IRRIGATION INFLUENCE ON WATER CONSUMPTION, YIELD AND WATER USE EFFICIENCY IN ALFALFA IN THE CRIŞURILOR PLAIN

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Abstract

Alfalfa is a very important plants for fodder in the Crişurilor Plain and the paper presents the research results which carries out on the preluvosoil from Agricultural Research and Development Station Oradea during 2007-2010. Ten to ten day determination of the soil moisture emphasized the decrease of the soil water reserve on watering depth (0-100 cm) bellow easily available water content (every year) for maintaining the soil water reserve between easily available water content and field capacity an irrigation rate of 4650 m^3/ha in 2007, of 5300 m^3/ha in 2008, of 5400 m^3/ha in 2009 and of 3780 m^3/ha in 2010 were used. The irrigation determined the increase of the daily water consumption; in these conditions total water consumption increased with 70% in 2007, with 92% in 2008, with 114% in 2009 and with 82% in 2010. The irrigation determined the yield gains very significant statistically every year; the relative differences were of 42% in 2007, of 108.4% in 2008, of 126.5% in 2009 and of 38%. in 2010. The irrigation determined the improve of the water use efficiency every year. The results obtained emphasizes the irrigation opportunity in alfalfa 2nd year from Crişurilor Plain.

Key words: climate elements, pedological drought, irrigation, yield gain, alfalfa.

INTRODUCTION

The irrigation influence in alfalfa was studied in the Crişurilor Plain starting with 1969 (Domuța, 1995, Ciobanu and Domuța, 2003, Domuța, 2003, Domuța, 2008) and the positive influence on soil water reserve, microclimate, plants water consumption, yield and water use efficiency were quantified (Grumeza and Kleps, 2005, Man. et al, 2007, Domuța et al., 2008, Borza et al, 2010, Domuța, 2010). Other researches (Grumeza et al., 1989, Luca and Nagy, 1999, Borza et al., 2009, Domuța, 2011) quantified the same influence in the other areas of Romania.

MATERIAL AND METHODS

The paper presents the researches carried out during 2007-2010 in the long term trial for soil water balance study placed in 1976 in Agricultural Research and Development Station Oradea, Western Romania in the conditions of a preluvosil. All the preluvosoil 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 36 years of good 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.

There are a big hydro stability (47.5%) of the aggregates (Φ = 0.25 mm) on ploughingland; the bulk density (1.41 g/cm^3) indicates a low settling soil, total porosity is median. On the subjacent depth of the ploughing layer the 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 (Domuța C. et al, 2009).

The source of irrigation water was a drill of 15 m depth. Irrigation water quality was very good: pH = 7.2; Na^+= 12.9; mineral residue = 0.5 g/l; CSR = -1.7; SAR = 0.52.

In Romania, the watering depth for alfalfa 2nd year is fixe one, 0-100 cm foor this area. Soil moisture of 0 – 100 cm depth was determined ten to ten days and monthly on 0 – 150 cm depth. In the variant irrigated, the moment of the irrigation use was when the soil water reserve on 0 – 100 cm depth decreased to easily available water content. On the 0-100 cm the value of the easily available water content (Wea) is of 19.7% (3055 m^3/ha). Easily available water content was established in function of clay content (Brejea R., 2009, 2010) using the formula: Wea = WP+2/3 (FC-WP); in wich: FC= field capacity (24.3%) and WP= wilting point (10.5%).

The water consumption was determined by the soil water balance method. Water use efficiency was calculated like report between yield and water consumption. (Borza. and Stanciu, 2010)

The experiment data were calculated using the variance analysis method (Domuța C, 2006).

RESULTS AND DISCUSSION

The annual rainfall during the studied period were of 556.1 mm in 2007, of 585.7 mm in 2008, of 501.4 mm in 2009 and of 889.5 mm in 2010; the average temperatures were of 12,6°C in 2007, of 11,0°C in 2008, of 11,6°C in 2009 and 11.3 in 2010; the values of the air humidity were of 66% in 2007, of 72% in 2008, of 70% in 2009 and of 78% in 2010. (table 1).

Table 1

Climate elements of the agricultural years average 2007-2010
(after Meteorological Station Oradea)

Specification	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Sum/ Average
Air temperature, °C													
2007	11.2	6.6	2.3	4.3	4.7	8.7	12.2	18.2	22.2	23.6	22.3	14.4	12.6
2008	10.3	3.7	-0.4	1.4	3.4	6.5	11.6	16.9	21.0	20.9	22.0	15.4	11.0
2009	12.3	6.7	3.2	-1.0	0.3	5.4	14.4	17.3	19.8	23.1	22.2	15.5	11.6
2010	11.3	7.7	3.0	- 1.3	2.4	6.1	11.5	16.2	19.8	22.4	21.6	15.2	11.3
Multianual average*	10.6	6.7	3.2	- 2.2	0.3	5.0	10.5	15.8	19.1	20.8	20.0	16.2	10.5
Rainfall, mm													
2007	24.4	27.4	9.7	36.8	69.3	13.0	3.2	80.6	50.5	67.6	82.4	91.2	556.1
2008	75.1	62.6	29.4	21.3	12.5	67.9	43.3	38.9	92.1	69.3	27.3	46.0	585.7
2009	29.9	33.7	62.6	21.2	36.1	60.2	13.3	27.1	97.6	21.9	89.4	8.4	501.4
2010	91.5	86.0	55.6	63.1	48.8	24.3	61.2	118.9	82.8	81.6	82.3	93.4	889.5
Multianual average*	40.4	49.2	50.1	34.7	38.8	34.5	46.3	61.8	84.9	71.0	58.9	45.9	616.5
Air humidity, %													
2007	70	79	84	79	81	63	46	61	59	53	63	72	66
2008	77	82	86	82	74	71	67	65	68	67	61	67	72
2009	75	74	81	85	82	73	53	53	64	57	91	56	70
2010	74	87	81	88	84	69	70	78	75	73	72	82	78
Multianual average*	79	84	89	85	86	77	72	72	73	73	71	75	78

*1931-2010

Pedological drought in unirrigated alfalfa

Pedological drought is considered the periods with soil water reserve on watering depth bellow easily available water content (Domuța C., 2005). The periods with soil water reserve bellow wilting point is considered strong pedological drought (Domuța C., 2009). The annual graphs of the soil water reserve dynamics realized by soil sample emphasized the values bellow easily available water content in every month of the alfalfa vegetation period. Total days with pedological drought were of 164 in 2007, of 161 in 2008, of 165 in 2009 and of 45 in 2010. (table 2).

Table 2

Number of days with pedological drought in unirrigated alfalfa 2nd year,
Oradea 2007-2010

Year	Month						Total
	April	May	June	July	August	September	
2007	30	31	26	31	28	18	164
2008	24	31	30	31	31	14	161
2009	28	31	18	31	27	30	165
2010	12	8	5	10	10	-	45
Average	24	25	20	26	24	15	134

Strong pedological drought was determined every year: 14 days (10 days in July and 4 days in August) in 2007, 30 days (7 days in July, 13 days

in August and 10 days in September) in 2008, 58 days (12 days in June, 13 days in July, 16 days in August and 17 days in September) in 2009 and no in one day in the year 2010. (table 3).

Table 3

Number of days with strong pedological drought in unirrigated alfalfa 2nd year, Oradea 2007-2010

Year	Month						Total
	April	May	June	July	August	September	
2007	0	0	0	10	4	-	14
2008	0	0	0	7	13	10	30
2009	0	0	12	13	16	17	58
2010	-	-	-	-	-	-	-
Average	0	0	4	10	11	9	34

Optimum irrigation regime

For maintaining the soil water reserve on watering depth (0-100 cm) between easily available water content the irrigation was needed every year. Irrigation rate used in 2007 was of 465.0 mm/ha, in 2008 of 530.0 mm/ha, in 2009 of 540.0 mm/ha and in 2010 of 80.0 mm/ha. The number of rates were of 10 in 2007, of 11 in 2008, of 12 in 2009 and of 2 in 2010. The biggest month irrigation rate were used in Aprilie (115.0 mm/ha) in 2007, in July (150.0 mm/ha) in 2008, in May and July (130.0 mm/ha) in 2009, and also in May and July (40.0 mm/ha) in 2010. (table 4).

Table 4

Optimum irrigation regime in alfalfa 2nd year, Oradea 2007-2010

Year	April		May		June		July		August		September		Total	
	n	Σm	n	Σm	n	Σm	n	Σm	n	Σm	n	Σm	n	Σm
2007	2	115.0	3	110.0	2	90.0	2	100.0	1	50.0	-	-	10	465.0
2008	2	110.0	3	130.0	1	50.0	3	150.0	2	90.0	-	-	11	530.0
2009	2	90.0	3	130.0	2	90.0	3	130.0	2	100.0	-	-	12	540.0
2010	-	-	-	40.0	1	-	1	40.0	-	-	-	-	2	80.0
Average	2	79	2	103	2	58	3	105	2	60	-	-	11	405.0

The irrigation influence on alfalfa daily water consumption

Irrigation determined the increase of the daily water consumption. The biggest relative differences in comparison with unirrigated variant were registered in May (117%) in 2007, in May, too (146%) in 2008 and in June (128%) in 2009 and in 2010, in May (11%).

Table 5

The irrigation influence on daily water consumption in alfalfa 2nd year, Oradea 2007-2010

Year	Variant	April		May		June		July		August		September	
		mm/ha/ day	%	mm/ha/ day	%	mm/ha/ day	%	mm/ha/ day	%	mm/ha/ day	%	mm/ha/ day	%
2007	Unirrigated	2.35	100	2.40	100	2.56	100	3.31	100	2.69	100	1.44	100
	Irrigated	4.59	195	5.20	217	5.15	202	4.57	138	3.92	146	2.14	149
2008	Unirrigated	2.90	100	2.55	100	3.32	100	3.86	100	2.79	100	2.26	100
	Irrigated	4.61	159	6.27	246	6.71	203	6.00	155	4.38	157	2.90	128
2009	Unirrigated	2.74	100	2.49	100	3.00	100	3.76	100	2.70	100	1.83	100
	Irrigated	4.30	157	5.68	228	6.00	200	5.47	145	4.09	151	2.65	145
2010	Unirrigated	3.01	100	4.12	100	4.90	100	5.58	100	4.95	100	3.35	100
	Irrigated	3.09	103	4.56	111	5.08	104	6.02	108	5.07	103	3.42	102

The irrigation influence on total water consumption

The irrigation determined the increase of the total water consumption with 70% in 2007, with 92% in 2008 and with 114% in 2009 and 18% in 2010. The irrigation was the main source for optimum water consumption covering; their participation was of 53% in 2007, of 51% in 2008 and of 54% in 2009. In the year 2010 rainfall was the main source for optimum water consumption covering; their participation was of 80% In the irrigated variant, the alfalfa used a smaller quantity from soil water reserve in comparison with alfalfa from unirrigated variant (table 6).

Table 6

The irrigation influence on total water consumption [Σ(e+t)] and the covering sources in alfalfa 2nd year, Oradea 2007-2010

Year	Variant	Σ(e+t)		Covering sources					
		mm/ha	%	Soil water reserve		Rainfall		Irrigation	
				mm/ha	%	mm/ha	%	mm/ha	%
2007	Unirrigated	523.7	100	129.5	25	394.2	75	-	-
	Irrigated	888.3	170	29.1	3	394.2	44	465.0	53
2008	Unirrigated	538.5	100	157.1	29	381.4	71	-	-
	Irrigated	1034.2	192	122.8	12	381.4	37	530.0	51
2009	Unirrigated	467.7	100	210.0	45	257.7	55	-	-
	Irrigated	997.7	214	202.0	20	257.7	26	540.0	54
2010	Unirrigated	550.0	100	29.8	5	520.2	95	-	-
	Irrigated	651.0	118	50.8	8	520.2	80	80.0	12
Average	Unirrigated	519.9	100	203.2	26	388.4	74	-	
	Irrigated	892.8	172	101.1	11	388.4	47	403.8	43

The irrigation influence on yield

The irrigation determined the yield gain very significant statistically every year studied: 58200 kg/ha (42%) in 2007, 44800 kg/ha (108,4%) in

2008 and 44400 kg/ha (126,5%) in 2009. The biggest relative yield gain was obtained in the year 2009, the droughtest year.

In average on the studied period the yield in irrigated variant, the yield (88967 kg/ha) was bigger than the yield from unirrigated variant with 126,5% (table 7).

Table 7

The irrigation influence on yield in alfalfa 2nd year, Oradea 2007-2010

Variant	Yield		Difference		Statistically significant
	kg/ha	%	kg/ha	%	
2007					
Unirrigated	40100	100	-	-	Control
Irrigated	98300	142	58200	42	xxx
		LSD 5%	710		
		LSD 1%	1240		
		LSD 0.1%	1990		
2008					
Unirrigated	41300	100	-	-	Control
Irrigated	86100	208.4	44800	108.4	xxx
		LSD 5%	610		
		LSD 1%	990		
		LSD 0.1%	1470		
2009					
Unirrigated	35100	100	-	-	Control
Irrigated	79500	226.5	49400	126.5	xxx
		LSD 5%	820		
		LSD 1%	1310		
		LSD 0.1%	2200		
2010					
Unirrigated	70100	100	-	-	Control
Irrigated	84120	120.0	14020	20.0	xxx
		LSD 5%	710		
		LSD 1%	1010		
		LSD 0.1%	1670		
Average 2007-2010					
Unirrigated	46650	100	-	-	Control
Irrigated	87005	186.5	40355	86.5	xxx
		LSD 5%	713		
		LSD 1%	1136		
		LSD 0.1%	1833		

The irrigation influence on water use efficiency

The use of the optimum irrigation determined the increase of the yield main quantity obtained by 1 mm of water used with 44.5 % in 2007, with 17.6% in 2008 with 6.2% in 2009 and with 23.5% in 2010.

Table 8

The irrigation influence on water use efficiency (WUE) in alfalfa 2nd year, Oradea 2007-2010

Variant	WUE		Difference
	kg/mm	%	%
2007			
Unirrigated	76.57	100	-
Irrigated	110.67	144.5	44.5
2008			
Unirrigated	70.79	100	-
Irrigated	83.25	117.6	17.6
2009			
Unirrigated	75.05	100	-
Irrigated	79.68	106.2	6.2
2010			
Unirrigated	127.45	100	
Irrigated	97.45	76.5	23.5

CONCLUSION

The researches regarding the irrigation opportunity carried out during 2007-2010 in Oradea determined the following conclusions:

- Ten to ten determination of the soil moisture on the watering depth emphasized the presence of the pedological drought in 164 days in 2007, in 163 days in 2008 and in 165 days in 2009; the soil moisture decreased bellow wilting point 14 days in 2007, 30 days in 2008 and 58 days in 2009.
- Maintaining the soil water reserve between easily available water content and field capacity determined to use the irrigation: 4650 m^3/ha in 2007, 5300 m^3/ha in 2008 and 5400 m^3/ha in 2009.
- The irrigation determined the increase of the daily water consumption and, finally, total water consumption increased with 70% in 2007, with 92% in 2008 and with 114% in 2009. The irrigation was the mai source for water consumption covering all the year.
- The influence of the irrigation on yield was the yield gain very significant statistically every year: 42% in 2007, 108,4% in 2008 and 126,5% in 2009.
- The presence of the pedological drought and of the strong pedological drought every year and the yield gains very significant statistically are the arguments that the irrigation is a main method for drought control.

Acknowledgments

The researches were carried out in the project: PN-II-ID-PCE-2008; 1103/2009 ”Study of the relationships in the soil-water-plant-atmosphere system on the land affected succesivelly by excess and deficit of moisture from North Western Romania regarding the improve of the yield quantity and quality”.

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