STUDY OF WATER MANAGEMENT UNDER BI- AND TRICULTURE WHEAT POPULATIONS IN A LONG-TERM FIELD EXPERIMENT

Dóka Lajos Fülöp *

*University of Debrecen
Faculty of Agricultural and Food Sciences and Environmental Management
Institute of Crop Sciences

Abstract

The present studies were executed in a poly-factorial long-term field experiment set up in 1983. Winter wheat was used as test plant. Studies were executed in both bi- (maize-wheat) and tri-culture (maize-pea-wheat) crop rotation systems in two crop years (2012 and 2013). Nutrient supply level of N_{100}+PK was applied in the experiment. The dynamic change of soil moisture content (expressed in V/V%) of the upper 200 cm soil layer during the vegetation period of winter wheat from sowing until harvest, just as the water supply deficit values of the vegetation period were studied. Based on our results it has been stated that the water stock of the chernozem soil was significantly affected by crop rotation – beside other influencing factors (weather conditions, nutrient supply, tillage). Regarding the two studied crop rotation systems lower soil moisture content values expressed as volume percent were calculated for the triculture crop rotation system.

Key words: long-term field experiment, moisture content, water deficit, crop rotation, winter wheat

INTRODUCTION

Future possibilities of plant production will probably be extended or even limited by the extent of the adapting towards climatic changes. Adapting urges primarily the more effective water management (Jolánkai and Birkás, 2009). Consequently, the study of the hydrological cycle and soil water management, just as its effective regulation are of particular importance from the aspect of both the production and environment protection (Várallyay, 1999, Várallyay and Németh, 1999, Várallyay, 2011). Water storage capacity has determining role in the undisturbed functioning and adequate water supply of agro-ecosystems, because springtime ‘water deficit’ of plants (e.g. winter cultures) can be properly supplied only from the soil water stock filled up previously during the autumn-winter period (Farkas et al., 2004; Várallyay, 2005, 2006). According to the results of Kátai (2006) it has to be stated that soil microbial life is enhanced by adequate water supply, beside this its enzymatic activity and carbon-cycle is improved as well.

Winter wheat is one of the most important field crops all over the world. Its yield development shows significant differences in different crop years, sensitive reaction is observed especially by extreme conditions, too high amount of precipitation or even drought. Water deficit affects yield significantly, in particular in the generative phase. As a consequence of stress caused by early spring dry weather the number of heads does not decrease, but the amount of grain yield will be lower (Kirkpatrick et. al, 2006; Harsh and Deepti, 2006; Kassai et al., 2012; Szécsényi et al., 2013; Ibrahim et al., 2012). According to the research results of Zhang et al. (2007) already a one-time executed irrigation in the different phenological phases affects yield, yield-producing factors, water utilization and leaf area index respectively. As soil moisture content decreases, plants need to use more energy to take up water. The intensity of transpiration does not decrease until 50% of the disposable soil water amount is available. Wheat takes up 400 mm water during the vegetation period in Hungary. Water deficit in the phenological phase of shooting and grain filling results in significant yield decrease (Varga and Veisz, 2013; Klupács et. al, 2010).

MATERIAL AND METHOD

The studies were executed in the crop years 2012 and 2013 in the polifactorial long-term field experiment set up 1983 at the Látókép Field Research Centre of the University of Debrecen, Centre for Agricultural Sciences. The experimental soil was a calcareous chernozem. The size of each experimental plot was 41.1 m^2. Experimental treatments were the following: the applied nutrient supply level was N_{100}+PK, beside this two irrigation ($Ö_1$ = not irrigated, $Ö_2$ = irrigated) and two crop rotation systems were involved. The crop rotation of the bi-culture system covered maize – winter wheat, while in tri-culture maize – winter wheat – pea followed each other. The studied winter wheat variety was GK Csillag. Soil tillage, plant protection and harvest measurements were applied uniform. Irrigation was applied in both crop rotation systems in the maize pre-crop populations.

In order to study the soil water management soil samples were taken with four replications from the upper 200 cm from each 20 cm layer four times during the vegetation. First sampling time was before sowing, while the fourth after harvest of winter wheat, from the stubble. The two other samplings were executed in the main phenological phases of wheat (shooting, flowering). Wet weight of the taken soil samples was measured and samples were dried in a laboratory oven at 105 °C until constant weight. Dry samples were weighed again and the difference between the wet and the dry sample was registered as soil moisture content, which was expressed in % by weight. These results were re-calculated with the soil water management parameters to % by volume.

The amount of fallen precipitation (Table 2) of the two studied crop years (2011/2012, 2012/2013) was enough to supply the water demand of winter wheat, however, the distribution of precipitation was rather unbalanced. The recorded amounts of each September (before sowing) were by 31.8 mm less than the 30-years average value in 2011, while by 34.5 mm lower in 2012, so the seeds were sowed in dry soil. In the vegetation period of 2011/2012 extreme low amount of water was available for the germination and early development of winter wheat. These drought conditions were eased by the amount of precipitation (71.1 mm) that fell in December. The amount of fallen precipitation in the winter months (December, January and February) was 116.9 mm.

Table 2

The main weather parameters of the vegetation years 2011/2012 and 2012/2013 (Debrecen-Látókép, 2011/2012, 2012/2013)

Month	2011/2012		2012/2013		30-years average	
	Precip. (mm)	Temp. (ºC)	Precip. (mm)	Temp. (ºC)	Precip. (mm)	Temp. (ºC)
August	42.7	21.4	4.1	22.5	*60.7*	*19.6*
September	6.2	18.0	3.5	18.5	*38.0*	*15.8*
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 amount of precipitation during the vegetation (October – July) (mm)	**386**	**-**	**495.8**	**-**	***466.6***	**-**
Average temperature in the vegetation (October – July) (ºC)	**-**	**8.3**	**-**	**9.1**	**-**	***8.3***

60% (228.9 mm) of the total amount of precipitation in the winter wheat populations fell during the period May, June and July. Thus the water supply of yield producing processes (tasseling, flowering, fertilization, grain filling) was ensured.

The crop year of 2012/2013 was more balanced from the aspect of precipitation distribution. The dry conditions in the period before and after sowing were moderated by the amount of precipitation that fell in December (that was 22.3 mm higher than the 30-years average value). A total amount of precipitation of 157.4 mm was recorded in the winter months of the vegetation (December, January and February). The crop year of 2013 was rather wet even until harvest – unlike the previous crop year: a total amount of 391 mm fell from January till July.

Analysing the average temperature data it can be stated that both crop years were warmer than the average of the previous 30 years.

RESULTS AND DISSCUSIONS

The soil water stock development of two crop rotation systems were compared regarding the average of irrigation systems. At the beginning of the crop year 2011/2012, directly before sowing soil water stock of the upper 100 cm soil layer ranged between 20 and 28 V/V% (Figure 1). As an effect of the pre-crop (maize) soil moisture content values that were 8-10 V/V% less than these were measured in the 100-140 cm soil layer. Soil was dry in this zone, no plant available water stock could be found in it. Soil moisture content increased till April 2012: moisture content values were measured, that were 3-5% less than the field capacity values. According to our measurements soil water content of the upper 40 cm layer ranged between 16 and 22 V/V% due to the water uptake of winter wheat for its biomass production. Despite the high amount of precipitation in the spring – early summer months soil water content decreased further by supplying high amount of water for the plants in the phenological phases of shooting, tasseling, flowering and grain filling. Curves reached the value of plant unavailable water amount: moisture content values between 13 and 15% were measured in the upper 100 cm layer till the harvest.

According to the present research results it can be stated that the beginning of the vegetation period of 2012/2013 was also dry, that can be attributed to the pre-crop, the low amount of precipitation in the end of summer, just as to the warm period (Figure 2). Soil moisture content values ranged between 14 and 21 V/V%. Autumn aridity was only partly moderated by the 157.4 mm precipitation that fell during the winter period, soil moisture content increased by 2-6 V/V% in the upper 0-140 cm soil layer. 253 mm precipitation that fell from March till May ensured favourable water supply conditions for the development of winter wheat. Increasing amount of produced biomass, just as the increasing water demand of the generative phenological phase decreased soil water stock: even lower volume percentage values were found downwards in the upper 0-120 cm soil layer at the sampling time of June. From our results it can be stated that the lowest amount was observed in the layer of 80-100 cm where soil moisture content decreased even until the unavailable water content (16 V/V%) was reached.

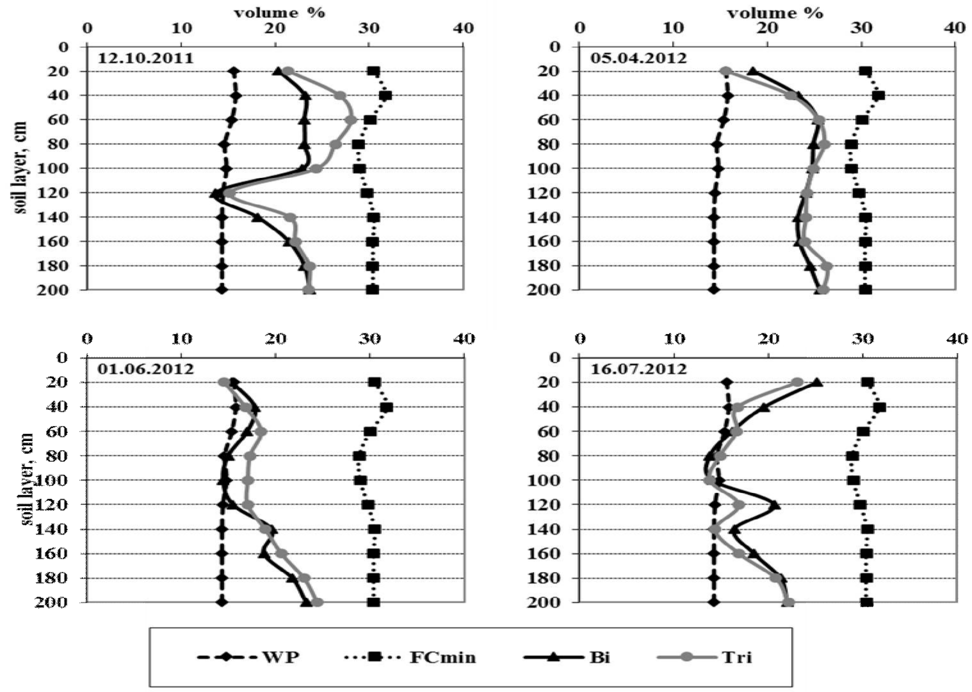

Figure 1 Soil moisture content (V/V%) in different winter wheat crop rotation systems in the crop year of 2011/2012 (N_{100}+PK)

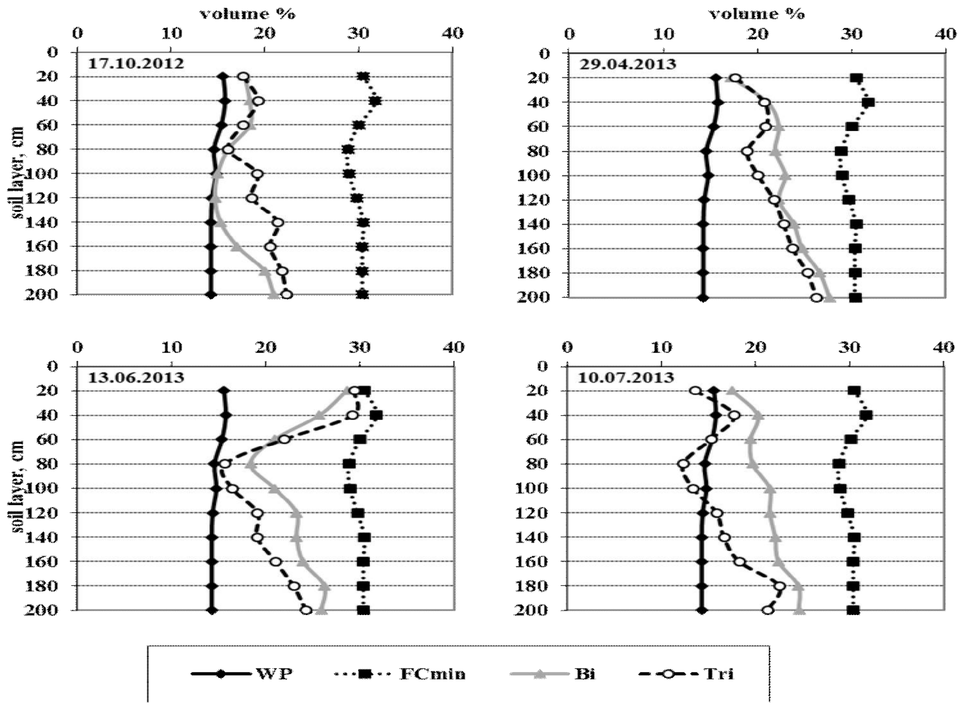

Figure 2 Soil moisture content (V/V%) in different winter wheat crop rotation systems in the crop year of 2011/2012 (N_{100}+PK)

Due to the lower amount of precipitation (30.8 mm in June; 15.6 mm in July resp.), the increasing temperature and the water demand of ripening processes soil moisture content of the whole root volume of winter wheat (0-120 cm) decreased to 13-17 V/V% till the harvest.

At the beginning of both crop years higher soil moisture content was measured in the soil of the tri-culture cropping system (in 2012 in the layer of 0-160 cm, while in 2013 in the layer of 80-200 cm). In bi-culture soil moisture content curves ran close to the unavailable water content value (16 V/V%) in the layer of 0-140 cm. In the tri-culture cropping system the pre-crop of wheat was pea, that has neither the same water uptake, nor similar rooting zone (maximum to 60-100 cm) as maize (the other pre-crop). It is harvested early and it does not deplete soil water stock (Sárvári, 2005).

However, this observed fact turned to be the opposite during the vegetation period: lower soil moisture content values were measured in the treatments of the tri-culture winter wheat.

Soil water deficit values were calculated based on the soil moisture content data (Table 3). Water deficit values in October 2012 were far lower (71.9-82.4 mm) than those in the next year in both crop rotation systems that can be explained by the amount of precipitation that fell in the end of the summer period.

Both August and September of 2013 were dry, that is confirmed by the water deficit values calculated for both crop rotation systems (bi-culture: 255.7 mm, tri-culture 213.4 mm). As a result of the winter precipitation that filled up the soil water stock water deficit values in April were lower in both crop years and both crop rotation systems (in 2012 by 78.2-7.4 mm, while in 2013 by 113.7-46-8 mm in bi- and tri-culture). Despite the rainfalls in May and June 2012 soil water deficit values over 200 mm were calculated again and this tendency remained till the end of the vegetation period, furthermore in case of the tri-culture deficit value increased by 22.4 mm.

Table 3

Dynamic development of soil water deficit values in winter wheat population in bi- and tri-culture crop rotation systems (Debrecen, chernozem soil, 2011/2012, 2012/2013)

time of soil sampling	biculture	triculture
12.10.2011	173	142
05.04.2012	95	134
01.06.2012	217	239
16.07.2012	205	262
17.10.2012	256	213
29.04.2013	142	167
13.06.2013	128	164
10.07.2013	176	269

In the crop year of 2013 water deficit values measured in June were similar to those calculated for April (in bi-culture: 142 mm in April, 128.5 mm in June, while in tri-culture 166.6 mm in April and 164.5 mm in

June resp.). This confirmes the favourable effect of the high amount of precipitation in March, that resulted in favourable water supply circumstances – that was complemented by the precipitation fell during the later months – and thus the water demand of the vegetative and generative development of winter wheat populations was ensured. Soil water deficit increased till harvest (in bi-culture by 47.9 mm, in tri-culture by 104.7 mm).

CONCLUSIONS

Winter wheat affects the water management of the upper 0-120 cm soil layer. Water loss of the layer 40-100 cm proved to be the most intensive. According to this, the most of the winter wheat root system is placed in this layer (40-100 cm). Soil moisture management of the upper 0-40 cm soil layer is mainly affected by weather conditions, in particular by precipitation and temperature. The most dynamic change of soil water content volume percent values during the vegetation period was observed in this layer.

Based on the present research work it has been stated that water stock of the chernozem soil is significantly determined by crop rotation – beside other factors, such as weather conditions, nutrient supply and agrotechnical measurements. Regarding the two studied crop years and the two crop rotation systems higher water deficit was observed in the tri-culture crop rotation system during the whole vegetation period of winter wheat: water deficit of the tri-culture system was by 39 mm higher in April 2012, while in June by 22.6 mm, in July by 56.6 mm and in April 2013 by 24.6 mm, in June 36 mm and in July by 92.8 mm.

Based on the results of the present research work it can be stated as well that in order to draw more precise conclusions further research work is essential in crop years with weather conditions different from the ones detailed above. Furthermore, the evaluation of winter wheat soil water profile shall be studied more often, in more phenological phases during the vegetation in order to determine the dynamic change of soil water stock.

REFERENCES

1. A., Kirkpatrick, L., Browning, J., W., Bauder, R., Waskom, M. Neibauer, G., Cardon: 2006. Irrigating with Limited Water Supplies: A Practical Guide to ChoosingCropsWell-Suited to Limited Irrigation. Extension Water Quality Program. Bozeman. Montana State University. 15.
2. Farkas Cs. – Tóth E. – Várallyay Gy.: 2004. A talaj fizikai tulajdonságainak vizsgálata talajművelési kísérletben. „AGRO-21" Füzetek. Agroökológia. Agroökoszisztémák környezeti összefüggései és szabályozásának lehetőségei. 2004. 37. szám. 111.
3. H., Klupács, Á., Tarnawa, I., Balla, M., Jolánkai: 2010. Impact of water availability on winter wheat (Triticum aestivum L.) yield characteristics. Agrokémia és Talajtan. 59. 1. 151–156.

4. Harsh, N., Deepti G.: 2006. Differential sensitivity of C3 and C4 plants to water deficit stress: Association with oxidative stress and antioxidants. Environmental and Experimental Botany. 58. 106–113.
5. Jolánkai, M., Birkás, M.: 2009. Klímaváltozás és növénytermesztés. Növénytermesztés: Gazdálkodás – Klímaváltozás – Társadalom. Szerk.: Harcsa M.. V. Növénytermesztési Tudományos Nap. 27-34.
6. Kassai M. K., Nyárai H. F., Máté A., Tarnawa Á., Szentpétery Zs., Jolánkai M.: 2012. Az évjárat hatása az őszi búza (Triticum aestivum L.) termésmennyiségére és –minőségére. Talaj – Víz – Növény – kapcsolatrendszer a növénytermesztési térben. (Szerk.: Lehoczky É.) I. Talajtani, Vízgazdálkodási és Növénytermesztési Tudományos Nap. Debrecen. 197-204.
7. Kátai J.: 2006. changes in Soil Characteristics in a Mono- and Triculture Long-term Field Experiment. Agrochemistry and Soil Science. 55. 1. 183-192.
8. M., M., Ibrahim, S., A., Ouda, A., Taha, G., El Afandi, S.,M. Eid: 2012. Water management for wheat grown in sandy soil under climate change conditions. Journal of Soil Science and Plant Nutrition. 12. 2. 195-210.
9. Sárvári, M.: 2005. Borsó. In: Antal J. (Szerk.): Növénytermesztéstan 2. Gyökér- és gumós növények. Hüvelyesek. Olaj- és ipari növények. Takarmánynövények. 109-134.
10. Szécsényi M., Cserháti M., Zvara Á., Dudits D., Györgyey J.: 2013. Monitoring of Transcriptional Responses in Roots of Six Wheat Cultivars during Mild Drought Stress. Cereal Research Communications. 41. 4. 527-538.
11. Varga, B., Veisz, O.: 2013. A szimulált aszály hatásai az őszi búza produkciójára és vízforgalmára. In: Janda T. (szerk.): II. ATK Tudományos Nap – Velünkl Élő Tudomány. 85-88.
12. Várallyay Gy.: 2005. A magyar Alföld szélsőséges vízgazdálkodása és az ahhoz történő alkalmazkodás lehetőségei és korlátai. In: Pepó P. (szerk.): Korszakváltás a hazai mezőgazdaságban: a modern növénytermesztés alapjai. Tudományos ülés. Debrecen. 43-51.
13. Várallyay Gy.: 2006. A talaj multifunkcionalitása és szerepe a tájökológiában. II. Magyar Tájökológiai Konferencia Debrecen, 2006. április 7-9. Az előadások és poszterek összefoglalói. 2.
14. Várallyay, Gy., Németh, T.: 1999. A környezetkímélő növénytermesztés talajtani-agrokémiai alapjai. In: Ruzsányi L., Pepó P. (szerk.): Növénytermesztés és környezetvédelem. „Magyarország az ezredfordulón" – Stratégiai kutatások a Magyar Tudományos Akadémián. Budapest. 69-75.
15. Várallyay, Gy.: 1999. A talaj vízgazdálkodásának szabályozása, mint a környezetkímélő növénytermesztés egyik kulcskérdése. In: Ruzsányi L., Pepó P. (szerk.): Növénytermesztés és környezetvédelem. „Magyarország az ezredfordulón" – Stratégiai kutatások a Magyar Tudományos Akadémián. Budapest. 56-65.
16. Várallyay, Gy.: 2011. Water-dependent land use and soil management int he Carpathian Basin. Növénytermelés. 60. 2011. Suppl. 3. 297-300.
17. Zhang Bu, C. Huang G., B., Li Feng-Min: 2007. Effect of Limited Single Irrigation on Yield of Winter Wheat and Spring Maize Relay Intercropping. Pedosphere. 17. 4. 529–537.Domuţa C., 2009, Irigaţiile în Câmpia Crişurilor, Editura Universităţii din Oradea, pp. 50-120