NITROGEN USE EFFICIENCY IN WINTER WHEAT

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Abstract:
Nitrogen use efficiency of winter wheat grain, as valuable indicator for rational N fertilization supply, was investigated in a field experiment in middle continental Croatia under four mineral N fertilization treatments (0, 100, 200 and 300 kg N ha^{-1}) during two growing periods (2002/03, 2005/06). Total N content in grain, yield, N uptake by grain, and soil N ($N\text{-}NH_4$, $N\text{-}NO_3$) status were examined as well to indicate relations between N trial treatments and growing years. Over total investigated period, above mentioned factors significantly differ per nitrogen levels and years. The highest total N content in winter wheat grain was recorded in $N_{300}PK$ treatment during 2002/03, but the highest yield was reached in growing period 2005/06 in treatment with 300 kg N ha^{-1}. Growing period 2002/03 was signed as extremely hot and dry, which is the reason for lower yields, N content and NUE per fertilization treatment, compared to 2005/06. NUE values varied from 9.21 kg kg^{-1} in treatment with 300 kg N ha^{-1} (2002/03) up to 24.13 kg kg^{-1} in treatment with 100 kg N ha^{-1} (2005/06). During investigated growing years NUE was decreased with increasing nitrogen fertilization levels. The best use efficiency of applied nitrogen fertilization was at level of 100 kg N ha^{-1}, which is consider as rational application regarding nitrogen emissions into environment.

Keywords: nitrogen use efficiency, mineral N fertilizer rates, winter wheat, N content, soil available N status

Introduction

Efficient nitrogen fertilization is crucial for economic wheat production and protection of ground and surface waters. Dynamics of nitrogen (N) in soil-plant system is a part of much bigger environmental frame, including water ecosystems. Possible ground and surface water pollution caused by nitrate leaching is a result of excessive and inadequate N application. Valuable indicator for rational N fertilization supply is N use efficiency (NUE) of mineral nitrogen fertilizer by growing crop, winter wheat (*Triticum aestivum* L.) in this case, together with nitrogen status in soil and plant. Nitrogen cycle in agroecosystem in winter wheat as test crop has been investigated in number of studies. Mineral fertilizer NUE for winter wheat was shown as factor which decreases with increasing N levels (Sieling et al., 1998). Hatfield and Prueger (2004) found that the efficiency of N use by a crop depends upon the response of water and N availability during the growing season. Usage of nutrients from fertilizer and forming of wheat yield are influenced by growing year and site conditions (Bertic et al., 2007). The main issue of this paper was to investigate how different mineral nitrogen fertilization rates affect available soil N, total N content in grain, yield, N uptake by grain, and grain N use efficiency of applied fertilization in period of two vegetation years.

Materials and methods

Investigated experimental filed is a part of farmland in middle continental Croatia. Area has temperate continental climate, with 10.7°C mean temperature. The annual average rainfall takes 865mm. Region characteristic are small-holdings which dominates within agricultural land from one side, and hydro-ameliorated area with organized agricultural production within larger agricultural holdings. Terrain is flat with average altitude 97.2m, separated by dyke from wetland area on south-east side. Soil type is pseudogley

(Stagnosol), with unfavourable water regime and high level of ground water. It is plain, distric, with implemented drainage system of canals and pipes. Sufficient moisture is present in upper part of soil profile as result of precipitation and stagnation of water. Groundwater occurs under 175cm below soil surface. Precipitation water periodically stagnates on illuvial horizon. Trial presented here (cca. 1,5ha) is a part of a long time experiment conducting research on mineral nitrogen fertilization, nitrogen use efficiency and nitrogen leaching. This paper presents results for two growing years – 2002/03, 2005/06 - with a winter wheat as test crop. Field trial fertilization included four different mineral N amounts (NPK 10-30-20, UREA, CAN): I. N_0PK; II. $N_{100}PK$; III. $N_{200}PK$; IV. $N_{300}PK$, (kg N ha^{-1}). Each trial treatment has 4 replicates (30x30m). Parcel dimension is conditioned by distance between drain pipes. Each treatment area includes two drain pipes. Dimension of each trial treatment is 30x130m including blank space. Distance between treatments, as well as between 4 replicates, is 2m by each side. Fertilization and seeding practice is implemented on total area of each variant. After harvest in the late June, grain yield data were measured and standardized to t ha^{-1} of total dry matter, and adjusted to 14% moisture content. Soil samples were taken three times during vegetation period 2005/06 and two times at 2002/03, by each trial treatment and three horizon depths (0-30cm, 30-55cm, 55-80cm). Values of soil N status were averaged by treatments and times of sampling and presented by horizons as sum. Preparation of plant and soil samples for chemical analysis was conducted according to HRN ISO 11464:2004. For vegetative year 2005/06, NO_3^- content in soil was analyzed in soil water extract (1:10) according to HRN EN ISO 10304-1:1998, and soil NH_4^+ according to HRN EN ISO 14911:2001 on Dionex ICS-1000 system. In year 2002/03, samples analysis have been done by spectrophotometry method with phenil-disulphonic acid for NO_3^-, and by spectrophotometry Nessler method, for NH_4^+. Concentrations of total N (TN) in winter wheat grain was obtained by dry combustion method on CHNS Elemental Analyzer Vario Macro according to HRN ISO 13878:2004. The N uptake, needed to obtain NUE of the grain, was calculated by multiplying yield total dry matter by the total N content of the winter wheat grain. The N use efficiency of mineral N fertilization was calculated according to Craswell and Godwin, 1984, by equation:

$$NUE = (\text{Grain yield}_F - \text{Grain yield}_C) / \text{Fertilizer N applied} \quad \text{kg kg}^{-1}$$

F-fertilized crop; C-unfertilized control

Statistical analysis of the N content, grain yield, N uptake and NUE data were accomplished by standard analysis of variance (ANOVA).

Results and discussion

Mean values for soil N-NH_4 and N-NO_3 content in two vegetation years are shown in Table 1. Difference in N-NO_3 content between years per N levels indicates effect of water deficiency through lack of precipitation in year 2003 on nitrate accumulation in soil (0-80cm), especially on treatment with 300 kg N ha^{-1}. Results for N-NH_4 soil content show variability between years and N levels, which means that annual variations in mineralized soil N may be large. Values for nitrogen (N) content in winter wheat grain, yield and NUE are presented in Table 2. Total N content in winter wheat

grain in investigated period varied from 1.88 % in N_0PK treatment in vegetation period 2005/06 up to 2.82 % recorded in $N_{300}PK$ treatment during 2002/03. According to ANOVA results, N plant content was significantly affected ($P \leq 0.05$; $P \leq 0.01$) by increasing nitrogen fertilization in both growing years. Grain yield had in both years significantly increasing trend with N fertilization levels. The highest yield of 7.48 t ha^{-1} was recorded in growing period 2005/06 in treatment with 300 kg N ha^{-1}. Growing period 2002/03 was signed as extremely hot and dry, which is the reason for lower yields per fertilization treatment, compared to 2005/06. The same relation was investigated by Pepo (2007) who proved that the efficiency of fertilization was strongly modified by the properties of the year. According to statistical analysis for yield, significant differences ($P \leq 0.05$; $P \leq 0.01$) were obtained between trial treatments in both vegetation years.

Table 1. Soil N-NH_4 and N-NO_3 content per growing periods 2002/03 – 2005/06 and different mineral N fertilization levels

Mineral N fertilization levels, kg N ha^{-1}	Soil N-NH_4, kg ha^{-1}		Soil N-NO_3, kg ha^{-1}	
	2002/03	2005/06	2002/03	2005/06
N_0PK	105.60	148.47	22.55	38.06
$N_{100}PK$	83.91	181.04	58.03	39.45
$N_{200}PK$	124.15	89.22	161.77	82.38
$N_{300}PK$	125.34	69.77	174.07	104.54

Table 2. Effect of mineral N fertilization on total N content in grain (%), yield (t ha^{-1}) and apparent N use efficiency (kg yield per kg of mineral N applied) of winter wheat in growing periods 2002/03 – 2005/06

Mineral N fertilization levels, kg N ha^{-1}	N content in grain, %		Yield, t ha^{-1}		NUE, kg kg^{-1}	
	2002/03	2005/06	2002/03	2005/06	2002/03	2005/06
N_0PK	2.11	1.88	1.48	3.10	-	-
$N_{100}PK$	2.34	2.15	2.41	5.51	9.26	24.13
$N_{200}PK$	2.77	2.55	3.32	6.34	9.22	16.21
$N_{300}PK$	2.82	2.78	4.24	7.48	9.21	14.59
LSD 5%	0.23	0.13	0.70	0.51		
LSD 1%	0.33	0.19	1.00	0.74		

NUE values varied from 9.21 kg kg^{-1} in treatment with 300 kg N ha^{-1} (2002/03) up to 24.13 kg kg^{-1} in treatment with 100 kg N ha^{-1} (2005/06). NUE was decreased in response to fertilizer-N for winter wheat in both investigated periods (Figure 1). NUE had lower values in N treated plots during dry year 2003, compared to the vegetation period 2005/06. Decreasing NUE leaves N remaining in the soil.

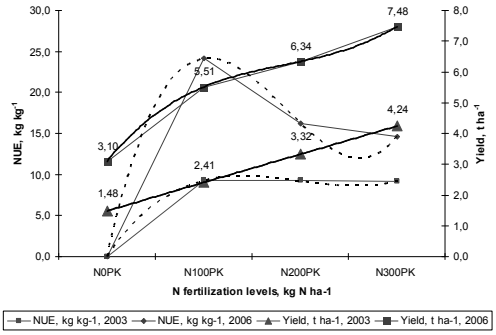

Figure 1. Effect of mineral N treatments on winter wheat N use efficiency (kg yield per kg of mineral N applied) and yield (t ha^{-1}) during two vegetation periods

Conclusions

Significant differences in total N content in grain, winter wheat yield and grain N use efficiency were obtained for two winter wheat vegetation years per N treatments. All mentioned parameters are conditioned by soil type and climate factors as precipitation and temperature during vegetation stages. Water stress was probably the main reason for lower yields, N uptake and NUE in year 2002/03. Due to NUE values, it is noted that the best use efficiency of applied nitrogen fertilization was at level of 100 kg N ha^{-1}, which is consider as rational application regarding increased N losses with excess mineral N by nitrogen emissions into environment like water pollution by nitrate leaching and NO_x emissions to the atmosphere. To improve NUE of N mineral fertilizer by winter wheat, more information on seasonal changes in crop utilization of soil fertilizer and non-fertilizer N.

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