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STUDY OF RELATIONSHIPS BETWEEN YIELD AND SOIL WATER MANAGEMENT OF WINTER WHEAT IN BI- AND TRICULTURE CROP ROTATION SYSTEMS

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Abstract. *The present research work was carried out within the confines of a polifactorial long-term field experiment set up in 1983 with bi- (maize-winter wheat) and triculture (maize-pea-winter wheat) crop rotation systems in two following crop years (2011/2012 and 2012/2013). Winter wheat was studied as test plant. Lower soil moisture volume percentage content values were calculated in the triculture among the studied systems. Water deficit values calculated for the bi- and triculture crop rotation systems proved the higher water use of winter wheat populations sown after pea pre-crop. Water deficit values before sowing confirm the different effect of pre-crops on soil water management. According to the results of the present study it has been stated that water stock of the chernozem soil is significantly affected by crop rotation.*

Keywords: long-term field experiment, winter wheat, crop rotation, soil water stock, yield

1. Introduction

Future possibilities of plant production will likely be extended or even limited by the adapting level in response of climatic changes. This adapting urges mainly the more effective water management [1]. Soil water retention capacity has a major role in the undisturbed functioning and adequate water supply of agro-ecosystems, because spring water deficit of plants (e.g. winter plants) can be ensured and supplied only from the soil water stock filled during the autumn-winter period [2, 3]. Soil microbial life, their enzymatic activity, just as their carbon cycle will be improved in case soil water supply is adequate [4]. Efficiency of agricultural water management is solely possible with the enhancement of water utilization efficiency. Basic element of this is the effective regulation of soil water balance, moisture management [5, 6].

Winter wheat is one of the most important crops produced worldwide. There are significant differences in its yield production in different crop years; it shows sensitive reaction especially towards extreme conditions, such as too high amount of precipitation or even drought. Production of high yield amounts is ensured in case climatic conditions (first of all water supply) match the demands of the plant populations optimally. Water deficit affects yield amount to a significant extent, especially in the generative phase. Stress caused by early spring dry weather conditions does not decrease the number of ears but the amount of grain yield will

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be lower [7, 8, 9, 10, 11, 12, 13, 14]. Even a single time applied irrigation affects yield producing factors, yield and water utilization, just as leaf area index [15]. If soil water content decreases plants have to input more energy in water uptake. Intensity of transpiration does not decrease until at least 50% of plant available water stock of the soil is accessible. Winter wheat has an uptake of 400 mm water per vegetation period in Hungary. Water deficit during the stem elongation and grain filling vegetation phases result in significant yield decrement [16, 17].

2. Material and methods

The study of water management of a chernozem soil type was executed within the confines of a polifactorial long-term field experiment set up in 1983 at the University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, Institute of Crop Sciences, Experimental Station at Látókép. Experimental soil is a calcareous chernozem with good water infiltration and water retention properties. The area of each experimental plot is 41.1 m^2.

Nutrient supply level of N_{100}+PK, two irrigation models (with and without irrigation) and two crop rotation systems (bi- and triculture) were studied in the experiment. Maize and winter wheat are sown in the bi-, while maize, pea and winter wheat in the tri-culture crop rotation system. The studied winter wheat variety was GK Csillag. Soil tillage, plant protection and harvesting measurements were executed uniform. Irrigation was applied in the vegetation of the maize pre-crop in case of both studied crop rotation systems.

For the study of soil water management soil samples were taken from each 20 cm of the upper 200 cm soil layer with four replications four times per each vegetation. Thus altogether 1280 samples were processed. First soil samples were taken before sowing, while the fourth after harvest from the stubble. The other two samplings between were taken in the main phenological phases during winter wheat vegetation (stem elongation and heading-flowering.

The amount of fallen precipitation ensured the water demand of winter wheat during the two studied crop years (2011/2012, 2012/2013) (Table 1). However, the distribution of the precipitation showed significant differences. Extreme low amount of water was available during the germination and early development of winter wheat in the vegetation 2011/2012. Dry conditions were only dissolved by the amount of 71.1 mm precipitation that fell in December. The amount of precipitation during the winter months (December, January and February) was altogether 116.9 mm.

60% (228.9 mm) of the total amount of precipitation in the vegetation of winter wheat was registered in May, June and July.

Vegetation period of the crop year 2012/2013 was more balanced from the aspect of precipitation distribution. Dry conditions of the period before sowing were dissolved by the amount of precipitation in December that was 22.3 mm higher than the 30-years' average value. Altogether 157.4 mm amount of precipitation fell during the winter months (December, January and February) of the vegetation. In contrast to the previous crop year 2013 was wet right until the execution of harvest measurements (391 mm fell from January to July). Four times higher amount of precipitation was measured in the early spring period, i.e. in March than the 30-years' average value.

Table 3) Main weather condition parameters of the crop years 2011/2012 and 2012/2013 (Debrecen-Látókép, 2011/2012, 2012/2013)

Month	2011/2012		2012/2013		30-years' average	
	Prec. (mm)	Temp. (°C)	Prec. (mm)	Temp. (°C)	Prec. (mm)	Temp. (°C)
October	18.1	8.6	22.4	11.1	*30.8*	*10.3*
November	0	0.6	16.6	7.2	*45.2*	*4.5*
December	71.1	1.5	65.8	-1.2	*43.5*	*-0.2*
January	28.0	-0.6	38.7	-1.0	*37.0*	*-2.6*
February	17.8	-5.7	52.9	2.3	*30.2*	*0.2*
March	1.4	6.3	136.3	2.9	*33.5*	*5.0*
April	20.7	11.7	48.0	12	*42.4*	*10.7*
May	71.9	16.4	68.7	16.6	*58.8*	*15.8*
June	91.7	20.9	30.8	19.6	*79.5*	*18.7*
July	65.3	23.3	15.6	21.2	*65.7*	*20.3*
Total precipitation (mm)	**386**	**-**	**495.8**	**-**	***466.6***	**-**
Average temperature (°C)	**-**	**8.3**	**-**	**9.1**	**-**	***8.3***

Regarding average temperature values it can be sated that both studied crop years were warmer than the average of the previous 30 years. Exceptions were November and February in the vegetation 2011/2012, when temperature was on average 3.9 °C, just as 5.5 °C lower, while December and March in 2012/2013 were on average 1, just as 2.1 °C respectively colder than the long-term average values.

3. Results and discussion

Soil moisture content was expressed as volume percentage. Using these values water deficit values were calculated. Water deficit value explains the water amount the actual soil water stock is lower of at the time of sampling in contrast to the water content values of state when soil is filled to field capacity. Water deficit values of the crop years 2011/2012 and 2012/2013 were assessed (Figure 1.) and compared to yield amount results. Soil water deficit values in October 2012 were significantly lower (71.9 and 82.4 mm resp.) in both studied crop rotation systems than those of the next crop year, which can be explained by the amount of precipitation in the end of the summer period.

Both August and September of 2013 were dry that is confirmed by soil water deficit values of both crop rotation systems (biculture: 255.7 mm, triculture: 213.4 mm). As an effect of soil water stock filling of winter precipitation water deficit values in April were lower in both crop years and in case of both crop rotation system soils (in 2012 by 78.2, just as 7.4 mm in bi- and triculture, while in 2013 by 113.7 and 46.8 mm respectively). Despite the rainfalls in May and June 2012 soil water deficit exceeded 200 mm as a consequence of water utilization of winter wheat populations, just as the increase of the average temperature. This tendency remained similar during the whole vegetation. Soil water deficit values did not decrease to a significant extent, but in case of the triculture crop rotation system they increased by 22.4 mm until the end of the vegetation period (Table 2).

However, in 2013 water deficit values calculated in June were similar to the previous sampling period (April), no significant difference could be determined between the two sampling times (biculture April: 142 mm, June 128.5 mm; triculture April: 166.6 mm, June 164.5 mm resp.). This confirms the favourable effect of the high amount of precipitation in March. This water management state was added to the amount of precipitation of the following months. Thus, the increasing water demand of vegetative and generative development stages of winter wheat populations could be ensured. Soil water deficit increased till the harvest (by 47.9 mm in biculture, by 104.7 mm in triculture) due to the increasing drought, the low amount of precipitation in July and the water demand of the plant population during the ripening processes.

According to the results of the present research work it can be stated that water stock of the chernozem soil is significantly affected by the applied crop rotation system. In the studied two crop years regarding the two crop rotation systems involved triculture system showed higher water deficit values during the whole vegetation period of winter wheat. The highest water deficit values were calculated in this treatment combination: water deficit was 39 mm (April 2012), just as 22.6 mm (June 2012) and 56.6 mm (July 2012) higher in the triculture crop rotation system than in the biculture system. In 2013 these values were 24.6 mm in April, 36 mm in June and 92.8 mm in July respectively. The obtained results prove the higher water utilization of winter wheat sown after pea, because plants needed higher water amount in order to ensure the higher nutrient uptake of plants (for the nitrogen content increasing effect of the pre-crop). Water deficit values before sowing prove the different effect of different pre-crops. At the beginning of the vegetation period soil moisture content after the pre-crop pea – despite a dry summer – was still significantly higher (water deficit was 31.8 mm higher in

2012, while 42.3 mm higher in 2013 in case of the biculture crop rotation system than after maize). In contrast to maize pea is harvested much earlier and it uses less water. Thus pea populations leave higher available water amount in the soil for the disposal of the next population in the crop rotation system.

Regarding average yield results of the two studied crop years it can be stated that in the crop year 2011/2012 winter wheat produced a yield amount of 7.273 kg ha^{-1} in the triculture, while 7.425 kg ha^{-1} in the biculture crop rotation system. There was only 152 kg ha^{-1} difference in the yield amounts, no significant difference (Table 2) was proved between the yield results of the two studied crop rotation systems.

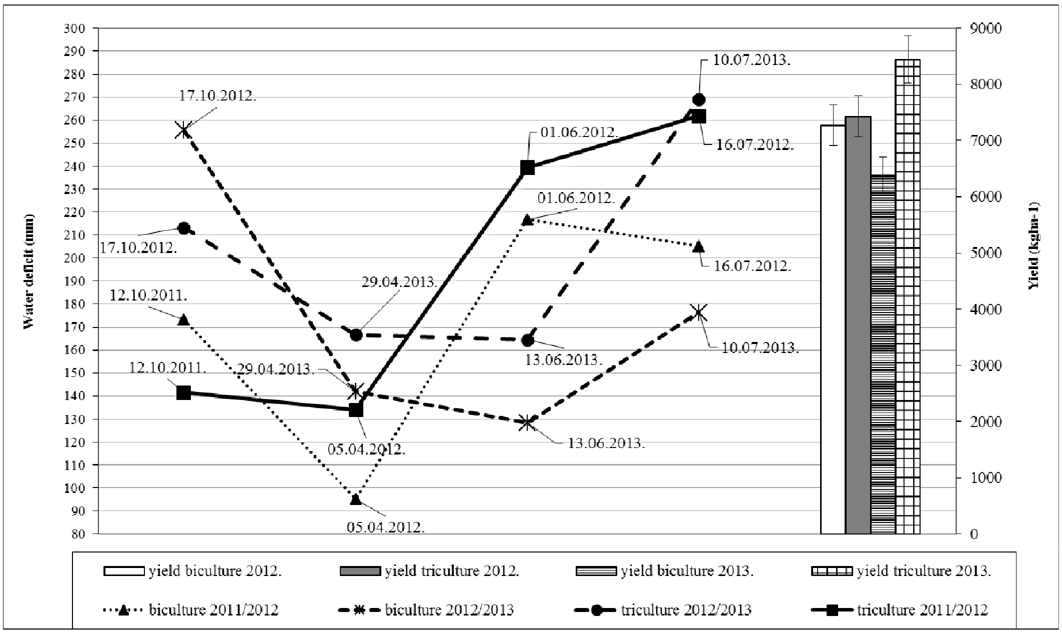

Figure 1. Dynamic changes in yield amounts and soil water deficit values of bi- and triculture winter wheat populations (Debrecen-Látókép, chernozem soil type, 2011/2012, 2012/2013)

Table 4) Table of variance for the evaluation of water deficit values and yield result of the crop years 2011/2012 and 2012/2013

$LSD_{5\%\ crop\ rotation}$	12.10.2011.	05.04.2012.	01.06.2012.	16.07.2012.
water deficit (mm)	64.7	62.3	67.2	42.9
yield (kg ha^{-1})	499.2			
	17.10.2012.	29.04.2013.	13.06.2013.	10.07.2013.
water deficit (mm)	10.1	22.7	16.3	41.0
yield (kg ha^{-1})	684.2			

In the crop year 2012/2013 6.382 kg ha^{-1} grain yield was harvested in the biculture, while 8.441 kg ha^{-1} in the triculture system. Consequently, significant (2.059 kg ha^{-1}) yield surplus was measured in winter wheat population of the triculture crop rotation system.

Conclusions

According to the calculated water deficit values and the obtained yield results it can be stated that regarding water supply the crop year 2012/2013 was more favourable from the aspect of yield producing processes of winter wheat. Pea – as a pre-crop in the triculture crop rotation system – has favourable effect on soil nutrient management. As soil moisture content enabled the production of higher yield amounts yield increasing effect of pea pre-crop is confirmed in the present study. In order to utilize the nutrients available in the soil winter wheat demands an adequate amount of disposable water. Yield results of the two studied crop years confirm this as well. In case – according to the demand of winter wheat – adequate water amount is not available in the soil in the critical phenological phases (stem elongation, heading-flowering) the favourable effect of the pre-crop cannot be confirmed – according to the yield results of the present research work.

Considering the results it can be stated that water deficit values of the triculture crop rotation system were higher in both studied crop years and water uptake of the plant population was more intensive. In contrast the winter wheat population of the biculture crop rotation system lower water deficit did not result in any significant yield surplus in the dryer crop year (2011/2012), because the population utilized the available soil water amount more wasting. Based on the results of the present work it can be stated that as an effect of the pea pre-crop (from the aspect of soil water and nitrogen stock) water utilization of the winter wheat population of the triculture crop rotation system was changed.

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