PEDOLOGICAL DROUGHT INFLUENCE ON YIELD QUANTITY AND QUALITY OF THE MAIZE IN THE CRIŞURILOR PLAIN

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Abstract

The were carried out in Agricultural Research and Development Station Oradea during 2006-2008 in the conditions of the preluvosoil from moderate wet area of the Crişurilor Plain. Six variants were studied: unirrigated, without suspending irrigation, irrigation suspending in May, June, July or August. In the variant with optimum irrigation, water reserve on 0-75 cm depth was maintained between easily available water content and field capacity. Pedological drought – the decrease of the soil water reserve on watering depth bellow easily available water content – was registered every year and the irrigation was also needed. The irrigation determined the yield gain very significant statistically in comparison with unirrigated variant. Irrigation suspending in different months determined the yield losses very significant statistically in comparison with the optimum irrigated variant. The biggest protein content was registered in the variant without irrigation suspending; the values registered in the variants with irrigation suspending in May, June, July and August and in the unirrigated variant are smaller, with differences statistically assured. There were an inverse link between pedological drought, and yield quantity, protein content and protein production.

Key words: pedological drought, irrigation regime, protein, yield, maize.

INTRODUCTION

The Crişurilor Plain occupies the central part of the Western Plain of Romania and maize and wheat are cropped on the biggest surfaces. The first researches from this area regarding the maize irrigation were started on the chernozem from Girişu de Criş in 1967 by Stepănescu E. and Mihăilescu V. The furrow irrigation was used and different level of easily available water content (50%, 70% for utile water capacity) and watering depth (0,50 m; 0,85 m and 1,2 m) were studied; the biggest yields were obtained in the variant with 70% from utile water capacity and of 0,8 m of watering depth. (Borza, 2007, 2009). There are the researches wich recomand a variable watering depth in function of roots development (Domuţa , 2008, Borza et al, 2009).

The researches regarding the pedological drought from Crişurilor Plain were carried out during 1976-2010 on the preluvosoil from Oradea in the research field from soil water balance study. Soil moisture on maize watering depth (0-75 cm) was determined ten to ten days. The results research during 1976-2008 emphasized the decrease of the soil moisture bellow easily available water content on 0-75 cm depth every year; the biggest number with pedological drought was registered in July (28 days).

Strong pedological drought was determined, too, the soil moisture decreasing bellow wilting point in 40% of the years studied; the biggest number of days with soil moisture bellow wilting point (7 days) were registered in August (Domuța, 2005, 2009).

The drought determines a smaller roots length and volume, a smaller fresh and dry weight of roots, a smaller leaf area per plant a lower level of turgescence, nitrogen and phosphorus in the leave (Domuța, 1995) the yields very significant smaller than the yield from optimum irrigated variant (Salisbury F.B. and Ross C.W., 1992, Doremboos J. and Pruitt W.O., 1993, Pakurar M. et al., 2004). The water use efficiency (WUE) in the drought condition decrease in comparison with irrigated variant (Nagy J., 1999, 2010) but in the years with rainfall over the multiannual average but with short period with drought in different maize vegetation stage the water use efficiency can be bigger than in irrigated variant (Domuța C. et al., 2009).

Irrigation suspending in different months of the vegetation period determines the yield losses and the smaller water use efficiency (Domuța, 2009).

The drought determines smaller protein content in the grains (Gyori et al, 2005).

The inverse link was registered between pedological drought and maize water consumption and yield level, respectively (Domuța Cr. et al, 2008) and a direct link between pedological drought and yield gain obtained using the optimum irrigation was quantified, too (Borza I., 2007).

This paper studies the presence of the pedological drought in unirrigated maize and in the variants with irrigation suspending in May, June, July or August. The paper quantifies the pedological drought and optimum irrigation influences on yield quantity and protein content and production. The correlations between pedological drought and yield quantity, protein content, protein production are quantified, too.

MATERIAL AND METHODS

The researches were carried out in Agricultural Research and Development Station Oradea during 2006-2008 on the preluvosoil with the following soil profile: Ap = 0-24 cm; El = 24-34 cm; Bt_1=34-54 cm; Bt = 54-78 cm; Bt/c =78-95 cm; C = 95-145 cm. There are a big hydro stability (47.5%) of the aggregates (Φ = 0.25 mm) on ploughingland; bulk density (1.41 g/cm^3) indicates a low settling and total porosity is median. On the subjacent depth of the ploughing layer bulk density characterizes the soil like moderate and very settled and total porosity is small and very small. Hydraulic conductivity is big (21.0 mm/h) on 0-20 cm; median (10.5 mm/h;

4.4 mm/h) on 20 – 40 cm and 40 – 60 cm and very small (1.0 mm/h) on 60 – 80 cm.

The watering depth (0-75 cm) was a fixed one and field capacity (FC = 24.2% = 2782 m^3/ha) and wilting point (WP = 10.1 = 1158 m^3/ha) have median values. Easily available water content (Wea) was established in function of texture: Wea = WP + 2/3 (FC – WP); (6); their values for 0-75 cm are 19.5% and 2240 m^3/ha.

All the soil profile are low acid (6.11 – 6.8), humus content (1,44 – 1.75 %) is small and total nitrogen is low median (0.127 – 0.157). After 30 years of good practices of soil management, the soil phosphorus content became very good (from 22.0 ppm to 150.8 ppm); on ploughing depth, potassium content (124.5 ppm) is median.

A drill is the water source for irrigation and their quality for irrigation is very good: pH = 7.2; Na^+ = 12.9%; mineral residue = 0.5 g/l; CSR = -1.7; SAR = 0.52.

In comparison with multiannual average (1931-2005) of 621.1 mm during the studied period the annual rainfall were of 684.7 mm in 2006; of 556.1 mm in 2007 and of 585.7 mm in 2008.

The following variants were studied: V_1 = unirrigated; V_2 = Irrigated without the irrigation suspending in the maize irrigation season; V_3 = Irrigated, with irrigation suspending in May, 4-9 leaves, V_4 = Irrigated, with irrigation suspending in June, 10-18 leaves; V_5 = Irrigated, with irrigation suspending in July, tassel growth – grains filling; V_6 = Irrigated, with irrigation suspending in August, grains filling-ripening. The surface of the experiment plot was 50 m^2. Number of repetition = 4; Irrigation method used was sprinkler with modifications for rectangular plots. Cultivar used: Fundulea 376. Fertilization system: $N_{120}P_{90}K_{60}$.

Soil moisture of 0 – 75 cm depth was determined ten to ten days. In the variant without irrigation suspending the moment of the irrigation use was when the soil water reserve on 0 – 75 cm depth decreased to easily available water content. In the variant with irrigation suspending in different months didn't irrigate in these months.

Protein content was determined using the specifically method in the laboratory of the Agricultural Research and Development Station Oradea. The experiment data was calculated by variance analysis method (Domuța, 2006).

RESULTS AND DISCUSSION

Pedological drought in maize

Pedological drought is considered when the soil moisture decrease bellow easily available water content on watering depth; the decrease of the soil moisture bellow wilting point is considered very strong pedological

drought. The determination of the number of days with drought is based on the soil moisture determination ten to ten days and on the soil water reserve graphs realized after that.

In unirrigated maize, in 2006, pedological drought affected the plants in 46 days. Irrigation suspending in July determined 23 days with pedological drought and irrigation suspending in August determined 6 days with pedological drought. (Table 1)

The biggest number with pedological drought in unirrigated maize was registered in 2007, 110 days. Irrigation suspending in every month of the maize irrigation season determined the appearance of the pedological drought, the biggest in the variant with irrigation suspending in July (24 days) and June (21 days) and the smallest in the variant with irrigation suspending in May (12 days). (Table 1)

In 2008, number of days with pedological drought in unirrigated maize was of 76 In the variant with irrigation suspending in August (28 days) and July (24 days) and the smallest in the variant with irrigation suspending in May. (Table 1)

Optimum irrigation water regime of the maize consists of 1160 m^3/ha and 3 rated in 2006, 2950 m^3/ha and 8 rates in 2007 and 3320 m^3/ha and 8 rates also in 2008. Irrigation suspending determined the decrease of the irrigation rate (Table 2).

Table 1

Number of days with pedological drought in maize from different variants of water provisionment, in the conditions from Oradea 2006-2008

Variant	Month					IV-VIII
	IV	V	VI	VII	VIII	
2006						
V_1	0	0	0	0	0	0
V_2	0	0	0	0	0	0
V_3	0	0	0	0	0	0
V_4	0	0	0	20	3	23
V_5	0	0	0	0	6	6
V_6	0	0	5	31	10	46
2007						
V_1	0	0	0	0	0	0
V_2	0	10	2	0	0	12
V_3	0	0	17	4	0	21
V_4	0	0	0	20	5	24
V_5	0	0	0	0	17	17
V_6	14	22	26	28	20	110
2008						
V_1	0	0	0	0	0	0
V_2	0	8	2	0	0	10
V_3	0	0	14	0	0	14
V_4	0	0	0	21	3	24
V_5	0	0	0	0	28	28
V_6	0	8	16	21	31	76

Table 2

Number of days with pedological drought (N) in maize from different variants of water provisionment, Oradea 2006-2008

Vari-ant	April			May			June			July			August			April - August		
	N	∑m	n	N	∑m	n	N	∑m	n	N	∑m	n	N	∑m	n	N	∑m	n
2006																		
V_1	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
V_2	0	-	-	0	-	-	0	-	-	0	1160	3	0	-	-	0	1160	3
V_3	0	-	-	0	-	-	0	-	-	0	1160	3	0	-	-	0	1160	3
V_4	0	-	-	0	-	-	0	-	-	20	1160	3	3	-	-	23	1160	3
V_5	0	-	-	0	-	-	0	-	-	0	-	-	6	-	-	6	-	-
V_6	0	-	-	0	-	-	5			31	1160	3	10	-	-	46	1160	3
2007																		
V_1	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
V_2	0	300	1	10	400	1	2	500	1	0	1200	4	0	550	1	12	2950	8
V_3	0	300	1	0	-	-	17	500	1	4	1200	4	0	550	1	21	2550	7
V_4	0	300	1	0	400	1	0	-	-	20	1200	4	5	550	1	24	2450	7
V_5	0	300	1	0	400	1	0	500	1	0	-	-	17	550	1	17	1750	4
V_6	14	300	1	22	400	1	26	500	1	28	1200	4	20	-	-	110	2400	7
2008																		
V_1	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
V_2	0	-	-	8	500	1	2	1020	2	0	1100	3	0	700	2	10	3320	8
V_3	0	-	-	0	-	-	14	1020	2	0	1100	2	0	700	2	14	2820	6
V_4	0	-	-	0	500	1	0	-	-	21	1100	2	3	70	2	24	2300	5
V_5	0	-	-	0	500	1	0	1020	2	0	-	-	28	700	2	28	2220	5
V_6	0			8	500	1	16	1020	2	21	1100	2	31	-	-	76	2620	5

∑m = irrigation rate; n = number of rate

Irrigation water regime in maize

Optimum irrigation water regime of the maize consists of 1160 m^3/ha and 3 rated in 2006, 2950 m^3/ha and 8 rates in 2007 and 3320 m^3/ha and 8 rates also in 2008. Irrigation suspending determined the decrease of the irrigation rate (Table 3).

Table 3

Influence on yield of the irrigation suspending in different months of the maize irrigation season Oradea, 2006-2008

Variant	Yield		Difference		Statistically significant
	Kg/ha	%	Kg/ha	%	
2006					
V_1	13200	100	-	-	Mt
V_2	13110	99.3	-90	-0.7	-
V_3	13410	101.6	+210	+1.6	-
V_4	9330	70.6	3870	-29.4	ooo
V_5	13340	101.1	140	1.1	-
V_6	9240	70.0	3960	-30.0	ooo
LSD 5% = 230		LSD 1% = 410		LSD 0.1% = 670	
2007					
V_1	13120	100	-	-	Mt
V_2	12100	92.2	-1020	-7.8	ooo
V_3	7900	60.2	-5220	-39.8	ooo
V_4	8300	63.6	-4820	-36.4	ooo
V_5	10490	79.9	-2630	-20.1	ooo
V_6	6470	49.3	-6650	-50.7	ooo
LSD 5% = 240		LSD 1% = 410		LSD 0.1% = 790	
2008					
V_1	14200	100	-	-	Mt
V_2	13180	92.8	-1020	-7.2	ooo
V_3	11620	81.8	-2580	-18.2	ooo
V_4	11540	81.3	-2660	-18.7	ooo
V_5	10340	72.8	-3860	-27.2	ooo
V_6	7610	51.5	-6590	-48.5	ooo
LSD 5% = 190		LSD 1% = 310		LSD 0.1% = 680	

Irrigation influence on protein content of maize grains

The biggest values of the protein content were registered in the variant without irrigation suspending: 12.2% in 2006; 11.12% in 2007; 11.38% in 2008 and the lowest were registered in the unirrigated variant: 8.27% in 2006; 7.0% in 2007 and 6.57% in 2008.

Irrigation suspending in May didn't determine the difference statistically assured in comparison with the variant without the irrigation suspending. Irrigation suspending in June determined the difference distingue statistically and the irrigation suspending in July and August determined the difference very significant statistically. Irrigation was needed only in June in 2006 and the irrigation suspending in this month determined a very significant decrease of the protein content (Table 4).

Table 4

Influence of the irigation suspending in different months of the irrigation season on content of the maize protein grains, in the conditions from Oradea, 2006-2008

Variant	Protein		Difference		Statistically significant
	%	%	%	%	
2006					
V_1	12.20	100	-	-	Mt
V_2	12.16	99.6	-0.04	-0.4	-
V_3	11.96	98.0	-0.24	-2.0	-
V_4	8.4	77.0	-3.8	-32.0	ooo
V_5	12.21	100.1	0.01	+0.1	-
V_6	8.27	67.8	3.93	-32.2	ooo
LSD 5% = 0.61 LSD 1% = 1.02 LSD 0.1% = 2.29					
2007					
V_1	11.12	100	-	-	Mt
V_2	10.44	93.9	-0.67	-6.1	-
V_3	8.56	77.0	-2.56	-23.0	oo
V_4	8.39	75.4	-2.73	-24.6	ooo
V_5	7.93	71.4	-3.19	-28.6	ooo
V_6	7.00	63.0	-4.12	-37.0	ooo
LSD 5% = 0.81 LSD 1% = 1.56 LSD 0.1% =2.63					
2008					
V_1	11.38	100	-	-	Mt
V_2	10.94	96.1	-0.44	-3.9	-
V_3	9.50	83.5	-1.88	-16.5	oo
V_4	9.19	80.8	-2.19	-19.2	ooo
V_5	7.94	69.8	-3.44	-30.2	ooo
V_6	6.75	59.4	-5.13	-40.6	ooo
LSD 5% = 0.50 LSD 1% = 1.06 LSD 0.1% = 2.00					

The correlations between pedological drought and yield, protein content, protein production

Five types of function – linear, logarithmic, polynomial, power, exponential – were used for cuantification of the pedologiacal drought correlations. In all the cases, polynomial function had the biggest correlation coefficient. There were inverse correlations very significant statistically, between number of days with pedological drought and yield obtained in the studied variant: ($y = 0{,}8487x^2 - 151.88x + 13380$; $R^2 = 0.7996$) The same kind of correlations were quantified between number of days with pedological drought and protein content ($y = 0{,}0009x^2 - 0{,}1441x + 11.732x$; $R^2 = 0.8541$) respectivelly protein production ($y = 0{,}0002x^2 - 0{,}0324x + 15664$; $R^2 = 0.8458$).

The researches results sustain the needed of the optimum irrigation in maize from Crişurilor Plain because the level of the yield and protein content and protein production is very significant influenced.

The climate of the Crişurilor Plain is characterized like „moderate wet" and the pedological drought was determined both in the year with rainfall over the multiannual average and stronger in the years with rainfall smaller than multiannual average.

Pedological drought was determined too in the months with irrigation suspending and few days in the next month after suspending.

Pedological drought influenced the level of the maize yields and yields losses very significant statistically, was registered due the irrigation suspending in May or June or July or August in the years with the rainfall smaller than multiannual average. In the year with rainfall bigger than multiannual average, the irrigation suspending in July, only determined the yield loss statistically assured.

Pedological drought has a big influence on protein content, the values determined in unirrigated variant were very significant statistically smaller than the values determined in the variant with optimum irrigation. In the rainy year, irrigation suspending in July only determined a protein content very significant statistically smaller than the protein content of the maize grains from optimum irrigated. In the droughthty years, the protein content of the grains was distingue significant statistically smaller than the protein content of the optimum irrigated variant in the variant with irrigation suspending in May and very significant statistically in the variants with irrigation suspending in June, or July, or August.

In the droughty years, the values of the grains protein content were smaller than the values registered in the year with rainfall over the multiannual average in the all 6 variant studied.

The increasse of number of days with pedological drought determined the decrease of the level of the yield, of the protein content of maize grains and of the protein production; these correlations are very significant statistically.

Our results researches confirm other result research regarding the drought influence on yield and protein content of the maize grains and in adition determine the influence of the irrigation suspending in different months of the maize irrigation season on soil moisture, yield and protein content of the maize grains in the conditions of the moderate wet climate of the Crişurilor Plain.

CONCLUSION

The researches carried out on the preluvosoil in 6 variants regarding the water regime determined the following conclusions:

- In unirrigated maize the pedological drought was determined every year: 46 days in 2006; 110 days in 2007 and 76 days in 2008. In the variants with irrigation suspending in the months of the maize irrigation season (May, June, July, August) the pedological drought was presented in these months and a few days in the next month.
- Maintaining the soil water reserve between easily available water content and field capacity determined to use an irrigation rates of 1160 m^3/ha in 2006, of 2950 m^3/ha in 2007 and of 3320 m^3/ha in 2008. The

irrigation rates were smaller in the variants with irrigation suspending in different months.

- In the all 5 variants with irrigations, the maize yields were bigger than the yields from unirrigated variant; the differences were very significant statistically. Irrigation suspending in different months of the maize irrigation season determined yield gains in comparison with the variant without irrigation suspending.
- Irrigation determined the increase of the protein content in comparison with unirrigated variant. As consequence the relative difference between total protein productions increased in comparison with the relative differences between grains yields. In the variants with the irrigation suspending, the protein content decreased in comparison with the variant without irrigation suspending; the differences were statistically assured.
- Inverse links, very significant statistically, were quantified between number of days with pedological drought and level of yields, between pedological drought and protein content and between number of days with pedological drought and protein production.

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