SOIL COMPACTION AND SOIL MOISTURE CONTENT IN EXTREME CLIMATE CONDITIONS

V. Rataj, M. Macák, M. Barát, J. Galambošová

Department of Machines and Production, Faculty of Engineering, Slovak University of Agriculture in Nitra

Abstract

The work deals with the impact of soil compaction on moisture content during extremely hot and dry season of 2015 with heavy storm rainfall. The period (July and August) is divided on three parts – period of drought, heavy rainfall, and drought after heavy rainfall. Soil moisture was measured at a depth of 20 cm at two blocks on a slope with a gradient of 2.5 °, yield of pumpkin seed (Cucurbita pepo L, var. olerifera) was monitored as well. The results show, that soil moisture is higher in compacted soil what resulted in better yield of pumpkin. Similar trend was confirmed also by control measurement in CTF experiment.

Key words: soil, humidity, compaction, dry, rainfall.

INTRODUCTION

Climate change and increased production of greenhouse gases are predicting more frequent occurrence of temperature extremes - droughts and heat waves, and intensive rainfall (BRESTIČ, 2010). In the context of sustainable farming and for maximizing crop yields it is necessary to know all the factors that have an influence on crop yield (KUMHÁLOVÁ, 2011). Terrain elevation (BAKHSH ET AL., 2000; KRAVCHENKO ET AL. 2000), slope (KRAVCHENKO AND BULLOCK 2002), location (KRAVCHENKO AND BULLOCK 2002B), flow indey, flow direction, flow length and flow accumulation (JENSON AND DOMINGUE 1988) are considered the most important topographical and hydrological attributes in crop production in conventional tillage systems.

Technological development in agriculture heads to increasing the working width of the machines along with the increasing power of tractors. Strong and heavy machinery has a negative impact on soil and its properties (RATAJ, 2014). Since 1966, the mean weight and power of agricultural machinery has increased three times (KUMHÁLA, 2013).

Publishes research results on the soil physical properties showed that the compaction of soil results in increasing the bulk density of soil, reducing the porosity (especially lowering the volume of non-capillary pores), and in higher level causes destruction of soil aggregates. These facts lead to further deterioration of the physical soil properties, such as a reduction in the water infiltration, changing the water content in the soil horizon and its relative movement in the soil (JAVŮREK, VACH, 2008). The inability to hold water also increases the probability of floods, drought, and other soil degradation as well. Lack of organic matter causes serious risk of erosion, reducing infiltration abilities**,** but also soil compaction and other degradation processes (HERMANOVSKÁ, 2013). Soil erosion robs the most fertile agricultural part of soil - topsoil. It also deteriorates the physical-chemical properties of the soil, it reduces the size of the soil profile, increases rockiness, it reduces the content of nutrients and organic matter, and also damages the arable crops. JANECEK (2012) refers, that in the Czech Republic, there is about 50% of arable land endangered by water erosion (JANEČEK, 2012).

Soil erosion is caused by poorly water infiltration in the soil. Infiltration indicates the volume of water, which soaks to the soil over time and additional water rolls off the surface - for example due to the heavy rainfall. Infiltration can be used as one of the important soil properties, which has a major impact on soil fertility and also on soil erosion (DIBAL, 2013). The amount of water that can soak the soil depends on the soil type as well. Sandy soils can retain more water than heavier clayish soils (SCHWANKL, 2007).

Excessive soil compaction causes creation of anaerobic environment, that reduces the air exchange and microbial activity, and increases the denitrification and also rate of the pores filled with water (Torbert - Wood, 1992). Soil compaction reduces pore size and this has a big impact on volume of water that can be absorbed into the soil. This reduces mainly the number of large pores (WOLKOWSKI - LOWERY, 2008).

Layed soil (slightly compacted) is important for optimal water regime. For better seed germination, the soil should be softened in the top layer, and slightly compacted in the bottom of seed bed. The optimal porosity in the seedbed is 48-52% for cereals on loamy soils. Also, the optimal bulk density for spring barley on loamy soils should be 1.30 – 1.40 t.m^{-3} (POSPÍŠIL, CANDRÁKOVÁ, 2015). Soil compaction has a direct impact on crop yield, but in conditions of extreme drought the yield could be positively affected (DEJONG-HUGHES, J. ET AL, 2001).

The aim of this work was to determine the level of soil moisture at differently compacted soil in conditions of extreme drought and heat. This effect is documented on yield of pumpkin seed (Cucurbita pepo L, var. olerifera).

MATERIALS AND METHODS

Experiments took place in Kolíňany in the area of University farm of the Slovak University of Agriculture in Nitra.

The experimental field was deep tilled up to 30 cm, followed by soil preparation technology with disc harrow and secondary tillage equipment (combinator). On this field two experimental zones were designed (55x55 m) with the chernozem soil types, middle-heavy soils, classified after BPEJ to 0139102 (VÚPU, 2015, LINKEŠ V. ET AL., 1996). These zones were 55 m apart on a slope with a gradient of 2.5 degrees (area TOP, area BOTTOM).

Each zone was divided into two blocks. One block was purposely compacted with tractor (track to track), the second block was not compacted and served as a control point (Fig. 1). Both blocks were located so two monitoring areas were assessed, location TOP and location BOTTOM. Locations were located 55 m apart along the slope.

Fig. 1. – Lokalisation of experimental blocks, left site of block – compacted wheel by wheel, right site – not compacted soil

Crop grown on this field was pumpkin for seed (Cucurbita pepo L, var. olerifera). Two sets of measuring systems Eas**y**Log (DECAGONDEVICES, 2015) were used to measure soil moisture content. Each set consists of volumetric soil moisture sensors and a datalogger, which ensures continuous monitoring of soil‘s volumetric water content (in units % VWC). The sensors were placed at the centre of each block, at a depth of 20 cm below the surface.

Fig. 2. – Installing the soil sensors

The level of soil moisture at different compacted soil in conditions of extreme drought and heat was studied in July and August of 2015. This period could be divided into 3 parts:

- A – long drought with minimal rainfall,
- B – period of heavy storm rainfall,
- C – dry period after heavy rainfall.

Climate characteristics of 2015 in Slovak Republic by LAPIN (2015) and resources SHMÚ (2015) states, that summer of 2015 was extremely abnormal, regarding the temperatures overall. The experimental area had an average summer temperature of 22.9 °C, with relatively low humidity, drought, and frequently high night temperatures above 20 °C. Summer of 2015 was very dry, with rainfall of only 82 % of long-term observations (1901-1990).

Weather development was monitored with the weather station located in the area of University farm in Kolíňany, in a distance of 500 m from the experimental field. In this monitored period of time the values of air temperature, relative humidity, and rainfall volume were recorded. Data sampling frequency was 10 minutes.

The period of extreme drought is well documented on rainfall, in April – 25 mm precipitation with a maximum value of 1.2 mm, in May – 43.4 mm with maximum of 35.6 mm (29.05.2015) and in June – 25.6 mm – maximum of 18.6 mm (09.06.2015). The overview of monitored values during the experiment is shown in Tab. 1.

To complete the information on climate conditions, which affected the soil moisture predominantly, air temperature and moisture content of the second decade of August is provided. Here, in the period of 3 days (17th to 19th August 2015), precipitation of 98.2 mm was observed, what is equal to 96.5% of the total month precipitation. Looking at the all assessed period (July – August), this is equal to 81% (Fig. 3).

Tab. 1. – Overview of climate parameters at University farm in summer 2015

Average value	1. - 10. 07. 2015	11. - 20. 07. 2015	21. - 31. 07. 2015
Air temperature, °C	23.06	23.04	24.58
Air humidity, %	63.10	63.41	72.54
Rainfall, mm	6.80	2.30	11.50
Average value	1. - 10. 08. 2015	11. - 20. 08. 2015	21. - 31. 08. 2015
Air temperature, °C	24.31	23.69	23.09
Air humidity, %	63.89	68.87	81.02
Rainfall, mm	0.30	98.90	2.53
Rainfall totally, mm		147.93	

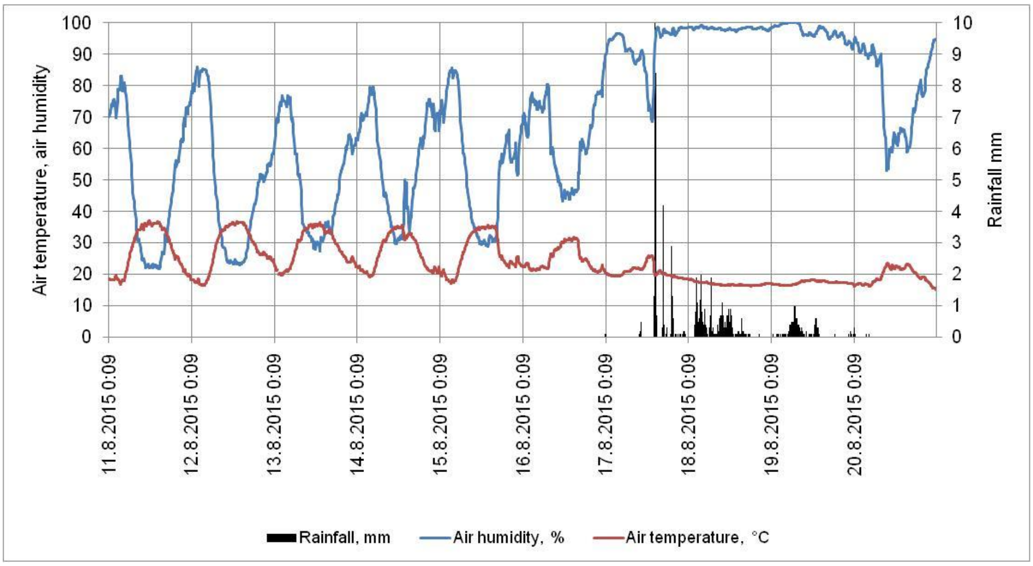

Fig. 3. – Climate parameters during the assessed period of the august 2015

Fig. 4. – Soil moisture sensor used in the experiment

Soil sensors were placed into non-disturbed soil. In order to do this, installing pit was excavated and the sensor´s fork was plugged into the pit-site (Fig. 4). The pit was filled with soil afterwards.Soil moisture data measured with the sensor were downloaded from the web server of company Physicus (PHYSICUS, 2015). To analyse the data these were downloaded and statistically processed. As a result of dry weather, the crop suffered from drought stress and the soil cracks were present as showed in Fig. 5.

Fig. 5. – Pumpkin crop during the heat stress

The soil moisture was assessed during 2 months (July to August 2015). Effect of soil compaction on soil moisture content was determined according to formula 1.

$$\Delta W = Wc - Wu \tag{1}$$

where: ΔW difference of soil moisture content, %

Wc soil moisture content of compacted soil, %

Wu soil moisture content of non-compacted soil, %

Following parameters were evaluated for each set of sensors:

- Changes on soil moisture during the 62 days period
- Basic statistics parameters of soil moisture on hourly base
- Extend of variation of hourly monitored soil moisture
- Difference of soil moisture values ΔW

RESULTS AND DISCUSSION

Based on obtained data, following results were achieved. Fig. 6 shows the soil moisture data of compacted and non compacted soil at the experimental area TOP. Results show, that the soil moisture of compacted soil reached higher values during all experiment.

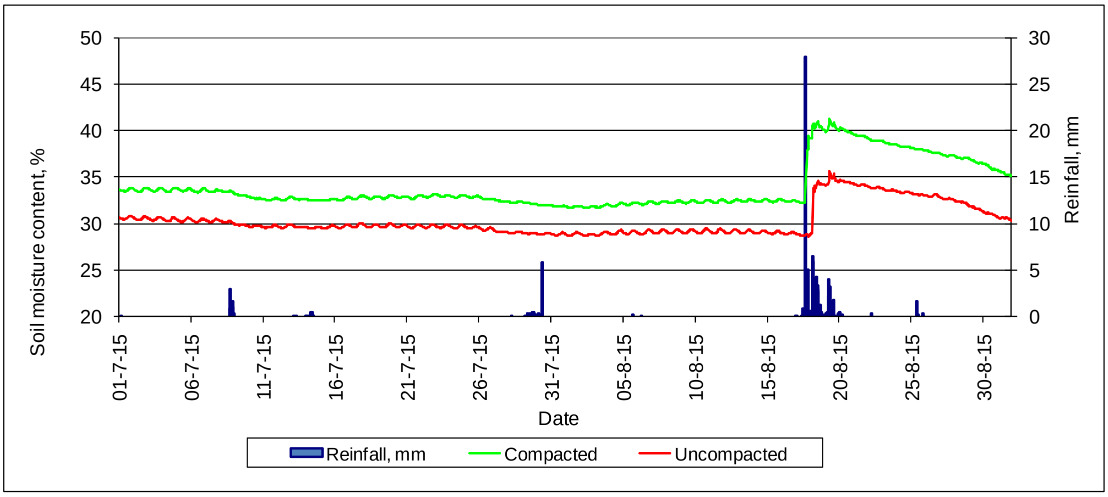

Fig 6. – Soil moisture content in the area TOP

Drought time period (A)

Drought time period lasted 48 days (1st July 2015 to 17th August 2015) with precipitation of 22 mm only. Soil moisture content decreased due to the dry weather. The ΔW reached values in the range of 2.8 to 3.6% (Fig. 7, Tab. 2).

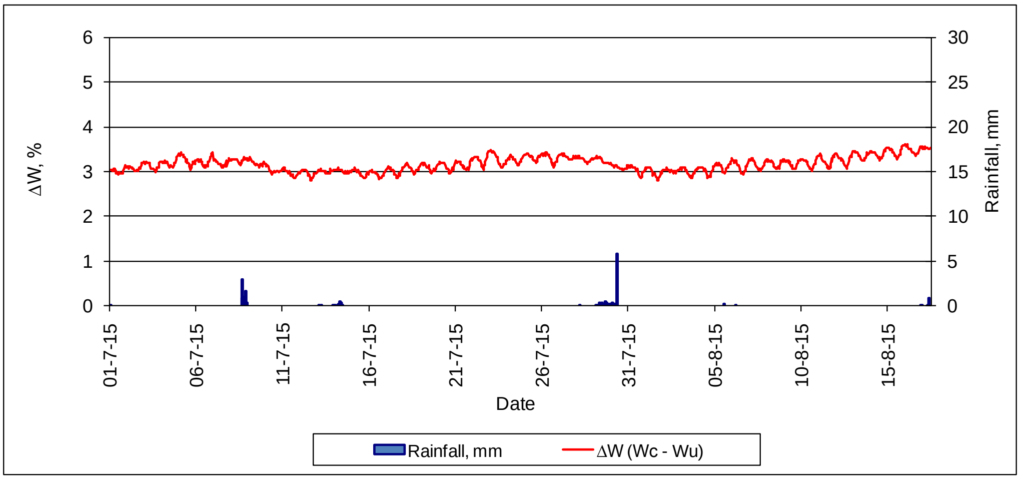

Fig.7. – Soil moisture difference ΔW at the experimental are TOP during the drought time period

Heavy rain period (B)

The time period of heavy rainfall lasted 2 days (17th to 18th August 2015). During the time of 27 hours, precipitation reached 79.1 mm. The soil moisture data during this time period are presented in Fig. 8.

Naturally, the rainfall increased the soil moisture content. In the depth of 20 cm, where the soil sensors were installed, soil moisture increased immediately at compacted area and after 13 hours at non-compacted area. The parameter ΔW increased to the range of 3.5 – 11.4% (Tab. 2).

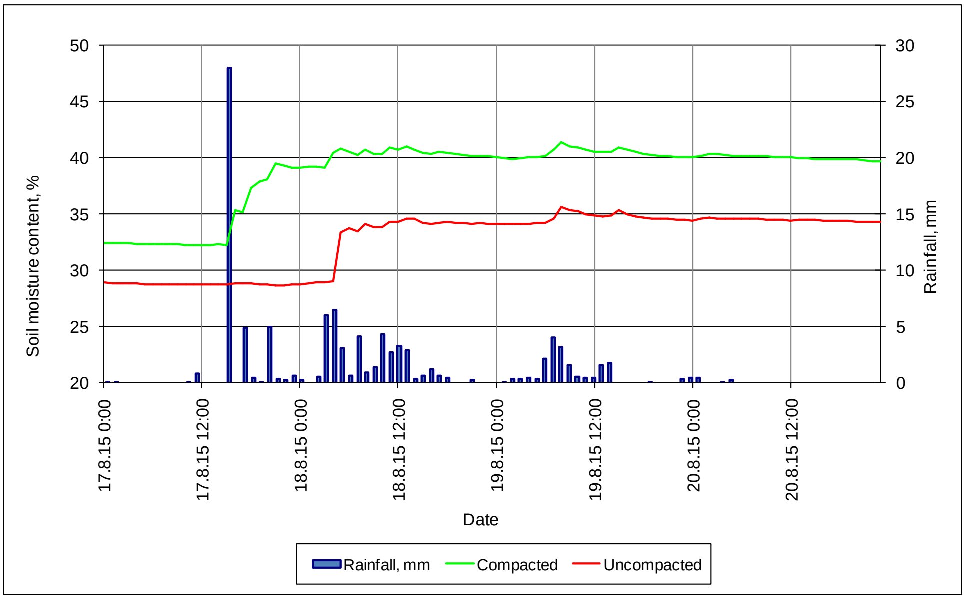

Fig.8. – Soil moisture data at the are TOP during the heavy rainfall time period

Dry period after heavy rain (C)

This period lasted 13 days (19. 08. – 31. 08. 2015). Precipitation was 21.2mm, out of which 13.6mm was considered as decay of the heavy rainfall from previous period. Soil moisture increased by 27% at the compacted area and by 18% at the non-compacted area. Same trend was present during next time period and the decrease of soil moisture was even more significant. The difference in soil moisture content expressed by parameter ΔW increased and ranged between values of 3.5 – 11.4 % (Fig. 9; Tab.2).

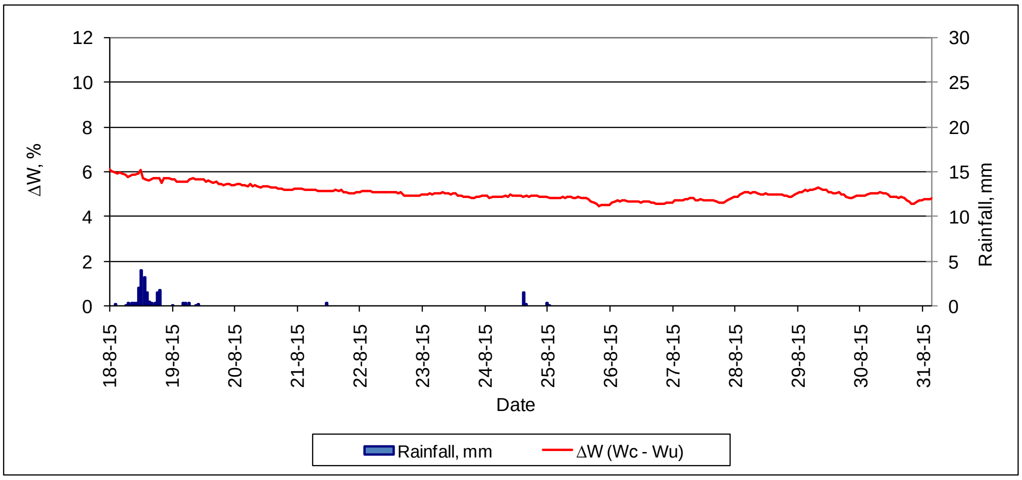

Fig. 9. – Difference in soil moisture content at the experimental area TOP during dry period after heavy rainfall

Tab. 2. – Basic parameters of the soil moisture difference at the areal TOP during monitored periods

?W -difference of soil moisture content	Monitoring period		
	A	B	C
Average, %	3.16	7.83	5.07
Standard deviation, %	0.16	2.06	0.34
Minimum, %	2.80	3.49	4.47
Maximum, %	3.62	11.39	6.14
Number of observations	1142	28	317

End of the monitored period was typical with high air temperature, the soil moisture reached values similar to the time of experiment start.

At the experimental area BOTTOM, same situation was observed, where the compacted soil showed higher soil moisture content (Fig. 10).

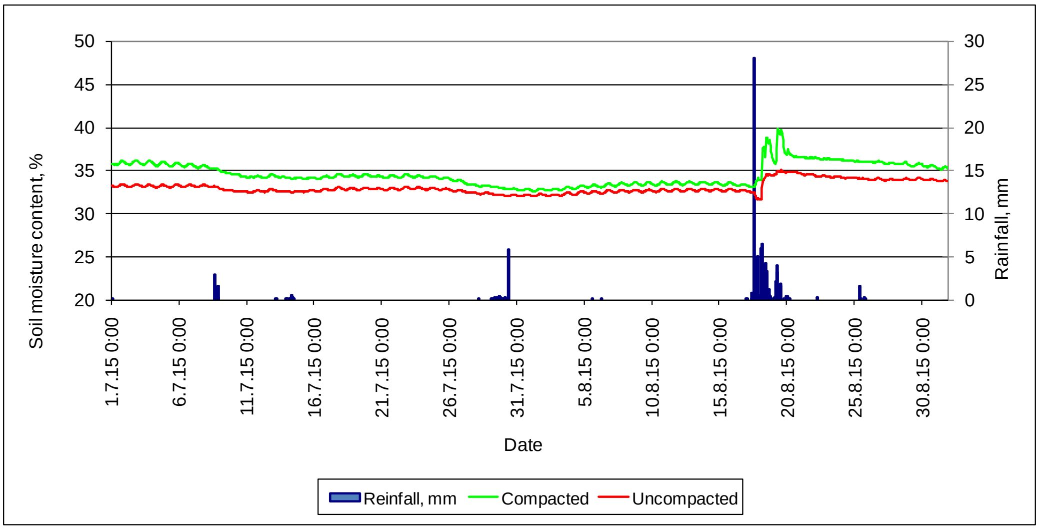

Fig. 10. – Soil moisture content at the area BOTTOM

Values of the parameter ΔW were, however, significantly lower. Experimental measurements of soil moisture using this principle are conducted at experimental field with controlled traffic farming at the moment. This project has been since 2009. Permanent traffic lines are considered to be compacted block and areas with zero traffic as non-compacted block. Data from the period 1st May 2016 to 27th May 2016 are provided in Fig. 11. Soil moisture content at the permanent traffic lines (compacted soil) was significantly higher compared to the non compacted soil.

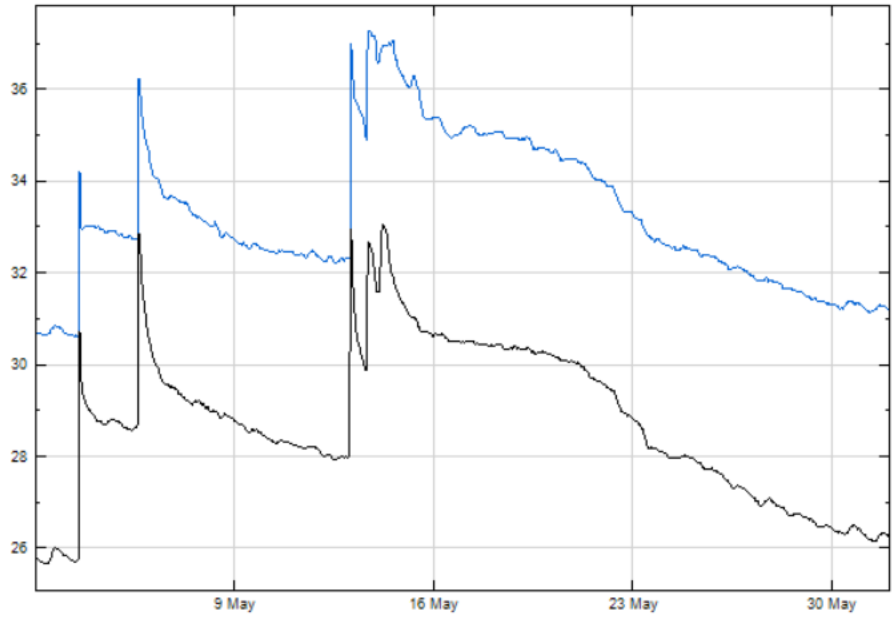

Fig. 11. – Soil moisture content at the experimental field with CTF, top line – permanent traffic line, bottom line – uncompacted soil (PHYSICUS, 2015)

Effect of soil compaction on soil physical parameters is well known. Among all, the infiltration is affected. Results showed, that in conditions of extreme drought, soil moisture is higher in compacted soil. Crops, grown in 2015 were exposed to extreme temperature stress and deficit of available moisture in soil. Yield of the pumpkin seed was low and effect of different soil moisture was reflected on yield (Fig.12).

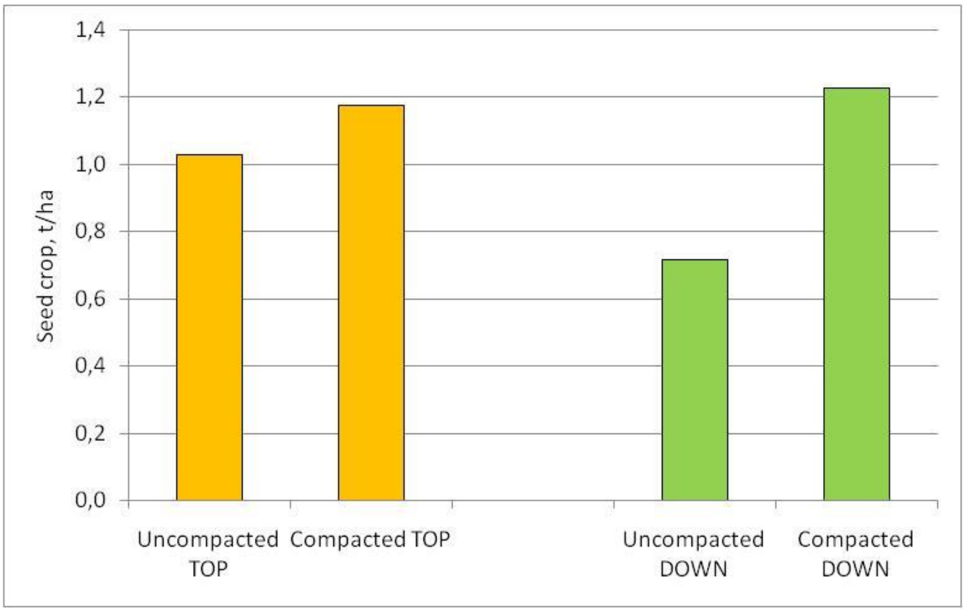

Fig. 12. – Yield of the pumpkin seed reached at the experimental blocks at the two locations

Generally, soil compaction is one of the factors reducing yield, lowering water infiltration to the soil, and factors that cause environmental risks of water erosion (BRANT, V. ET AT. , 2016 and others) However, in extreme drought an opposite effect can be found. At example of pumpkin, results of DEJONG-HUGHES, J. ET AL, 2016 were confirmed saying that during the extreme dry weather conditions, soil compaction may increase yield. AL KAISI AND LICHT (2016) states that there are relations that sets the maximum soil compaction according to the soil moisture content.

CONCLUSIONS

The work was aimed at effect of soil compaction on soil moisture content in the extreme drought conditions in the 2015. Experiments were conducted at University farm in Kolinany in the time period of extreme drought as well as heavy rainfall. Soil moisture content of the compacted soil was higher compared to the non compacted soil. Negative effect was evident in the time period of heavy rainfall. Soil moisture content of the compacted soil increased immediately what indicates the risk of water erosion. Soil moisture content of non compacted soil started to increase after 13 hours. In this time period, the threefold increased of the difference of soil moisture content of the compacted and non compacted soil was present. The year 2015 was extremely dry and hot, what effected the yield of grown crops.

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Corresponding author:
Vladimir Rataj, Department of Machines and Production Biosystems, Faculty of Engineering, Slovak University of Agriculture in Nitra, Slovak