EXAMINATION OF WATERDINAMIC OF CHERNOZEM SOIL IN MONOCULTURE MAIZE IN LONG-TERM FIELD TRIALS IN DIFFERENT CROP YEARS

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Abstract

The water cycle in chernozem soil in maize have been studied in a 28-year long field trial in different cropyears with different precipitation in droughty (2007), humid (2008) and dry (2009) cropyears in a 28 year-long field trial. The examined soil layer was divided into three zones (0-60 cm; 61-120 cm; 121-200 cm) and the moisture content of the soil was being analysed over the growing season. Our results revealed that the change in the moisture content was most intensive in the top soil layer; where the effect of both precipitation and irrigation was most apparent.

Key words: long-term field trial, soil moisture content, crop-year, irrigation, crop rotation, maize

INTRODUCTION

Global warming and climate change are proven facts by now. Temperature has increased by over 0.7 °C during the last century. Temperature rise is the result of human activities, at least from the mid 20th century (HARE, 2009). Recently started macroclimatic changes have been shifting Hungary's climate from its typical continental state. Adaptation to climatic changes is likely to increase or decrease future possibilities of crop production.

The predictions are confirmed by the climatic conditions during the last 6 years. Not only the frequency of dry or humid periods and weather extremes increased, but also the negative effects of these circumstances are intensifying (Sárvári, 2005; Birkás, 2006; Láng Et Al. 2007; Anda, 2008, Jolánkai És Birkás, 2009).

Water management is a vital component of agricultural production. It is the procedure of creating optimal moisture conditions in order to reach sustainable and safe crop yields through the combined application of technical, biological and agrotechnical processes. On the most important maize production areas the efficiency and safety of maize production is primarily determined by water supply (DÉGEN, 1967). If sufficient amount of precipitation is provided during the growing season of maize, outstanding crop yields can be achieved. In draughty year, due to stress caused by insufficient water supply the intensity of photosynthesis and transpiration is decreased, thus crop yield can drop to its half compared to humid years (Jambrovic Et. Al 2008, Hnilicka Et. Al, 2008, Ceska Et Al., 2008, Hoffmann et al., 2007). Although we can only adapt to given agroecological conditions with appropriate application of the components of the production technology, these factors can be influenced as well (fertilization, irrigation, cultivation, crop rotation) to a certain extent.

MATERIAL AND METHOD

The polifactor long term field trial was set by Prof. Dr. László Ruzsányi in 1983; from 2004 it is headed by Prof. Dr. Péter Pepó.

The long-term experiment involves three crop rotation systems (monoculture: maize, biculture: maize-wheat, triculture: maize, peas, wheat), two irrigation systems (irrigated, non-irrigated), two crop density levels (60000 ha^{-1} and 80000 ha^{-1}) and 3 fertilizer levels (control, $N_{120}P_{90}K_{90}$, $N_{240}P_{180}K_{180}$). The soil of the research site is calcerous chernozem with good water content and water holding capacity. There was 4x50 mm=200 mm irrigation in 2007 and 2x50 mm irrigation in 2009. Cultivation, plant protection and harvesting were similar in each treatment. The hybrid used was Reseda (PR37M81). In 2008 no irrigation was applied due to the favourable distribution of precipitation during the growing season.

To examine water circulation, soil samples were taken 6 times from each 20 cm zone of the top 200 cm soil layer in mono-, bi- and triculture, at 60000 plant ha^{-1} and 80000 plant ha^{-1} crop density levels with $Ö_1$ and $Ö_3$ moisture content. The sampling time was as follows: the first sample was taken before sowing, the last one was taken from the stubble after harvesting, and the samples in between were taken in the main phenologic phases (3-4 leaves stage, tassel formation, fruit setting, maturing).

The wet soil samples were measured and dried to stable weight at 105 °C. The dry samples were weighed and the moisture content was calculated as the difference between the wet and the dry weight expressed in weight %. The results were expressed in % w/v as well using the w/v results of the specific soil zone.

From the three examined years (Table 1) the weather in 2007 and 2009 was dry, being well expressed by the deviance from the 30-year average. In August and September 2007, around the end of the growing season the difference was positive, i.e. the moisture deficiency was compensated and the total precipitation in the growing season was 61.3 mm lower than the 30-year average. However, the dry cropyear of 2009 was still different. Except from June, the precipitation was lower than the 30-year average in each month of the growing season. It is also reflected by the cumulated amount of the 6 months (176.3 mm difference compared to the 30-year average).

In contrast to the other two years, the growing season was rather humid in 2008. The total amout of precipitation was 483.9 mm in the growing season, 138.8 mm above the 30-year average. The amount of precipitation was below the 30-year average in May and August, in all the other months the precipitation was well above (by 33-79 mm) the 30-year average.

Table 1

Monthly precipitation values in the season of maize and deviations from the 30-year average (Debrecen, 2007, 2008, 2009)

	2007		2008		2009		30 years average
	value (mm)	deviation (mm)	value (mm)	deviation (mm)	value (mm)	deviation (mm)	
April	3,6	-38,8	74,9	32,5	9,9	-32,5	42,4
May	54,0	-4,8	47,6	-11,2	20,1	-38,7	58,8
Jun	22,8	-56,7	140,1	60,6	96,6	17,1	79,5
July	39,7	-26,0	144,9	79,2	9,2	-56,5	65,7
August	77,6	16,9	34,2	-26,5	11,3	-49,4	60,7
September	86,1	48,1	42,2	4,2	21,7	-16,3	38,0
Total (mm)	***283,8***	***-61,3***	***483,9***	***138,8***	***168,8***	***-176,3***	***345,1***
Average temp (^oC)	*18,8*	*2,0*	*17,4*	*0,6*	*19,5*	*2,7*	*16,8*

The precipitation (42.2 mm) was near the 30-year average (38 mm) in September, though this effect had no significant influence on maize.

Similarly to precipitation, the temperature values were different in the three examined years: 2007 and 2009 were rather hot, while 2008 was rather cool. Although the cropyears of 2007 and 2009 were dry, the temperature was well above the 30-year average (in 2007 by 2.0 ^oC, in 2009 2.7 ^oC). The table reflects another important fact, i. e. each year the average temperature of the growing season increased.

RESULTS AND DISSCUSIONS

The figures (Figure 1,2,3) depict the moisture content of the soil in % w/v in monoculture at 60000 crop ha^{-1} crop density and N_{120}+PK fertilization level with six sampling times. The standard soil profile (200 cm) was divided into three levels according to the root system of maize: 0-60 cm – the major root mass of maize is found here, 61-120 cm – a part of the root mass is found here, cca. 1/3 of the root mass enters into this layer, 121-200 cm – as regards the root system of maize, this layer is insignificant, however, it plays an important role in the water management of the whole soil profile. The average of the results of each 20 cm zone within the three main layers was taken. The results of 2007 (Figure 1) show that the water supply of the soil decreased in each crop rotation system, at each fertilization level and at each crop density level by August (the moisture content of the soil ranged between 17 and 26 % w/v and between 12-18 % w/v in April and August, respectively).

The moderate increase of the parameters at the last sampling time was due to early spring rains and the fact that the intensity of physiological processes in maize has significantly dropped from the beginning of August; the assimilation and transpiration surface was much smaller and the process of grain filling slowed down or stopped.

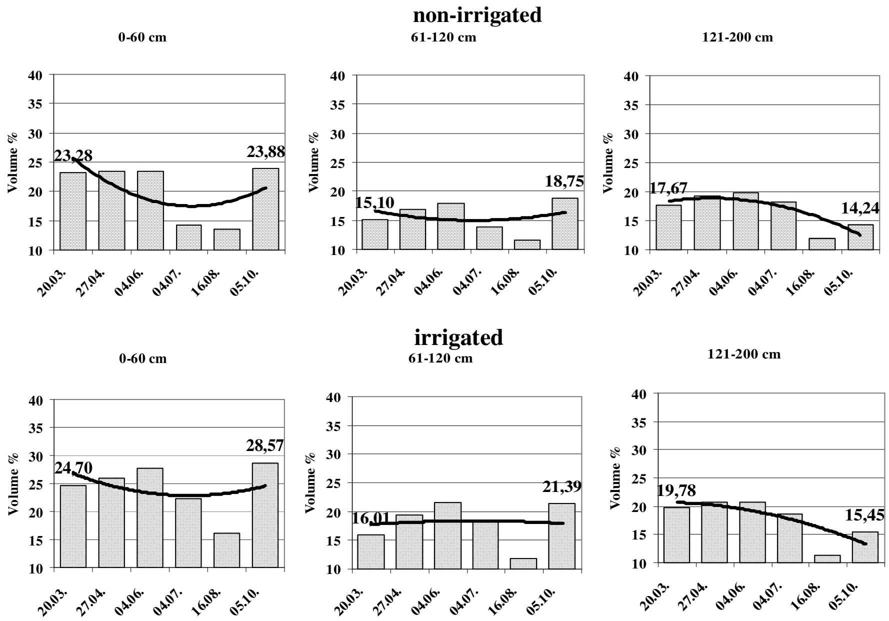

Figure 1. Soil moisture content (v%) in monoculture in 2007 (60000 plants ha^{-1}, N_{120}+PK)

The processes in the 61-120 cm soil zone were similar to those in the top layer. The roots entered into this layer in the middle of the growing season in the flowering stage in July, as it is reflected by the moisture values (12-16 % w/v). At the end of the vegetation period the moisture content increased again (to 24-28%) though stayed below the moisture content of the top level. In the lowest soil profile (121-200 cm) the moisture content was decreasing. The reason is that this layer supplied moisture for the upper layers through capillary water rise in the hot periods of July and August. The slight moisture regain in the middle layer (61-120 cm) is in part resulted from this fact. The change in the moisture content of the upper 0-60 cm layer is similar to that of the irrigated plots. However, the parameters were higher during the whole vegetation period (by 4-5 % w/v on the average). The effect of irrigation water and precipitation on the moisture content of the soil was most apparent in the top layer, but it had a beneficial effect in the middle layer as well; the minimum moisture levels in August were significantly (by 2-3 %) higher in the irrigated treatments than in the non-irrigated treatments. Irrigation does not seem to have an effect on the moisture content of the bottom soil layer. In 2008 (Figure 2), the water content was favourable for maize in each of the three crop rotation systems (18-30 % w/v); however, at the end of summer the moisture content dropped to unavailable level (17-24 % w/v) in some layers.

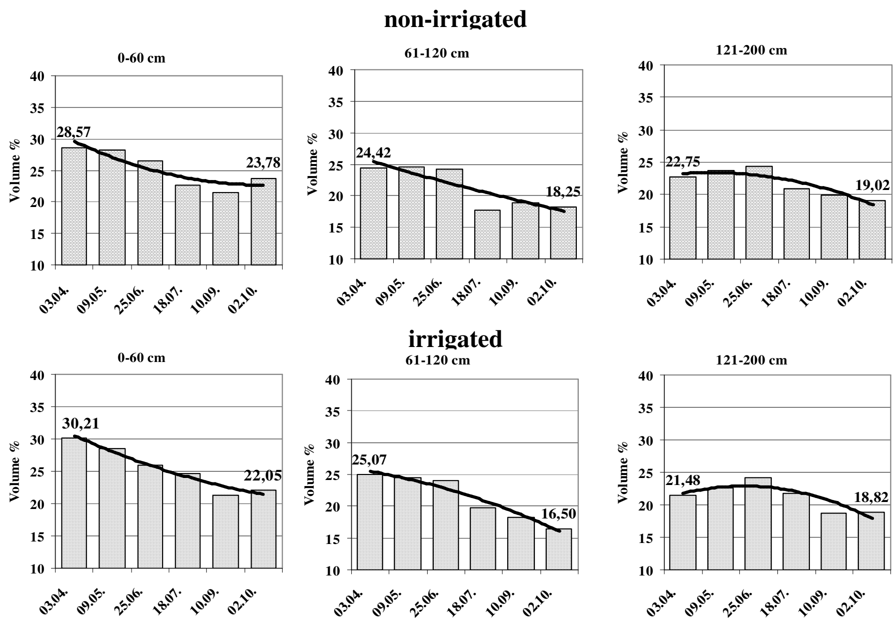

Figure 2. Soil moisture content (v%) in monoculture in 2008 (60000 plants ha^{-1}, N_{120}+PK)

There is a very slight decreasing trend in the moisture loss in the top 0-60 cm layer. The moisture loss of 3-4 % w/v in the grain filling period was caused by the substantial water demand of the huge vegetative and generative mass of plants. The precipitation was well distributed in 2008; by the harvesting period the moisture content of the soil started to increase again. The same tendency applies in the 61-120 cm soil layer, the only difference is that the results of the last sampling time remain the same; the moisture content level was similar to the values obtained at the end of August – beginning of September (16-21 % w/v); together with precipitation, this soil layer contributed to the accumulation of water in the upper layer throught water rise in the soil. The tendency in the 121-200 cm layer is similar to that in the top two zones; except for the end of the vegetation perion, when the moisture moved upwards to the relatively dryer top zones; thus, water rise through evaporation and capillary water rise result in stagnating values. Since there was enough precipitation and no irrigation was applied in 2008, no significant difference was detected between the moisture values of the irrigated and non-irrigated plots.

In the vegetation period in 2009 (Figure 3) the moisture supply that accumulated before sowing was similar to that in 2007 and 2008 (24-30 % w/v) irrespectively of the crop rotation systems, fertilization levels, irrigation treatments or crop density levels.

In the 0-60 cm zone the moisture content decreased with slight fluctuation in the first half of the growing season. Since the precipitation exceeded 100 mm, the moisture content was sufficient even in the flowering stage. This rate decreased by 8-9 % w/v to its minimum by August, and the moisture content increased by 2-3 % by the end of the vegetation period through water rise from lower levels.

The dinamics of the moisture content in the 61-120 cm layer is similar to the top zone. However, moisture values were rather stagnating in the harvesting period (13-15 % w/v); moisture moved upwards and the moisture content in the below zone was not sufficient to compensate for this loss in the draughty period.

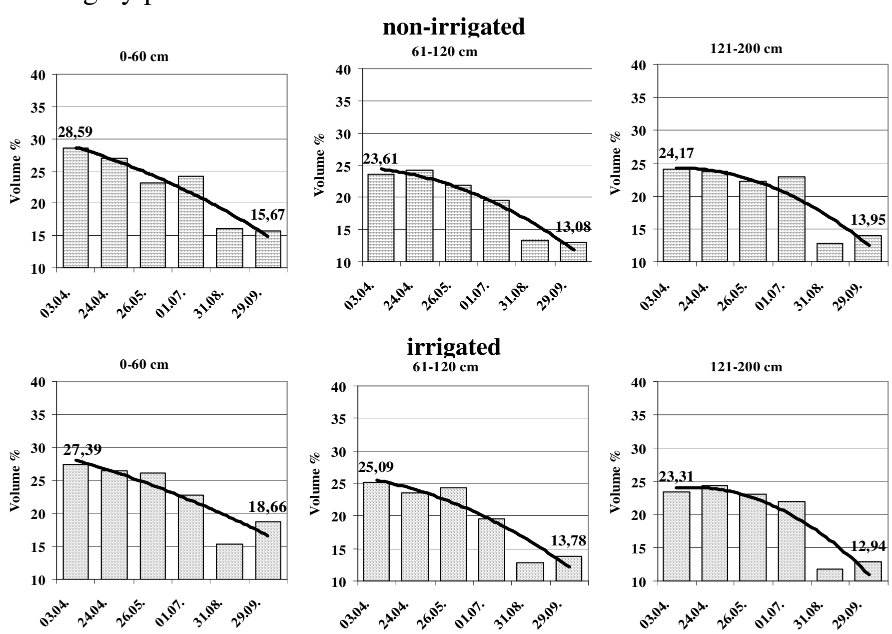

Figure 3. Soil moisture content (v%) in monoculture in 2009 (60000 plants ha^{-1}, N_{120}+PK)

This tendency applied for the moisture dinamics in the 121-200 cm soil layer as well.

Extreme weather has drastic effect on the top soil layer and the plant growth as well. The moisture content decreased with slight fluctuation from the beginning of the vegetation period each year; it reached its minimum in the flowering and fruitification stages and started to increase again in September, according to the volume and distribution of precipitation.

The moisture content in the second soil zone (61-120 cm) decreased from April to July. The root system of maize reached this zone by mid-end of August, thus, a drastic drop is observed in the moisture content of this layer. The degree of moisture loss depends on the precipitation in the growing season. The water uptake of plants and precipitation has the least influence on the moisture content in the 121-200 cm layer. The water content in this layer is primarily determined by the accumulation of winter precipitation. The 61-120 cm zone gains water from this level through evaporation and capillary water rise.

We found that irrigation was most efficient in the 0-60 cm zone in 2007 and 2009, it filled the top soil layer near to water capacity level and provided favourable moisture and nutritional conditions for plants. As irrigation was ceased and the only source of moisture was precipitation, the moisture content of the soil dropped.

The moisture dinamics in the 61-120 cm zone is very similar to that on the non-irrigated plots and confirm that irrigation primarily increases the moisture content in the top soil zone. Irrigation had favourable effects in 2008 as well; the moisture content of the soil was higher not only in the top zone but in the middle zone as well.

Examining the moisture content of the three years we found the most significant change in the top 0-60 cm zone. The diagrams and trend lines in the figures show that the influence of irrigation water was most significant here, precipitation increased the moisture content of the soil at the highest degree and due to the huge root mass the water intake by plants was most intensive. In the 61-120 cm zone the dinamics of soil moisture is more equalized and the moisture loss is lower than in the top zone. The 121-200 cm zone indirectly takes part in the water dinamics of the soil and in the supplementation of plants with moisture through capillary water rise; thus, the change in soil moisture content is most equal in this zone, as it is represented by the trend lines and diagrams as well. There was significant decrease in the moisture content in the grain filling period in August, when the moisture loss in the upper layer was compensated from this zone.

CONCLUSIONS

The water cycle in chernozem soil in maize have been studied in a 28-year long field trial in three cropyears with different precipitation. The relevant soil profile was divided into three leves according to the root zone of maize: 0-60 cm; 61-120 cm; 121-200 cm. Combined analysis of the moisture supply throughout the three years revealed that the change in the moisture content was most intensive in the top 0-60 cm soil layer. The change in the soil moisture content was more levelled and the moisture loss was lower in the 61-120 cm zone than in that one above. Through capillary water rise, the 121-200 cm layer indirectly takes part in the water cycle of the soil and in the supplementation of plants with water. There is a significant drop in the moisture content of the soil in the grain filling period in August, when the moisture loss of the middle zone was recovered from this layer. We found that the influence of irrigation was highest in the top 0-60 cm zone, filled the soil near to water capacity and provided favourable nutritional and moisture conditions for plants.

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