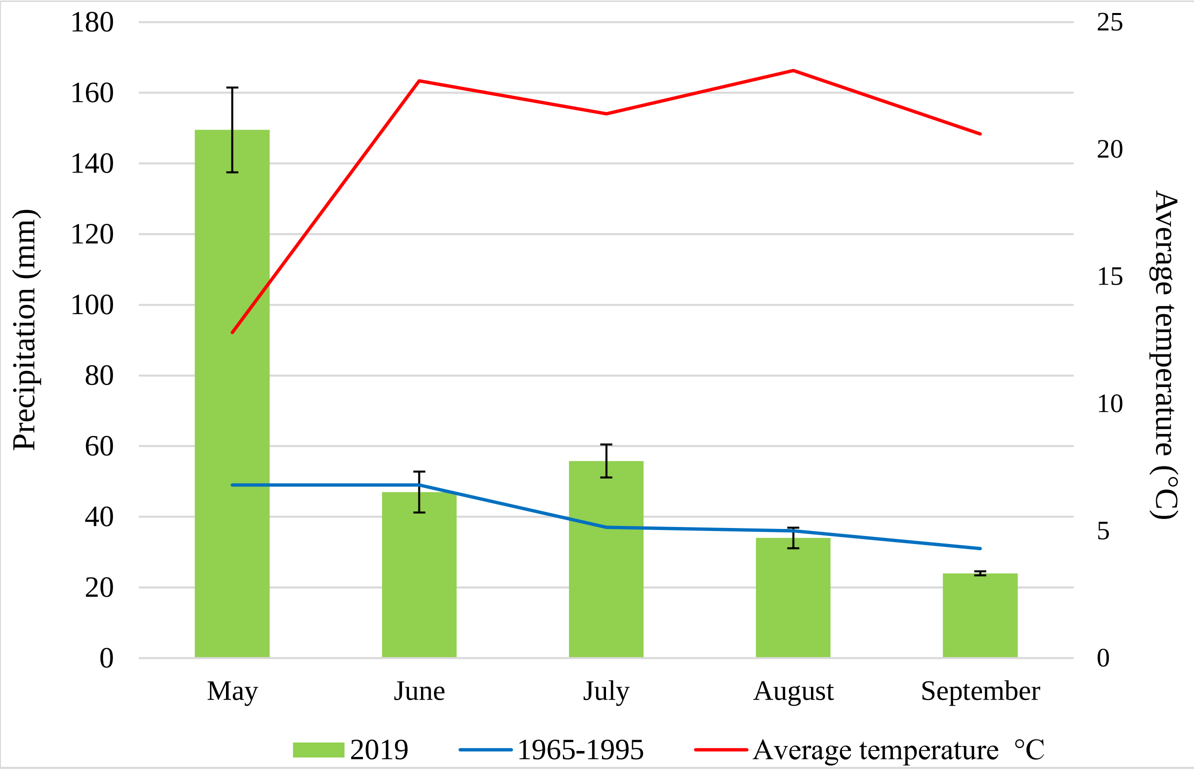

Figure 1. Precipitation (mm) and air temperature (°C) from May to September on a monthly basis and the long-term average of the 1965-1995 period (Gödöllő).

The weather conditions were noticeably different between the five study months. In reference to the long-term average during maize vegetation (202 mm), during the experiment precipitation sums were higher (by 53.6%). The rainfall distribution during the growing season differed among the months. The most rainfall fell in May (149.5 mm) of which 51.5 mm fell in one day (29^{th} May). In June fell 47 mm of rain, 2 mm less than the long-term average. July was wetter (+18.8 mm), while August and September were drier (2 and 7 mm) from the long-term average.

The average annual temperature is expected to be between 9.7-10.0 °C, while during the vegetation period 16.0-17.0 °C. Based on the long-term average, the warmest period was summer with a daily maximum of 32.5-33.0°C. In our case, during the experiment, on average May was the coldest (12.8°C) and August was the warmest (23.1°C).

Unprotected soil is prone to detrimental factors such as direct heat from the sun, and falling raindrops hitting the bare ground causing degradation. It is recommended that for protection of soil management such as mulching needs to be employed to reduce the raindrop intensity and cover the soil from direct sunlight.

Soil physical parameters

In the experiment, I examined the physical parameters of the soil eight times, at 3-3 measurement points.

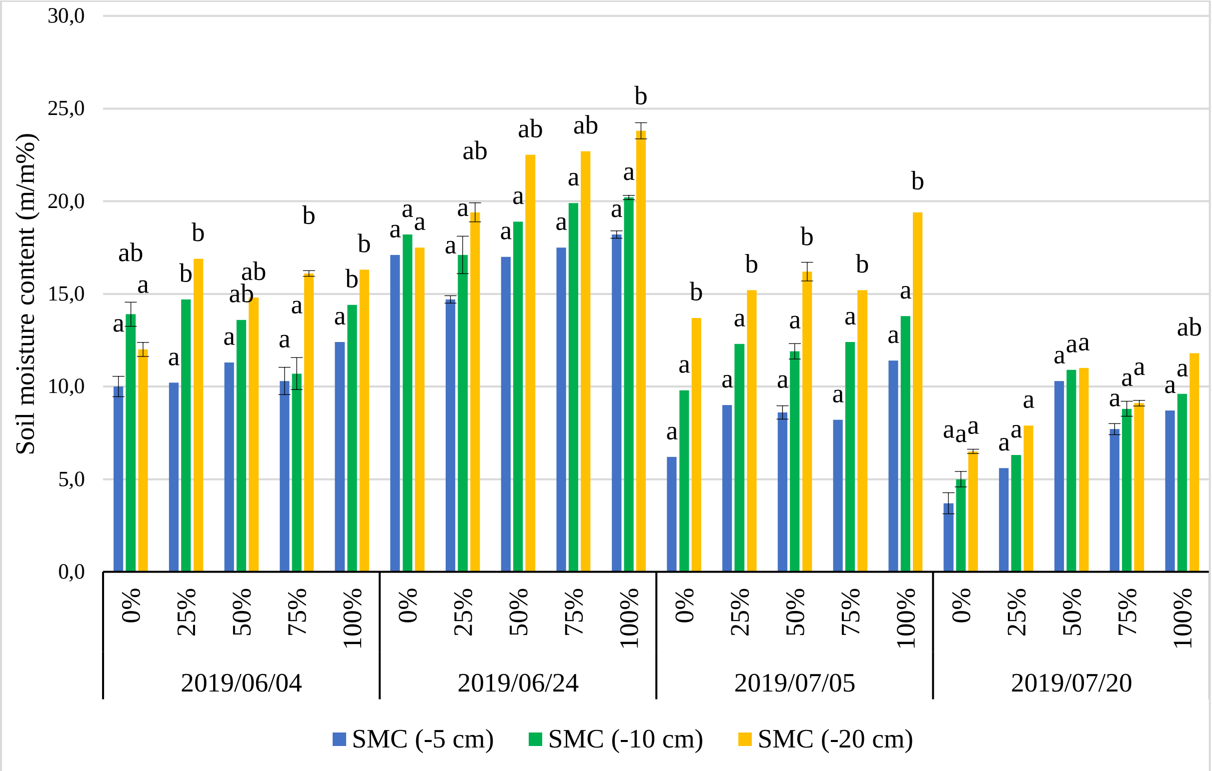

Figure 2. Soil moisture content measured from June to mid-July.

*Note: The different letters (a, b) above the columns indicate a significant difference, *(p < 0.05)*

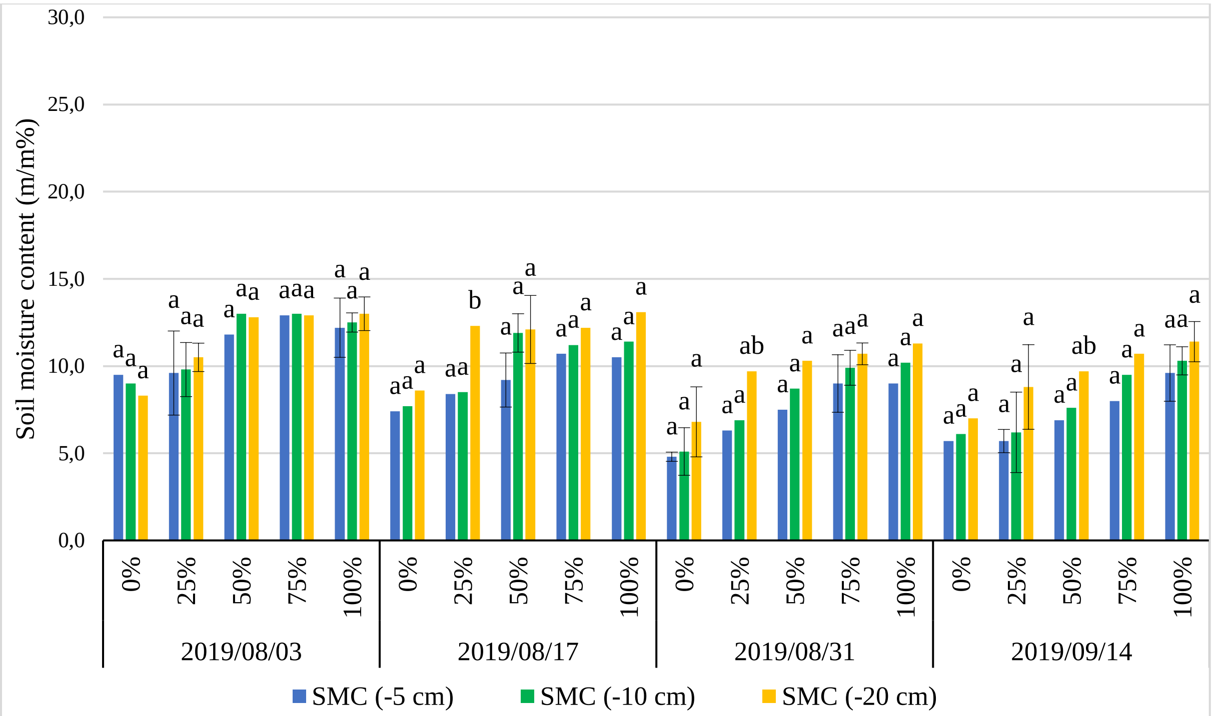

Figure 3. Soil moisture content measured from August to September.

*Note: The different letters (a, b) above the columns indicate a significant difference, *(p < 0.05)*

The soil's physical and biological properties examined during the 2019 growing season are shown in Figures 2 and 3. Soil moisture content (SMC) and soil penetration resistance (SPR) were measured eight times simultaneously throughout the duration of the study.

According to our results overall, there was no significant difference in SMC on one occasion (2019/08/31) in all treatment plots. Regardless of high (51.5 mm) precipitation on May 29th and sporadic rainfall in June, the lowest SMC in all treatment plots was observed at 5 cm in the control plot (M0%). Abdul Kader et al. (2017) outlined that during hot summer times, high soil temperature speeds up soil surface evaporation thus reducing soil moisture, consequently negatively impacting the growth and development of the crop. The highest SMC (23.8m/m%) was measured in the plot with 100% mulch (M100%). Results obtained in our study agree with Akhtar et al. (2018) who recorded higher SMC in treatment due to the application of a thick level of mulch (5000 kg ha $^{-1}$).

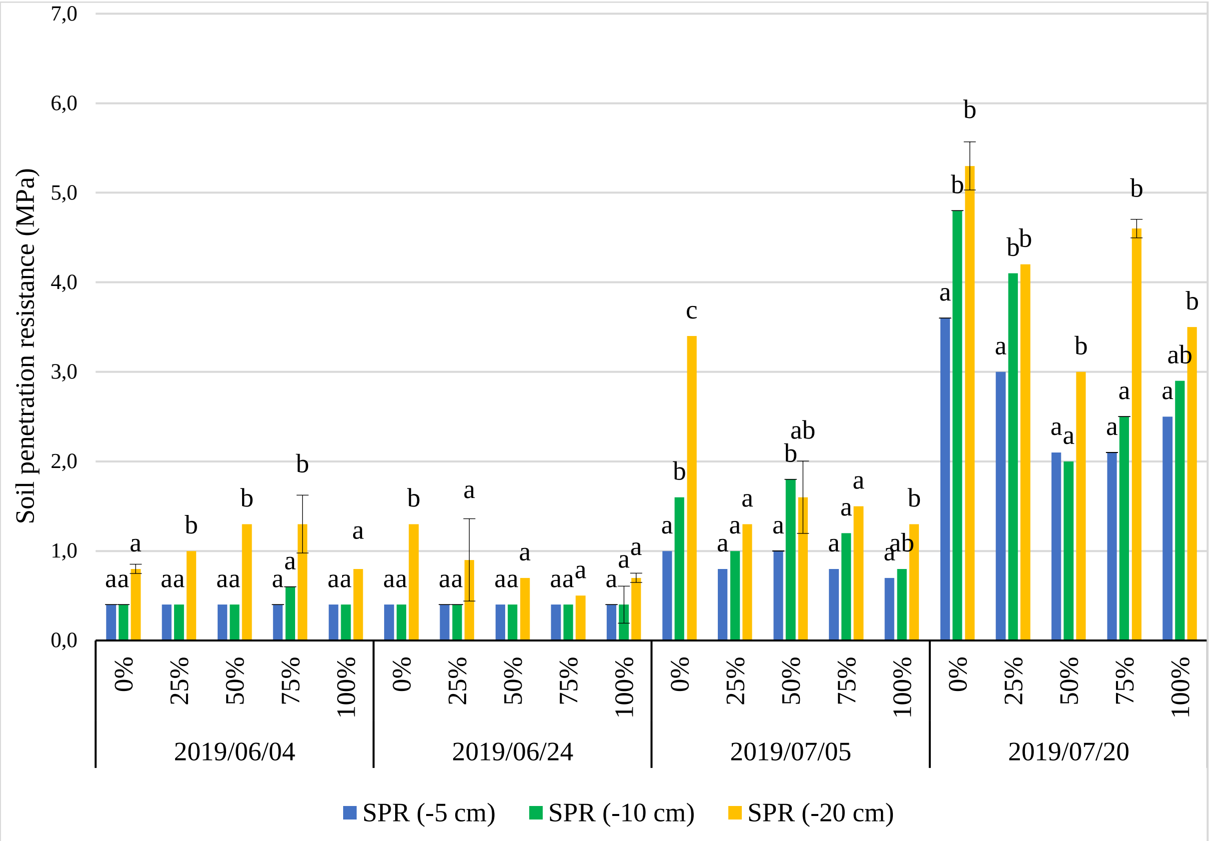

Figure 4. Soil penetration resistance measured from June to mid-July.

*Note: The different letters (a, b) above the columns indicate a significant difference, *(p < 0.05)*

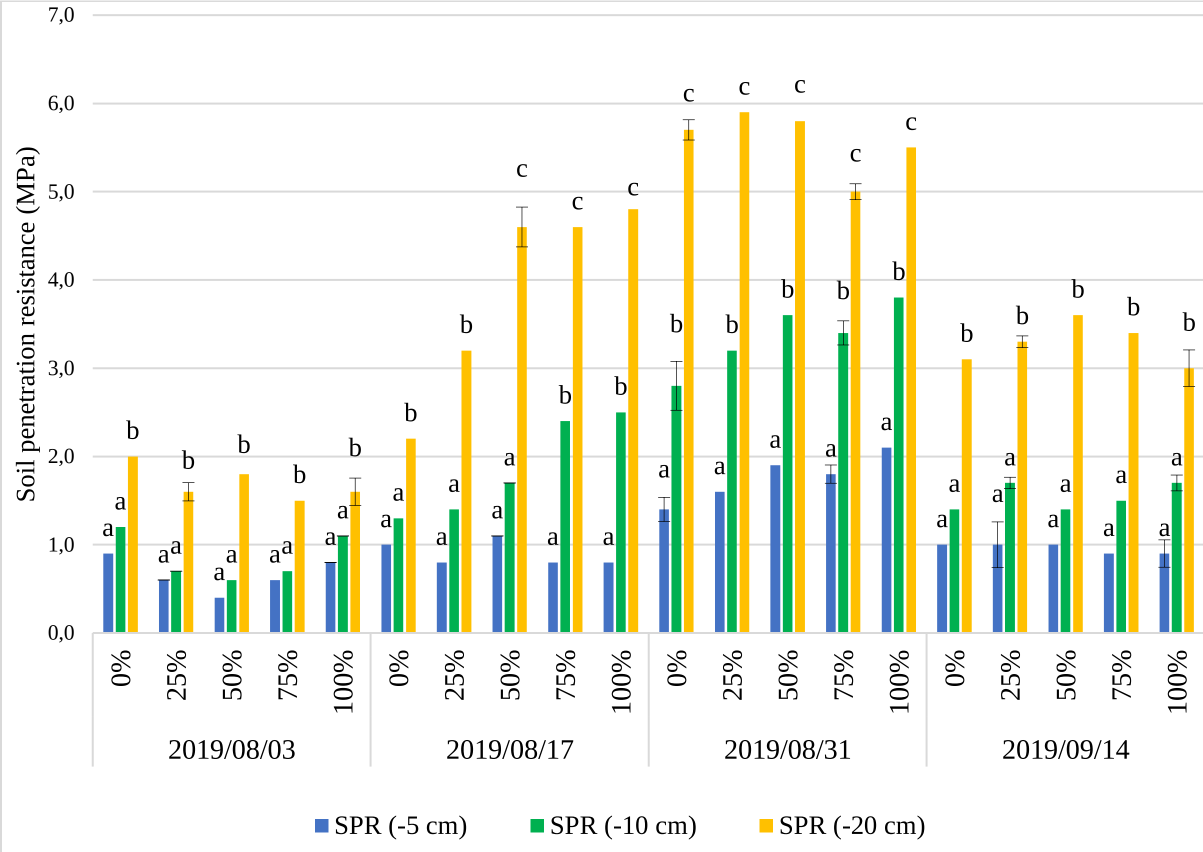

Figure 5. Soil penetration resistance measured from June to mid-July

*Note: The different letters (a, b) above the columns indicate a significant difference, *($p < 0.05$)*

Our soil penetration resistance (SPR) data showed a significant difference in various depths in all the treatment plots throughout the growing season (June-August). However, the first measurements (2019/06/04) showed no significant difference between 5 and 10cm in all treatment plots.

In contrast, we observed a significant difference in plot M0% with, the highest SPR obtained at 20 cm depth. In July we observed statistical differences in three treatments (M0%, M50%, and M100) at all depths. Mid-July, M100% showed significant differences at all the depths however, there were no significant differences in other plots at various depths. In August there was no significant difference between 5 and 10 cm in all treatment plots. Mulch had no significant influence on SPR from M0%-M50% however, from M75%-M100% there was a significant effect of mulch difference at all depths. SPR values increased sharply with increasing depth in all five treatment plots on August 31st. Relatively our highest (5.9 MPa) SPR value for the end of August (2019.08.31). This can be justified by the amount of rainfall received (34 mm) and the average temperature of 21.4 ℃, which led to the loss of moisture and intensified SPR. The last measurement of the study was measured on 2019.09.14. Based on our results, SPR was not significantly influenced by mulch in both 5 and 10 cm in all the treatment plots

Biological properties (earthworm abundance)

The earthworm abundance data are shown in Figure 6.

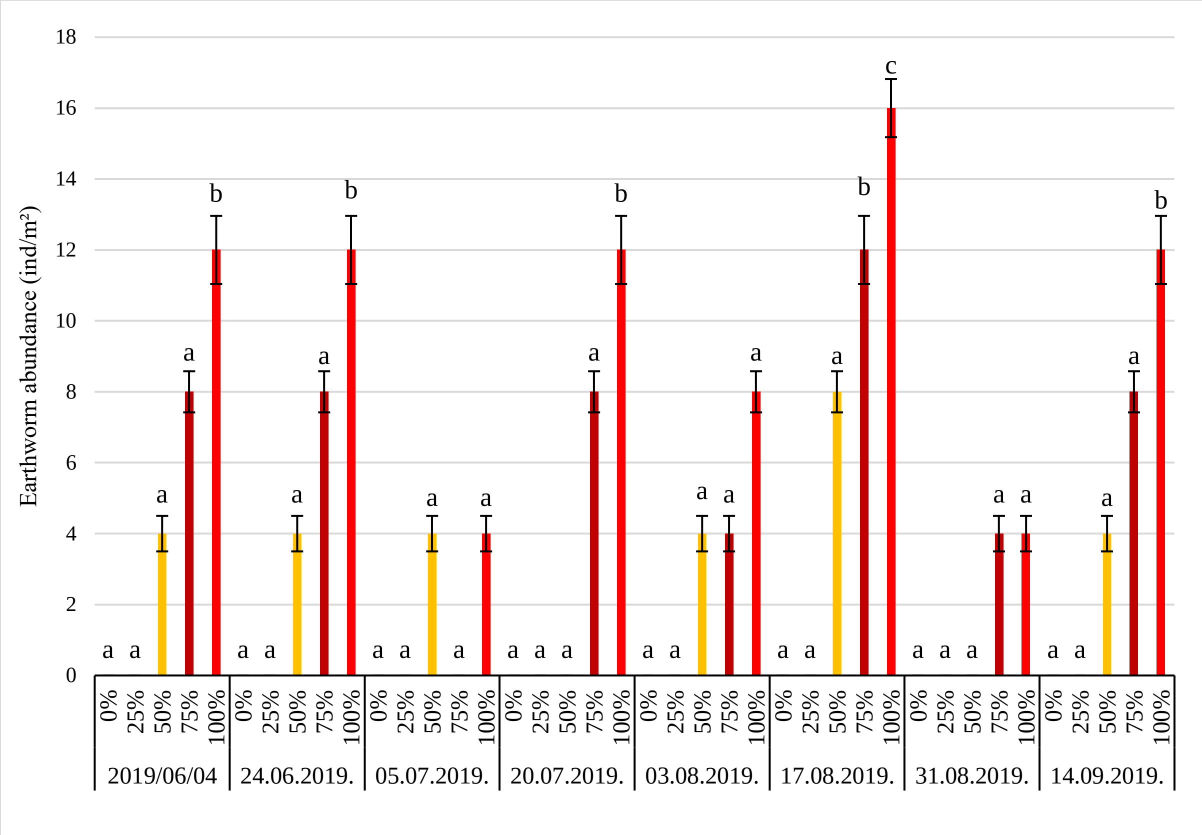

Figure 6. Earthworm abundance measured from June to August 2019

*Note: The different letters (a, b) above the columns indicate a significant difference, *(p < 0.05)*

POSTMA-BLAAUW et al. (2010) mentioned a few factors that can be used to explain greater earthworm abundance in M100% treatment. These are: (a) disturbance and/or physical injury from tillage operations is minimal, and (b) the availability of food (plant residue). Thick mulch was provided which improved the soil and acted as a source of food making a good habitat for earthworms and providing them with food.

Dominance was observed in earthworm abundance throughout the research period in the M100% treatment except at the end of August. Earthworm sampling indicated that the treatment plot with the most abundant earthworms was M100% plot regardless of high SPR at 10 cm and 20 cm. Our results agree with ABAIL and WHALEN (2018) who discovered high earthworm populations in a field that had high corn residue retained compared to soybean residue. Throughout the study period treatments, M0% and M25% recorded 0 ind/m^2 earthworm abundance.

Maize yield

The maize yield data are shown in Figure 7.

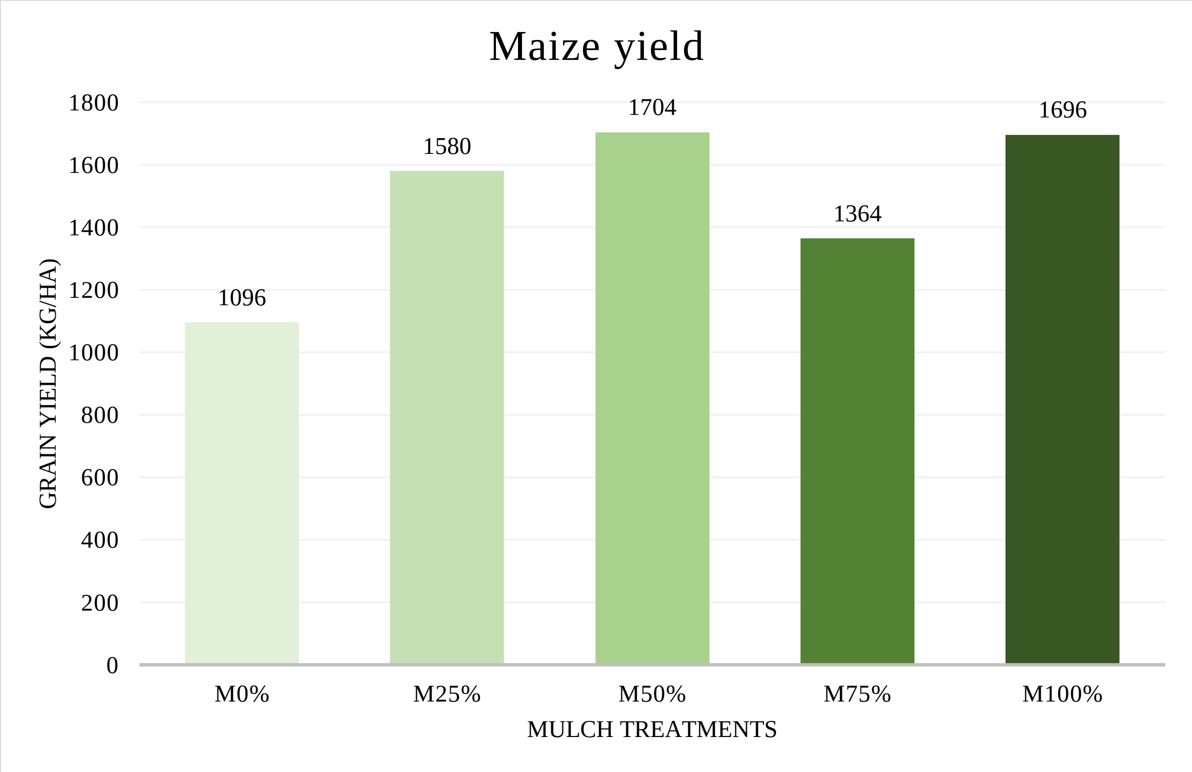

Figure 7. Average maize grain yield of 2019 growing season per treatment

The potential mechanism of straw mulching can help to improve maize yield and yield components because it can effectively improve soil nutrient availability, increase plant growth (FANG et al., 2011), and influence soil's physical and chemical properties (JIN et al., 2009). SHEN et al. (2012) discovered that straw mulching can significantly enhance grain yield in summer under rainfed conditions in northern China.

In our present study, the obtained yield in terms of grain was high (1704 kg/ha) at M50% followed by M100%, M25%, M75% and M0% which obtained 1696 kg/ha, 1580 kg/ha, 1364 kg/ha and 1096 kg/ha respectively. We could not perform the statistical analysis due to the experiment being set up in one replicate. However, the relationships between treatments are visible. Correlation data indicated a strong relationship between moisture content and yield (R^2=0.6966). This justifies our result of low yield in the control plot and the decrease can be attributed to high moisture loss by evaporation. Moreover, due to strong winds

However, SPR indicated a weaker relationship (R^2=0.4168) with yield. A very strong relationship was observed between SPR and SMC (R^2=0.7571) as the moisture averages increased, and SPR concurrently increased as well.

There was a moderate (R^2=0.4915) relationship between root length and root weight, which means that the length of the root does not depend on its biomass. Our results differed with Wu et al (2016) in a study to investigate the relationships between root diameter and other root architectural characteristics for two maize cultivars, who discovered that most roots decreased in diameter, while others increased, and then decreased.

Conclusion

In our present study, we can conclude that the straw mulch quantity on the physical and biological properties of the soil had no effect on any of the measured parameters. On most occasions, the recorded high SMC was due to sporadic monthly rainfall. There was no straightforward evidence of improvement in mulch quantity in the treatment plots. The process of land amelioration it takes slow, and, in my opinion, the study was conducted in a short period of time hence we could not observe obvious benefits or effects of mulch on the soil's physical and biological properties of soil.

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Authors

Modiba Maimela Maxwell
PhD student
Hungarian University of Agriculture and Life Sciences, Institute of Crop Production Sciences, Department of Agronomy, H-2100 Gödöllő, Páter K. u. 1. Hungary

Hanaa Tharwat Mohamed Ibrahim
PhD student
Hungarian University of Agriculture and Life Sciences, Institute of Environmental Sciences, Department of Soil Science, H-2100 Gödöllő, Páter K. u. 1. Hungary

Barbara Simon, PhD
levelező szerző
associate professor
Hungarian University of Agriculture and Life Sciences, Institute of Environmental Sciences, Department of Soil Science, H-2100 Gödöllő, Páter K. u. 1. Hungary
simon.barbara@uni-mate.hu

Igor Dekemati, PhD
Hungarian University of Agriculture and Life Sciences, Institute of Crop Production Sciences, H-2100 Gödöllő, Páter K. u. 1. Hungary