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Mineral nitrogen in the soil and its effect on corn yield

ABSTRACT. Experiments were conducted in a long-term stationary field experiment established at the experimental field of the Institute of Field and Vegetable Crops in Novi Sad in 1965. A part of the trial included corn monoculture, another part a two-crop rotation of corn and spring barley. This paper presents the results obtained in the period 1992-1995. The content of mineral nitrogen was found to depend on fertilization variant. The highest content of mineral nitrogen was found in the variants DVS+NPK and S+NPK, the lowest in the control variant. The distribution of mineral nitrogen along the soil profile varied among the test years and it depended on the amount of rainfall in the period preceding the growing season. The lowest grain yield was in the control variant. The effect of the applied mineral and organic fertilizers ranged in the monoculture from 132 to 156 %. In the variants NPK and MC-S-NPK, the highest yields were achieved with 120 kg N ha^{-1}; in the variants MC-M-NPK and DC-M-NPK, the highest yields were achieved with 60 kg N ha^{-1}. The mutual relationship between grain yield and the content of mineral nitrogen was high and it fitted the quadratic regression, while the correlation coefficients were high.

KEY WORDS: corn, monoculture, crop rotation, N-min, yield

Serbia and Montenegro ranks the third in Europe for its corn acreage and the fifth for the overall production of corn grain. It is also among fifteen largest corn producers in the world. Corn is the main crop in our country, its acreage taking about 38% of the total arable land. In other words, the corn acreage exceeds those of wheat, sugar beet and sunflower together [Starčević, Latković 1997]. In the course of the past twenty years, the average corn acreage was 1,430,000 ha, with the average yield of 4.30 t ha^{-1}. The high portion of corn in the crop structure explains why it is frequently grown successively in the same field or in monoculture. Long-term studies have shown that corn may be safely grown in monoculture if provided with intensive cultural treatments. Yield reductions in relation to two- and several-crop rotation have not exceeded 3 to 10% [Starčević, Marinković 1988].

The objective of this study was to follow the dynamics of mineral nitrogen in the soil in order to see if it is feasible to recommend corn fertilization on the basis of mineral nitrogen content in the soil in the spring, with the ultimate intention of improving the cost effectiveness of corn fertilization and reducing contamination of the environment.

METHODS

Dynamics of mineral nitrogen in the soil was studied in a long-term stationary field experiment established at the experimental field of the Institute of Field and Vegetable Crops in Novi Sad in 1965. A part of the trial included corn monoculture, another part a two-crop rotation of corn and spring barley. This paper presents the results obtained in monoculture and in the part of two-crop rotation.

The trial was established on the calcareous chernozem soil with good physical, chemical and biological properties. At the time of the establishment of the experiment, the content of humus was 2.74 %, the content of total nitrogen was 0.15%, the content of available P_2O_5 was 23.6 mg and the content of K_2O was 26.8 mg per 100 g of soil. The following fertilization variants were used in the monoculture: control (0); NPK – only mineral fertilizers; NPK + corn stalks (MC-S-NPK); NPK + manure (MC-M-NPK). The variant NPK + manure (DC-M-NPK) was used in the two-crop rotation (corn – spring barley). In the part of the trial in which corn was grown in two-crop rotation, manure was applied each year under corn at the rate of 25 t ha^{-1}. In the monoculture, manure was applied at two-year intervals, at the same rate.

Starting from 1986, all of the above variants except the control received three levels of; Nitrogen 60 kg N ha^{-1} in the fall; Nitrogen 60 kg N ha^{-1} in the fall + 60 kg N ha^{-1} in the spring; Nitrogen 60 kg N ha^{-1} in the fall + the amount calculated on the basis of the N-min method in the spring.

For determination of mineral nitrogen, soil samples were taken from 30-cm layers to the depth of 120 cm. The samples were analyzed by the method developed by Scharp and Werhmann [1975]. This report uses the results for the content of mineral nitrogen before planting. Grain yield per hectare was calculated on 14% moisture basis and expressed in t ha^{-1}. Quadratic regression and correlation coefficients were calculated on the basis of mutual relationships between N-min content and yield. The paper deals with the results obtained in the period 1992–1995.

RESULTS

The level of nitrate nitrogen in agricultural soil depends on soil type, method of land utilization, systems of soil cultivation used, temperature, moisture and air content. Nitrate nitrogen status in the soil changes with the ascending and descending movements of soil water. The dynamics of nitrate nitrogen is considerably affected by the application of fertilizers, both organic and mineral.

After several years of application of mineral fertilizers, combinations of mineral and organic fertilizers and the increasing nitrogen rates, the analysis of soil samples taken before planting in the spring showed that that the amounts of NO_3-N in the soil layer 0 to 120 cm ranged between 34 kg ha^{-1} to 188 kg ha^{-1} (the average of the variant DC-M-NPK). The highest amount of NO_3-N, 230 kg ha^{-1}, was found in the variant DC-M-NPK_3, which received 25 t ha^{-1} of manure and 60 kg N ha^{-1} in the fall. Increased amounts of NO_3-N were also registered in the variant MC-M-NPK in monoculture, the average of 168 kg ha^{-1} [Deutsch 1991]. In the variants MC-S-NPK and NPK, the amounts of NO_3-N were similar, 80 and 90 kg ha^{-1}, respectively. The lowest amount of NO_3-N, 34 kg ha^{-1} was registered in the control variant.

The average data in Table 1 and Figure 1 show that highest amounts of mineral nitrogen in the spring were found with the third rates of nitrogen, in the so-called N-min variant. It was true for all fertilization variants except MC-M-NPK_2. The former variant received 60 kg N ha^{-1} in the fall + organic fertilizers. The amount of mineral nitrogen in the N-min variant ranged from 111 kg NO_3-N, in the variant NPK, to 230 kg NO_3-N, in the variant DC-M-NPK. One of the reasons for such high amounts of mineral nitrogen determined in the variant N-min is that in 1985 and 1986 the third nitrogen rates received 60 kg N ha^{-1} in the fall and 180 kg N ha^{-1} in the spring a total of 240 kg N ha^{-1} plus corn stalks and manure in the variants where these organic fertilizers were applied. Another reason for the high content of NO_3-N in the N-min variant may be that the application of large amounts of mineral nitrogen fertilizer was followed by very dry years of 1988, 1989, 1990, 1992, in which corn yields were low because nitrogen could not be used by corn plants.

Table 1. Distribution of mineral nitrogen along soil profile

Year	Depth cm	Fertilization variant												
		Control	NPK			K + NPK			S + NPK			DVS + NPK		
			N rate			N rate			N rate			N rate		
			N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
		kg ha^{-1}												
1992	0-30	16	25	31	17	30	55	29	48	44	48	37	46	62
	30-60	7	13	18	8	21	20	15	44	55	21	38	36	41
	60-90	2	5	9	4	8	17	12	32	47	17	15	26	49
	90-120	1	2	9	2	5	44	6	40	68	15	9	29	49
	0-120	26	45	67	31	64	136	62	164	213	101	99	137	201
1993	0-30	7	7	9	85	15	16	27	26	24	48	56	41	43
	30-60	12	10	16	63	18	19	56	32	37	69	74	70	65
	60-90	6	9	13	26	16	18	31	31	41	41	31	31	50
	90-120	2	6	11	16	16	19	15	28	52	34	28	27	58
	0-120	27	32	49	190	65	72	130	117	154	192	189	169	216
1994	0-30	15	12	15	26	17	19	30	31	41	65	38	44	49
	30-60	19	15	15	31	22	22	33	32	59	64	35	58	80
	60-90	14	11	17	37	21	20	48	45	59	83	46	46	90
	90-120	7	19	21	50	15	27	57	42	55	103	42	45	90
	0-120	55	57	68	144	75	88	168	150	214	315	161	193	309
1995	0-30	10	15	9	25	6	17	19	22	22	21	46	62	55
	30-60	10	21	14	19	10	20	27	30	12	27	38	49	52
	60-90	7	9	46	25	24	28	41	53	58	23	43	51	53
	90-120	2	10	76	27	17	26	14	46	54	32	36	64	33
	0-120	29	55	145	96	57	91	101	151	146	103	163	226	193
Mean	0-30	11	13	16	38	17	27	26	32	33	38	44	48	52
	30-60	12	16	16	30	18	20	33	35	41	45	46	53	60
	60-90	8	9	21	23	17	21	33	40	51	49	34	39	61
	90-120	3	9	29	24	13	29	23	39	57	46	29	41	57
	0-120	34	47	82	111	65	97	115	146	182	178	153	181	230

Distribution of mineral nitrogen along soil profile in the spring depends on the amount of winter precipitation and the distribution of nitrogen at the end of the growing season of the previous crop. Of the four analyzed years, the winter precipitation in 1991-1992 was below the long-term average; consequently, increased amounts of NO_3-N were found in the soil layer 0-30 cm. In the other three years, the winter precipitations were considerably above the long-term average. Thus, the highest amounts of NO_3-N were found in the layers 30-60 cm and 60-90 cm, except in the variant MC-M-NPK_2, in which the largest amount of NO_3-N was in the layer 90-120 cm.

The application of mineral and organic fertilizers caused significant increases in grain yield (Tab. 2). The yields in the fertilized variants were 132 to 156 % higher than that in the control variant. The highest increases in relation to the control were registered in the two-crop rotation and in the monoculture with manure. Among the variants in monoculture, the NPK variant yielded significantly less than the variants with corn stalks and manure while there were no significant differences between the latter variants [Starčević et al. 1994; Starčević et al. 2002].

The analysis of grain yields in different variants of nitrogen fertilization showed that the increases in grain yield were statistically significant to the second rate of nitrogen (60 kg N in the fall + 60 kg N in the spring). In the variants of monoculture (NPK and MC-S-NPK), the highest yields were obtained with 60 + 60 kg N ha^{-1}, except in the two-crop rotation and the variant MC-M-NPK in monoculture, in which the highest yields were obtained with 60 kg N in the fall.

Table 2. Grain yields in the years 1992-1995

Fertilization variant	N rate			Mean	%
	N_1	N_2	N-min		
	t ha^{-1}				
Control	3.34			3.34	100
MC-NPK	6.95	7.89	8.41	7.75	232
MC-S-NPK	8.14	8.77	8.60	8.51	255
MC-M-NPK	8.62	8.30	8.73	8.54	256
DC-M-NPK	9.47	9.33	9.34	9.38	281
Mean	7.30	7.52	7.68	Mean	

	LSD	
	1%	5%
For variants	0.82	0.59
For N rates	0.47	0.37

Using the analysis of variance and LSD test the level of mineral nitrogen in the soil was determined in the spring before planting, which supported a statistical increase of grain yield. The amount of mineral nitrogen from the soil reserve, which provided the maximum grain yield (Figure 1) was calculated by the quadratic regression analysis.

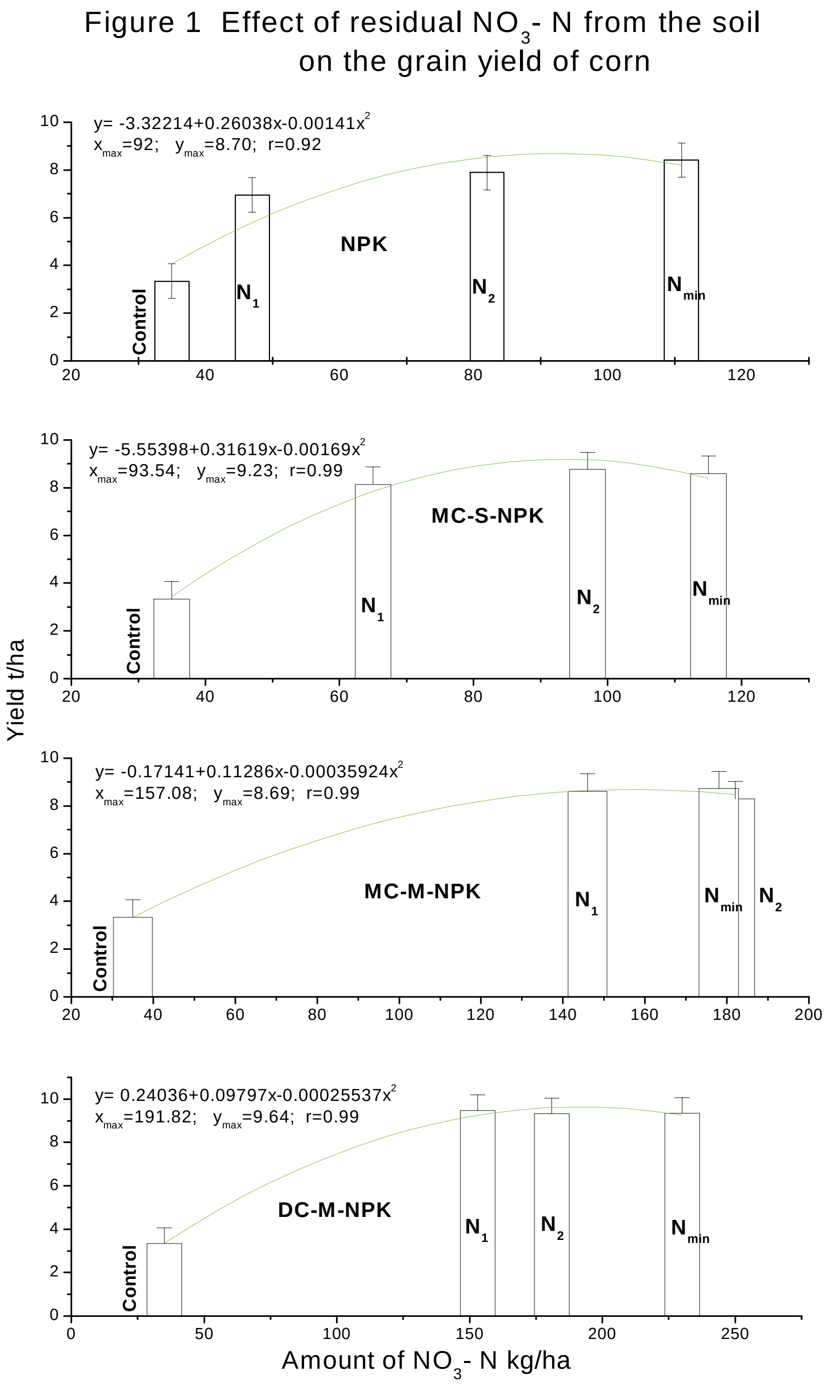

Figure 1. Effect of residual NO_3^- N from the soil on the grain yield of corn

Applying the quadratic regression analysis to the NPK variant, it was calculated that the amount of 92 kg ha^{-1} of residual nitrogen was needed to achieve the maximum rain yield. The analysis of variance and LSD test showed that the yield in the NPK variant increased significantly to the second nitrogen rate (N_2), which contained 82 kg N ha^{-1} in the spring.

For the variant which combined the application of mineral fertilizers with the ploughing under corn stalks, the regression analysis indicated that 94 kg NO_3-N were needed for the maximum grain yield while the LSD tests showed that the highest yield (8.77 t ha^{-1}) was obtained with the second nitrogen rate. The analysis of mineral nitrogen content in the spring showed that the N_2 variant had 97 kg NO_3-N ha^{-1} in the soil layer 0-120 cm.

For the variant which combined the application of mineral fertilizers with the ploughing under 25 t ha^{-1} of manure in alternate years, the regression analysis showed that 157 kg NO_3-N were needed for the maximum grain yield. The analysis of variance showed that a statistically significant yield increase was obtained with the N_1 variant, which contained 146 kg NO_3-N ha^{-1} in the spring.

For the variant DC-M-NPK, the regression analysis showed that 192 kg NO_3-N ha^{-1} were needed for the maximum grain yield. The analysis of variance showed that the highest yield was obtained with the N_1 variant, which contained 153 kg NO_3-N ha^{-1} in, the spring.

The mutual relationship between grain yield and mineral nitrogen level in the soil was high and it fitted the quadratic regression. The coefficients of correlation were high, ranging from r=0.92 to r=0.99 [Marinković 1989].

CONCLUSIONS

1. The content of mineral nitrogen was found to depend on fertilization variant. The highest content of mineral nitrogen was found in the variants DC-M-NPK and MC-M-NPK, 188 kg ha^{-1} and 169 kg ha^{-1}, respectively, the lowest in the control variant, 34 kg ha^{-1}.

2. The distribution of mineral nitrogen along soil profile varied among the test years and it depended on the amount of rainfall in the period preceding the vegetation season.

3. The lowest grain yield was found in the control variant. The effect of the applied mineral and organic fertilizers ranged in the monoculture from 132 to 156 %.

4. In the variants NPK and MC-S-NPK, the highest yields were achieved with 120 kg N ha^{-1}, in the variants MC-M-NPK and DC-M-NPK, the highest yields were achieved with 60 kg N ha^{-1}.

5. The mutual relationship between grain yield and the content of mineral nitrogen was high and it fitted the quadratic regression, while correlation coefficients were high.

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