

INFLUENCES OF IRRIGATION AND FERTILIZATION ON SOYBEAN PROPERTIES AND NITROGEN LEACHING

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Abstract

Influences of irrigation rates and N fertilization on soybean grain yield and N leaching were tested under field conditions on Osijek, during the growing seasons 2001, 2003 and 2005 (A). The irrigation started on level of 80% field water capacity, A1 (FWC) and at level of 65% FWC, A2 and irrigate up to FWC, and non-irrigated, A3. Increased rates of N: 0, B1; 100, B2 and 200 kg N ha⁻¹, B3 were applied. The experiment was conducted by split-plot method. Ebermeier's lysimeters (open type: 80 x 80 x 10 cm) were conducted for collecting leachate for measuring nitrogen leaching. The soybean grain yield showed statistical very significant differences in growing season, irrigation and interaction of growing season and irrigation. Mean leaching NO₃-N varied from 0.32 kg N ha⁻¹ to 7.88 kg N ha⁻¹ in year 2001, while were greater in year 2005 and varied from 2.41 kg N ha⁻¹ to 23.71 kg N ha⁻¹.

Key words: soybean, irrigation, nitrogen fertilization, yield, protein, oil, leaching

Introduction

Nutrient transport down the soil profile varies considerably depending on soil properties and climate. Nutrient losses by leaching are most pronounced in the tropics and in the humid temperate zones especially on light textured soils. The rate of leaching is mainly measured using different type of lysimeters. Nitrogen (N) leaching is mainly in form of nitrates and its excess in ground water is in close connection with ecological degradation. For this reason, control of N leaching is contribution for healthy environment. Some general aspects of N leaching and nutrition were shown by Mengel and Kirkby (1987), Bergman (1992), Eerd and Fong (1998), Galloway (1998), Oad et al. (2004), Kladiwko (2004). Aim of this study was testing N removal by leaching under conditions of Croatia as affected by fertilization and irrigation. Aim of this study was testing soybean response to irrigation and fertilization with nitrogen (N), as well as N removal by leaching on hydro meliorated hypoglay.

Methods

Influences of irrigation rates (IR) and N fertilization were tested under field conditions on Osijek (45°32' N and 18°44' E; 90 m above sea level) anthropogenic hydro meliorated hypoglay during the growing seasons 2001, 2003 and 2005 (soybean growing: cultivar Tisa). The influence of year (the factor A) was as follows: A1=2001, A2=2003 and A3=2005; IR (the factor B) was as follows: B1 = irrigation starting on level of 80% field water capacity (FWC); B2 = irrigation starting on level of 65% FWC, B3 = non-irrigated. Soil saturation by water because of IR was up to level of 100% FWC. Quantities of water added by IR were as follows: B1 = 140 mm (four times by 35 mm); 280 mm (eighth time by 35 mm) and 35 mm (once); B2 = 100 mm (twice by 50 mm); 250 mm (five times by 50 mm) and 50 mm (once) for the 2001, 2003 and 2005 years, respectively. Experimental plots were 1008 m² (B) and 336 m² (C). Self moving irrigation sprinkler (typhon) were used. Irrigation water were analyzed, also (electro conductance; NO₃, NO₂ and NH₄ forms of N; pH, sodium). Increased rates of N (the factor C: 0, 100 and 200 kg N ha⁻¹, for the C1, C2 and C3, respectively) and

same rate of P and K ($104 \text{ kg ha}^{-1} \text{ P}_2\text{O}_5$ and $104 \text{ kg ha}^{-1} \text{ K}_2\text{O}$) were applied. P and K were added in form of NPK 8:26:26 fertilizers (400 kg ha^{-1} as a basic and pre sowing fertilization). Urea was used for adding rest of N by pre sowing fertilization (0, 50 and 100 kg ha^{-1} , for C1, C2 and C3, respectively). The experiment was conducted by split-plot method. Ebermeier's lysimeters on 80 cm of depth were conducted. The leachate was taken from lysimeter reservoir by mechanical pump and analyzed by standard methods of APHA (1992) by ionic chromatograph Dionex 120. Soybean was sown in the middle of April and harvested in the first half of October. Plant densities were 550 plants per square m. Grain yields were calculated on 13% grain moisture basis. The statistics was performed according Vukadinović, 1994. The soil had retention water capacity close the value of FWC. Irrigation water had electro conductance due to much salt content and irrigation class C₂S₂ (Table 2). Growing seasons 2001 and 2005 were favorable as regard of precipitate and air temperature (Table 3). Drought stress was main weather characteristic of the growing season 2003 (212 mm rainfall, period May-September). During the 2003 growing season, the hottest months were June and August (means 24.7 and 24.6°C). Rainfall shortage, especially during July and August is in close connection with low yields of spring crops in Croatia (Kovacevic and Josipovic, 2001).

Table 1 Some physical properties* of the soil (Osijek hydro meliorated hypoglay)

The soil depth, cm	g/cm ³			% Vol.		Soil texture (%)			
	BD	SGM	RWC	TotalP	AirP	Sand	Silt	Clay	API
0-31	1.50	2.58	36.56	41.82	5.25	2.75	64.70	32.55	19.12
31-50	1.54	2.65	35.59	41.83	6.24	2.32	66.36	31.33	21.73
51-70	1.38	2.68	38.14	48.59	10.45	6.32	68.17	25.51	

*BD = bulk density; SGM = specific gravity mass; RWC = retention water capacity;
TotalP = total porosity; AirP = air porosity; API = Atterberg's plasticity index

Table 2 Some chemical properties of the soil and irrigation water

The soil properties (0-30 cm)				Properties* of the irrigation water						
pH		%		mg/l			pH	EC	SAR	Irrig. Class
H ₂ O	1nKCl	Humus	N	NO ₃	NO ₂	NH ₄				
7.5	6.9	2.01	0.13	0.10	0.04	0.79	7.49	0.724	8.12	C2S2

* EC = electro conductance (dS/m); SAR = sodium adsorption ratio (meq/l) determined by graph (Bover and Cooper, 1956); Irrigation Class = accor. US Salinity Laboratory (1964)

Table 3 Precipitation and mean air-temperatures for period of study (Osijek Weather Bureau)

Month	Osijek Weather Bureau: three years and long-term means (LTM: 1971-2000)							
	Precipitation (mm)			Mean air-temperatures (°C)			LTM	
	2001	2003	2005	2001	2003	2005	mm	°C
I - IV	248	89	201	6.9	3.0	3.0	167.6	4.8
May	60	43	60	18.4	20.5	17.4	59.2	16.7
June	239	25	92	18.1	24.7	20.1	82.0	19.6
July	77	70	117	21.6	22.9	21.8	66.3	21.3
Aug.	7	23	218	22.7	24.6	19.6	61.9	20.8
Sept.	195	49	72	14.9	16.7	17.4	51.0	16.5
V-IX	578	212	558	19.1	21.9	19.3	320.4	19.0

Results and discussion

The soybean grain yield showed statistical very significant differences in growing season, irrigation and interaction of growing season and irrigation while nitrogen level and other interactions not (Table 4). The highest grain yield achieved in year 2001, 3.34 t ha^{-1} against 2003, 2.83 t ha^{-1} . Irrigation B1 resulted by grain yield 3089 t ha^{-1} against control 2.95 t ha^{-1} and C2 treatment, 3.080 kg ha^{-1} . As affected by dry conditions, there were not found leachate

in the 2003 growing season. Mean leaching $\text{NO}_3\text{-N}$ varied from $0.32 \text{ kg N ha}^{-1}$ (B3C1) to $7.88 \text{ kg N ha}^{-1}$ (B2C3) in year 2001, while were greater in year 2005 and varied from $2.41 \text{ kg N ha}^{-1}$ (B3C1) to $23.71 \text{ kg N ha}^{-1}$ (B2C3), (Table 5). Nitrogen leaching in NO_2 and NH_4 forms showed together them amount of leaching was very poor against NO_3 form (Table 5).

Table 4 Influences of the year, irrigation and N fertilization on soybean properties

Influences of year (factor A: 2001, 2003 and 2005), irrigation (B-1: 80-100% FWC, B-2 = 60-100% FWC, B-3 = non-irrigated) and nitrogen fertilization (kg N ha^{-1} : C-1= 0; C-2=100, C-3=200) on soybean (Cultivar Tisa) yield and quality												
The factor		AC interaction			BC interaction			AB interaction			Mean	
A	B	C-1	C-2	C-3	C-1	C-2	C-3	B-1	B-2	B-3	A	B
Grain yield of soybean (t/ha on 13% grain moisture basis)												
2001	B-1	3.30	3.42	3.31	3.03	3.18	3.06	3.30	3.31	3.42	3.34	3.09
2003	B-2	2.87	2.97	2.92	2.97	3.13	3.06	3.19	3.02	2.55	2.92	3.06
2005	B-3	2.81	2.86	2.81	2.99	2.93	2.92	2.78	2.84	2.87	2.83	2.95
Mean C		2.99	3.08	3.01	A:	B:	C:	AB:	AC:	BC:		
LSD 5%					91	74	73	142	140	140		
LSD 1%					120	97	96	199	196	196		

Table 5 Nitrate leaching as affected by growing season, irrigation and N fertilization

Irrigation rates	The leachate quantities (LQ) and $\text{NO}_3\text{-N}$ leaching (to 80 cm of depth) on three rates of fertilization (kg N/ha)								
	LQ, liters/pot			$\text{NO}_3\text{-N}$, kg N ha^{-1}			$\text{NO}_3+\text{NH}_4\text{N}$, kg N ha^{-1}		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
	0	100	200	0	100	200	0	100	200
The growing season 2001									
B1=85-100% FWC	9.81	11.21	12.37	0.78	3.15	7.04	0.016	0.062	0.142
B2=65-100% FWC	7.18	10.30	12.39	0.42	2.50	7.88	0.036	0.072	0.173
B3= control	8.28	9.95	10.23	0.32	2.30	5.40	0.022	0.070	0.137
The growing season 2003, were not leachate (drought stress)									
The growing season 2005									
B1=85-100% FWC	32.4	34.6	30.8	3.16	13.47	22.44	1.12	0.99	1.13
B2=65-100% FWC	28.4	27.6	30.2	4.54	14.44	23.71	0.78	0.57	0.57
B3= control	27.6	29.4	28.1	2.41	13.42	17.47	0.72	0.92	1.15

Our findings of N leaching are lower or similar compared to the other studies in Croatia. Sestic et al. (1989) tested nutrient leaching found mean leaching 33.4 kg N/ha ($29.4 \text{ kg NO}_3\text{-N}$ and $4.0 \text{ kg NH}_4\text{-N}$); Mesic et al. (1999) testing N leaching found $\text{NO}_3\text{-N}$ leaching 7.1 and 30.2 kg N/ha ; Tursic et al. (1999) found range of $\text{NO}_3\text{-N}$ leaching from 7.1 kg N/ha to 27.5 kg N/ha . The other authors founds: in Germany, Vömel (1966) found N leaching between 0 and 27 and between 5 and 44 kg N ha^{-1} on sandy loam and loam soil, respectively; Müller et al. (1985) found N leaching 144.0 , 16.5 and 6.5 , kg N ha^{-1} per year for vineyards, arable lands and forest, respectively. Carcinogenic and mutagenic influences of N-nitrosamines were clearly demonstrated in experiments with animals (Meier-Ploeger, 1990). The FAO/WHO limit value for nitrate intake of an adult person with 60 kg weight should only be 1540 mg NO_3 per week (Owen and Jurgens-Geschwind, 1986). NO_3 levels in commercially prepared foods made from spinach and other vegetables for infants and small children do not exceed 250 ppm of fresh mass, while limits for NO_3 and NO_2 in drinking water are 40 ppm and 0.2 ppm , respectively (cit. Bergmann, 1992). Based on our experiences, $\text{NO}_3\text{-N}$ leaching rates under conditions of the eastern Croatia are under dangerous degree for groundwater contamination, especially because N fertilization is mainly lower than 200 kg ha^{-1} (C3 level).

Conclusions

Weather conditions and N fertilization are considerable factors influencing N leaching through hydromeliorated hypogley. Drought stress was main weather characteristic of the growing season 2003. The soybean grain yield showed statistical very significant differences in growing season, irrigation and interaction of growing season and irrigation while nitrogen level and other interactions not. Mean leaching $\text{NO}_3\text{-N}$ varied from $0.32 \text{ kg N ha}^{-1}$ to $7.88 \text{ kg N ha}^{-1}$ in year 2001, while were greater in year 2005 and varied from $2.41 \text{ kg N ha}^{-1}$ to $23.71 \text{ kg N ha}^{-1}$. Nitrogen leaching in NO_2 and NH_4 forms was very pure against NO_3 form.

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