Environmental and production aspects of maize cultivation in relation with the different time-applied nitrogen

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Abstract: In order to determine the influence of nitrogen fertilization on status of mineral nitrogen in soil and yield of maize two stationary field experiments were set up in Croatian Pannonia agricultural region in vicinity of Vukovar city. Field trials include four fertilizer treatments in four replications. The treatments are: (i) Fall (autumn) - 180 kg N/ha, (ii) Spring (pre-plant) - 180 kg N/ha, (iii) Fall and spring – 70 kg N/ha in fall and 110 kg N/ha in spring, (iv) Fall, spring and topdressing - 70 kg N/ha in fall, 70 kg N/ha in spring and 40 kg N/ha in topdressing application. Results of two-year studies at two location reviled that treatments did not significantly affected on maize grain yield and they were in the range of 13.4 t/ha to 14.0 t/ha in 2014 and 10.1 t/ha to 11.3 t/ha in 2015 at Vukovar location and 16.2 t/ha to 16.9 t/ha in 2014 and 8.3 t/ha to 8.8 t/ha in 2015 at Belje location. The relatively highest grain yields in both years of investigations and on both locations were achieved with the application of all nitrogen in the fall. Although the fall nitrogen applications is not recommended due to greater risk of N loss, results of nitrogen content up to 90 cm soil depth show that different nitrogen application time did not significantly influenced on nitrogen accumulation in soil. Fall (autumn) fertilizer application has relatively contributed an increscent of nitrate nitrogen accumulation in soil.

Keywords: fertilization, soil, mineral nitrogen, environment, yield

Introduction

Over the past 40 years a broad range of environment legislation has been put in place. Among other things General Environment Action Programme of EU set the priority objective to protect, conserve and enhance the Union's natural capital which also includes soil fertility. All this imposes an obligation to scientists to provide the best advice how to preserve the environment. In terms of maize production in Croatia according to FAOSTAT (2017) data base in period from 1997 to 2014 average production was 1.98 M tonnes with average yield of 5.94 tonnes/ha and in average 338865 ha of land was harvested. That means that 6 % of Croatian terrestrial territory was fertilized in order to achieve appropriate maize yield. Due to the known fact that excessive fertilization has a negative impact on soil conditions and in order to protect the health of people, nature, environment and the interests of consumers an increasing number of producers implement the principles of integrated agriculture in their production. Integrated production means a balanced application of agro-technical measures for the production of environmentally and economically friendly products with minimal use of agrochemicals. In this mode of farming crop nutrient management plan is indispensable and highest average annual application of nitrogen (mineral and/or organic) is 170 kg/ha/year for arable crops except for silage maize when Regulation allows a maximum of 200 kg N/ha. Many authors worldwide investigated the influence of increasing doses of nitrogen fertilization on temporal and spatial distribution of mineral nitrogen in soils. The conclusions derived from these studies can be summarized as follows: nitrogen variability in soil is influenced primarily due to the amount and type of applied fertilizer, by the type and characteristics of the soil, by the type of crop, by the presence or absence of a particular culture, by schedule and intensity of rainfall [Németh and Kádár (1999), Ikerra et al. 1999, Guo et al. (2001), Zebarth and Milburn (2003), Li et al. (2005), Fang et al. (2006), Mesić et al. (2007), Nance and Karlen (2007), Kristensen and Thorup Kristensen (2007), Gami et al. (2009), Jurišić et al. (2014)]. In contrast to the above studies the goal of this research was to determine the influence of different application periods of the same quantity of mineral nitrogen (180 kg/ha, allowed amount of nutrient in integrated farming practise) on the yield of maize but also on nitrogen variability in soil up to 0.9 m of soil depth.

Materials and methods

This study was carried out on two locations (Vukovar and Belje) in Croatian Pannonia agricultural region in vicinity of Vukovar city during two growing season (2014 and 2015) of maize (*Zea mays* L). The investigation area has a temperate continental climate. The annual mean temperatures slightly varied from 12.6 in 2015 to 13.4 °C in 2014. Total precipitation was in the range of 686.2 mm in 2015 to 823.0 mm in 2014. Soil types on locations and its chemical properties were listed in table 1. In order to determine the initial state of soil, samples were taken before the experiment was set up. Samples were air dried, milled, sieved and homogenized. The soil pH was determined in 1:2.5 (w/v) soil suspension in 1 M KCl. Plant available phosphorus and potassium were extracted by ammonium lactate (AL) solution (Egner et al., 1960) and detected by spectrophotometric and flame photometric, respectively. Total carbon and total nitrogen content for calculation of CN ratio were determined by dry combustion method (ISO 10694 and ISO 13878).

Table 1: Soil type and chemical characteristics of soils*

Location	Year	Soil type**	pH_{KCl}	mg P_2O_5 / kg	mg K_2O / kg	C/N ratio
Belje	2014	Gleysoils, Mollic	7.43	411.1	306.5	22.3
	2015	Gleysoils	7.35	243.6	158.2	26.9
Vukovar	2014	Eutric Cambisol	6.79	188.3	266.4	12.8
	2015	Chernozem Haplic	7.17	140.2	227.1	14.4

*surface soil layer (0-30 cm); ** WRB (2006)

The experimental design was a randomized block with four treatments and four replications. The size of each plot is 25 x 25 m and in total experiments included 16 plots. Treatments vary by the applications of different nitrogen fertilizer (Urea – 46 % N and potassium ammonium nitrate (KAN) - 27% N) or by the different times of fertilizer application (Table 2). In total on each treatment 180 kg N/ha was applied but in different time. Depending on the location and year of investigation, fall (autumn) nitrogen application was conducted in late October or early November, early spring or pre plant nitrogen application was initiated in April, while the topdressing fertilization was done in late May or early June.

Table 2: Treatments and applied amounts of nitrogen

Treatment	Nitrogen application (kg/ha)		
	Fall (autumn)	Early spring (pre-plant)	Topdressing
Fall (F)	180 kg N (Urea)	-	-
Spring (S)	-	180 kg N (Urea)	-
Fall + spring (F+S)	70 kg N (Urea)	110 kg N (Urea)	-
Fall + spring + topdressing (F+S+T)	70 kg N (Urea)	70 kg N (Urea)	40 kg N (KAN)

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Grain yield and moisture content (gravimetric method) in maize were determined after the harvest. During the vegetation of maize soil sampling was conducted six times. Composite samples per plot were taken from three depths (0-30 cm, 30-60 cm and 60-90 cm). During one vegetation season 288 soil samples were taken per one location. Totally, in 1152 soil samples nitrate-nitrogen content was determined by colorimetric method. Wet soil samples were extracted u 1M KCl solution. After the extraction, samples were centrifuged; filtrated and NO_3-N content was detected by spectrophotometric method (Cd reduction). Statistical analyses of differences in soil nitrate-nitrogen content according to fertilization treatments for soil depth and differences in grain yield according to fertilization treatments were computed by analysis of variance (ANOVA) (SAS 9.1, SAS Institute Inc., USA). The significance test was performed at probability level of $P < 0.05$. Differences among treatment means were separated using Fisher's least significant difference procedure.

Results and discussion

Results of two years of investigations relives that different application time of 180 kg

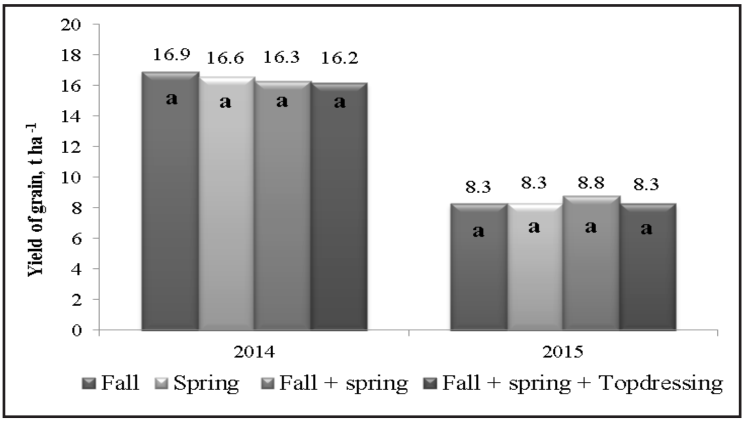

Figure 1: Effect of different time applied amount of nitrogen on grain yield of maize, Belje location; Pr>F: 0.6490 (2014) and 0.7400 (2015)

nitrogen / ha did not significantly affected on yield of maize grain neither on the Belje location (P = 0.6490 in 2014 and P=0.7400 in 2015) neither on the Vukovar location (P = 0.3342 in 2014 and P=0.8109 in 2015). Yield of grain varied from 16.2 t/ha to 16.9 t/ha in 2014 and from 8.3 t/ha to 8.8 t/ha in 2015 at Belje location (Figure 1).

At Belje location average grain yield in 2015 (8.4 t/ha) was 49 % lower than average grain yield recorded in 2014 (16.5 t/ha). Results can by partly explained by the fact that in 2015 according to the Thornthwaite water balance, water deficit (247.9 mm) was recorded in June, July, August and September, in months which are very crucial for maize development. Also, soil (Gleysoils, Mollic) at Belje location in 2014 was more supplied with phosphorus (411.1 mg/kg) and potassium (306.5 mg/kg) (Table 1).

Yield of grain varied from 13.4 t/ha to 14.0 t/ha in 2014 and 10.1 t/ha to 11.3 t/ha in 2015 at Vukovar location (Figure 2). According to the results and although this is only a relative differences the highest grain yield at Vukovar location in both investigations years and at Belje location in 2014 were achieved at treatment when all nitrogen was applied in fall (autumn). According to these results the rate of nitrogen leaching, especially nitrogen applied

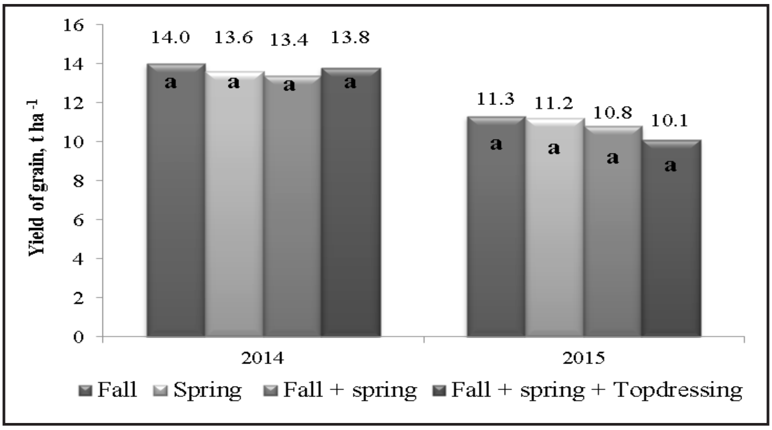

Figure 2: Effect of different time applied amount of nitrogen on grain yield of maize, Vukovar location; Pr>F: 0.3342 (2014) and 0.8109 (2015)

in the fall, is not in a large-scale that would have a negative impact on yield. The results shown in Tables 3 and 4 represent the average nitrogen content for six samplings times which were conducted during each growing season of maize. Variability of nitrate-nitrogen (NO_3-N) content in soil per treatments and soil depth at Belje location is presented in table 3.

Table 3: Variability of nitrate-nitrogen content in soil per treatments and soil depth at Belje location

Belje location, 2014									
Soil depth	Treatments				Statistics				
	Fall	Spring	Fall+Spring	F+S+T	LSD	Pr>F	Std	Cv	N
	mg NO_3-N/kg				mg/kg		mg/kg	%	
0-30 cm	35.6	33.9	34.6	32.6	11.8	0.9599	9.32	27.6	24
30-60 cm	37.1	33.3	30.8	33.7	11.7	0.7311	9.32	27.7	24
60-90 cm	31.8	30.1	30.3	32.1	9.9	0.9568	7.73	24.9	24
Belje location, 2015									
0-30 cm	37.5	36.7	38.9	31.3	15.7	0.7604	12.5	34.7	24
30-60 cm	36.4	42.0	38.2	33.3	21.8	0.8690	17.2	45.8	24
60-90 cm	46.5	37.1	41.3	37.6	21.2	0.7839	16.9	41.6	24

F+S+T – Fall+Spring+Topdressing; LSD – least significant difference; Std – standard deviation; Cv –coefficient of variation; N – number of observations

According to LSD values and results of analysis of variance different time of nitrogen application did not significantly influenced on nitrogen content in soil neither in 2014 neither in 2015 at Belje location.

With average coefficient of variation of 26.7 % nitrogen content at Belje location in 2014 varied in range from 30.3 mg/kg at last depth (60-90 cm) on treatment with spring nitrogen application to 37.1 mg/kg on treatment with fall nitrogen application in subsurface soil layer (30-60 cm). In 2015 up to 90 cm of soli depth and different time of nitrogen application, NO_3-N content in average varied 40.7%.

Although the nitrogen applied in fall can be lost before the crop uptake and although topdressing applications is much recommended in terms of environmental protection, results reviles no significant differences between nitrogen content in fall N application and topdressing application treatments.

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Relativity higher amount accumulated NO_3-N in soil at fall treatment (Table 3) compared to other treatments was recorder at first depth in 2014 (35.6 mg/kg), second depth in 2014 (37.1 mg/kg) and at the last depth in 2015 (46.5 mg/kg). Similar results were established at Vukovar location (Table 4).

Table 4: Variability of nitrate-nitrogen content in soil per treatments and soil depth at Vukovar

Vukovar location, 2014									
Soil depth	**Treatments**				**Statistics**				
	Fall	Spring	Fall+Spring	F+S+T	LSD	Pr>F	Std	Cv	N
	mg NO_3-N/kg				**mg/kg**		**mg/kg**	**%**	
0-30 cm	46.2	39.1	39.8	40.5	17.8	0.8289	14.1	34.1	24
30-60 cm	44.9	43.5	42.6	41.2	17.6	0.9750	13.7	31.8	24
60-90 cm	38.3	40.3	41.1	37.9	16.8	0.9728	13.1	33.2	24
Vukovar location, 2015									
0-30 cm	45.5	34.7	31.4	34.7	14.9	0.1556	11.4	31.2	24
30-60 cm	39.7	39.8	38.7	36.9	11.8	0.9499	9.22	23.7	24
60-90 cm	50.8	43.8	36.2	41.5	15.7	0.1485	11.2	26.0	24

F+S+T – Fall+Spring+Topdressing; LSD – least significant difference; Std – standard deviation; Cv –coefficient of variation; N – number of observations

Conclusions

In terms of environmental and production aspects of maize cultivation in relation to the different time-applied nitrogen, two years investigation at two location lead to the conclusion that the application rate of 180 kg nitrogen/ha in fall did not significantly increased content of accumulated nitrogen up to 90 cm soil depth. Nitrogen applied only in fall, or only in spring (pre-plant), or in fall and spring and even applied and distributed in fall, spring and during vegetation (topdressing) equally affected the spatial distribution of nitrate nitrogen in the soil. It also indicates that yield of grain was not under the influence of different time of nitrogen application. The extension of this research to the monitoring of groundwater quality would give much more detailed insight and answers about the risks associated with application of nitrogen in fall. The dynamics of nitrogen depends on precipitation and temperatures, so this investigation should be conducted for several more years in order to confirm the conclusions presented in this paper.

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