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INFLUENCE OF ORGANIC-MINERAL FERTILIZER AND MANURE ON THE CONTENT OF INORGANIC NITROGEN COMPOUNDS IN THE SOIL

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A b s t r a c t. This paper concerns the influence of a single application of various doses of organic-mineral fertilizer, combined with yearly application of ammonium nitrate, and a single application of manure plus NPK, on the content of nitrate and ammonium nitrogen in the soil, considering the soil moisture.

It was found that application of organic-mineral fertilizer at the dose of 12 t ha^{-1} plus N, caused a significant increase of the nitrates content in the soil. The content of ammonium nitrogen in the soil did not vary in the years, independently of the fertilizer doses. The nitrate nitrogen content in the soil was dependent on the moisture conditions, the lower the water content, the higher that of nitrates in the soil.

The moisture content had a greater impact on the mineral nitrogen content in the soil than the applied fertilization. With the plants growth and development, the nitrate content in the soil decreased, which indicates a steady uptake of this nitrogen form by the plants during the whole growing season. In the case of ammonium nitrate no such connection was found, and the ammonium content in the soil was stable. The nitrates content in the soil was higher than that of the ammonium forms, in the course of the whole experiment.

K e y w o r d s: organic-mineral fertilizer, manure, nitrates, ammonia salts, soil moisture.

INTRODUCTION

The content of nitrogen in the soil is one of the most important factors which determine the plants productivity. The fertilizer kind, doses, technique of application, environment factors, plant species, soil kind and reaction, affect the content of nitrates and ammonium in the soil and plants [3,7-9]. Of the factors which have the greatest influence on changes of nitrogen compounds content in the soil, the fertilization, both mineral and organic, should be considered [8,9]. The effect of the application of the fertilizers depends to a large degree on the weather conditions and the kind of cultivated area [2,8,13]. The aim of this study was the assessment of the effect single application of organic-mineral fertilizer combined with yearly application of ammonium nitrate, as compared with a single dose of manure plus NPK (yearly), in a four-year field experiment consisting of white cabbage - onion - red beet - white cabbage, on the content of $N-NO_3^-$ and $N-NH_4^+$ in the soil of various moisture content.

MATERIALS AND METHODS

The field experiments were carried out on a black earth, developed from a light clay, classified as the IIIb value. Three rotations of 4-field experiments were tested. The soil belongs to a good-wheat complex, contains 1.9% of humus, the reaction is neutral, the soil has low water and air permeability, and a tendency for crust formation and shrinking.

The experiment consisted of 6 objects:

1. no fertilizer,
2. ammonium nitrate (N),
3. organic-mineral fertilizer (6 t ha^{-1} + N),
4. organic-mineral fertilizer (12 t ha^{-1} + N),
5. organic-mineral fertilizer (18 t ha^{-1} + N),
6. manure (50 t ha^{-1}) + NPK every year.

The organic-mineral fertlizer contained per 1 ton: 200 kg fine brown coal, 560 kg volatile ash from brown coal, 100 kg granular superphosphate (20.2% P), 100 kg potassium chloride (41.5%). One ton of manure contained 5.2-5.8 kg nitrogen, 1.2-1.3 kg phosphorus, 4.4-5.0 kg potassium. The organic-mineral fertilizer and manure were applied once before the planting of the first plant of the crop rotation (cabbage). The nitrogen was applied yearly on the objects 2-5, the same dose for each kind of plants. For cabbage 300 kg N, for onion and red beet 200 kg N, in one dose was given before sowing or planting. On the object 6, NPK was applied every year in doses equivalent to 200 kg N, 184 kg P, and 200 kg K per 1 ha.

For chemical analysis the soil was sampled three times from the cabbage and beet plots, twice from the onion plots (during vegetation).

The mineral forms of nitrogen were assessed in soil extracts (0.3 M acidic acid) by the Bremner method. Soil moisture was measured by weight, soil was dried at 105 °C.

The results were evaluated statistically by the Tukey test, at 0.05% significance. Correlation between the content of $N-NO_3^-$ and $N-NH_4^+$ in the soil moisture was calculated by linear regression method.

RESULTS

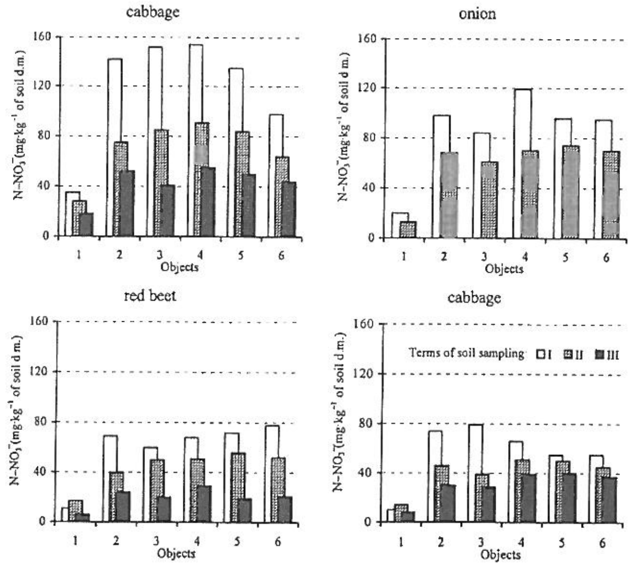
Data concerning the influence of the applied fertilization on the content of mineral nitrogen in the soil were presented in Tables 1-6, and Figs 1 and 2 .

Table 1. $N-NO_3^-$ content in the soil in the first four-year rotation (mg kg^{-1} of soil)

Object	Terms of soil sampling from										
	cabbage plots			onion plots		red beet plots			cabbage plots		
	I	II	III	I	II	I	II	III	I	II	III
No fertilization	50	26	30	24	8	17	18	8	10	22	7
NH_4NO_3 (N)	105	52	52	73	28	114	57	53	41	68	27
Organic-mineral fertilizer (6 t ha^{-1}+N)	105	49	54	67	12	88	73	41	65	47	31
Organic-mineral fertilizer (12 t ha^{-1}+N)	108	42	73	84	41	111	78	72	42	61	37
Organic-mineral fertilizer (18 t ha^{-1}+N)	104	46	67	66	27	107	75	40	22	72	23
Manure (50 t ha^{-1})+NPK every year	114	49	56	78	36	130	75	45	45	62	21
$LSD_{0.05}$	7.23	4.87	4.84	11.80	3.16	5.49	2.76	5.98	3.15	5.33	2.96

Table 2. $N-NO_3^-$ content in the soil in the second four-year rotation (mg kg^{-1} of soil)

Object	Terms of soil sampling from										
	cabbage plots			onion plots		red beet plots			cabbage plots		
	I	II	III	I	II	I	II	III	I	II	III
No fertilization	30	16	8	14	10	14	29	6	10	10	9
NH_4NO_3 (N)	95	44	35	97	101	85	57	13	41	41	26
Organic-mineral fertilizer (6 t ha^{-1}+N)	81	53	21	77	110	88	73	11	47	47	31
Organic-mineral fertilizer (12 t ha^{-1}+N)	84	53	27	103	111	86	67	11	66	66	49
Organic-mineral fertilizer (18 t ha^{-1}+N)	92	58	24	106	121	105	88	11	44	44	74
Manure (50 t ha^{-1})+NPK every year	67	25	21	91	83	93	69	10	46	46	67
$LSD_{0.05}$	3.72	3.78	5.49	5.80	5.90	5.90	5.11	2.83	56	4.32	5.66



	cabbage	onion	beet plots	cabbage
$LSD_{0.05}$ – for fertilization	8.5	10.8	12.9	12.4
$LSD_{0.05}$ – for terms	11.1	7.0	10.5	6.8
$LSD_{0.05}$ – for the years	12.0	10.4	10.6	6.0

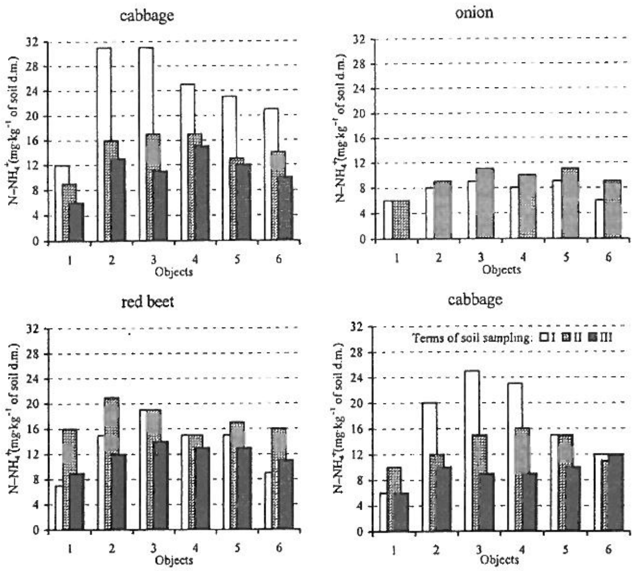
Objects:

1. no fertilization
2. NH_4NO_3 (N)
3. organic–mineral fertilizer (6 t·ha^{-1} + N)
4. organic–mineral fertilizer (12 t·ha^{-1} + N)
5. organic–mineral fertilizer (18 t·ha^{-1} + N)
6. manure (50 t·ha^{-1}) + NPK

Fig. 1. N- NO_3^- content in the soil in the four-year rotation (mg kg^{-1} of soil d.m.).

T a b l e 3. N- NO_3^- content in the soil in the third four-year rotation (mg kg^{-1} of soil)

Object	Terms of soil sampling from										
	cabbage plots			onion plots		red beet plots			cabbage plots		
	I	II	III	I	II	I	II	III	I	II	III
No fertilization	25	42	15	21	21	3	3	3	8	9	7
NH_4NO_3 (N)	227	129	69	123	75	7	7	7	95	28	38
Organic-mineral fertilizer (6 t ha^{-1}+N)	269	152	48	109	61	5	5	7	107	22	25
Organic-mineral fertilizer (12 t ha^{-1}+N)	271	177	65	171	59	8	7	5	62	25	30
Organic-mineral fertilizer (18 t ha^{-1}+N)	208	149	60	116	75	4	4	6	78	34	23
Manure (50 t ha^{-1})+NPK every year	113	119	54	117	90	11	11	9	64	26	23
$LSD_{0.05}$	10.60	48.40	5.30	7.25	9.62	1.83	2.54	2.17	3.89	2.00	2.70



	cabbage	onion	beet plots	cabbage
$LSD_{0.05}$ –for fertilization	10.2	n.s.	n.s.	5.6
$LSD_{0.05}$ –for terms	3.4	1.2	2.4	1.8
$LSD_{0.05}$ –for the years	3.3	1.8	2.4	1.9

Objects:
1. no fertilization
2. NH_4NO_3 (N)
3. organic–mineral fertilizer (6 t·ha^{-1} + N)
4. organic–mineral fertilizer (12 t·ha^{-1} + N)
5. organic–mineral fertilizer (18 t·ha^{-1} + N)
6. manure (50 t·ha^{-1}) + NPK

Fig. 2. N- NO_3^- content in the soil in the four-year rotation (mg kg^{-1} of soil d.m.).

Table 4. N – NH_4^+ ontent in the soil in the first four years rotation (mg kg^{-1} of soil)

Object	Terms of soil sampling from										
	cabbage plots			onion plots		red beet plots			cabbage plots		
	I	II	III	I	II	I	II	III	I	II	III
No fertilization	18	12	10	8	6	9	28	10	5	18	13
NH_4NO_3 (N)	26	15	14	10	11	19	38	4	20	22	13
Organic-mineral fertilizer (6 t ha^{-1}+N)	27	20	14	10	14	24	31	14	29	24	15
Organic-mineral fertilizer (12 t ha^{-1}+N)	28	17	19	10	13	11	19	18	38	22	14
Organic-mineral fertilizer (18 t ha^{-1}+N)	31	12	16	12	13	14	18	17	16	23	15
Manure (50 t ha^{-1})+NPK every year	28	19	19	10	9	9	24	11	10	18	23
$LSD_{0.05}$	3.95	3.99	3.01	2.40	2.42	3.99	3.18	2.37	3.40	3.25	2.76

Table 5. $N-NH_4^+$ content in the soil in the second four-year rotation (mg kg^{-1} of soil)

Object	Terms of soil sampling from										
	cabbage plots			onion plots		red beet plots			cabbage plots		
	I	II	III	I	II	I	II	III	I	II	III
No fertilization	10	8	4	-	3	8	11	9	10	7	4
NH_4NO_3 (N)	22	14	7	-	6	18	10	21	16	9	10
Organic-mineral fertilizer (6 t ha^{-1}+N)	17	5	7	-	8	22	14	20	20	14	8
Organic-mineral fertilizer (12 t ha^{-1}+N)	16	5	6	-	6	19	13	12	15	15	9
Organic-mineral fertilizer (18 t ha^{-1}+N)	12	4	6	-	8	23	20	10	15	14	10
Manure (50 t ha^{-1})+NPK every year	21	15	8	-	6	9	11	11	13	9	8
$LSD_{0.05}$	1.32	2.13	3.22	-	1.61	4.58	4.07	1.03	3.83	3.21	1.84

Table 6. $N-NH_4^+$ content in the soil in the third four-year rotation (mg kg^{-1} of soil)

Object	Terms of soil sampling from										
	cabbage plots			onion plots		red beet plots			cabbage plots		
	I	II	III	I	II	I	II	III	I	II	III
No fertilization	8	7	4	9	9	5	8	8	4	5	2
NH_4NO_3 (N)	45	20	27	13	10	7	14	10	23	5	7
Organic-mineral fertilizer (6 t ha^{-1}+N)	48	27	13	16	10	11	13	9	25	8	4
Organic-mineral fertilizer (12 t ha^{-1}+N)	32	28	19	15	12	14	14	11	15	10	4
Organic-mineral fertilizer (18 t ha^{-1}+N)	26	23	13	15	12	7	13	12	14	8	4
Manure (50 t ha^{-1})+NPK every year	13	9	4	9	11	9	13	10	12	7	5
$LSD_{0.05}$	2.56	3.99	2.96	3.00	2.48	1.67	3.21	2.50	2.34	1.36	1.27

In the first two years of the action of he organic-mineral + N fertilization it was found that the 12 ton dose significantly increased the nitrogen content in the soil. During the next two years the content of nitrates in soil which had been fertilized with 6, 12 or 18 t + N per 1 ha, levelled out (Fig. 1). In the first year of the experiment it was found that the soil of manure fertilized plot of cabbage (first link of the crop rotation), was characterized by the lowest $N-NO_3^-$ content, as compared with the remaining fertilizer objects. In the second year of the experiment the nitrogen content was similar to the plots fertilized with the highest dose of organic-mineral fertilizer + N. In the following two years the soil of plots which had

Table 7. Soil moisture in the first four-year rotation (%)

Object	Terms of soil sampling from										
	cabbage plots			onion plots		red beet plots			cabbage plots		
	I	II	III	I	II	I	II	III	I	II	III
No fertilization	14.8	10.2	15.1	16.4	17.9	11.2	6.5	3.0	13.9	12.7	12.1
NH_4NO_3 (N)	13.6	7.8	14.6	15.6	16.8	13.0	3.1	3.0	13.9	12.0	11.3
Organic-mineral fertilizer (6 t ha^{-1}+N)	14.6	8.5	15.1	15.7	17.3	12.3	6.6	3.1	13.8	12.6	11.1
Organic-mineral fertilizer (12 t ha^{-1}+N)	13.7	9.8	15.1	16.4	17.7	9.7	4.1	3.0	14.1	12.5	11.5
Organic-mineral fertilizer (18 t ha^{-1}+N)	15.1	10.5	14.9	16.2	18.9	12.6	5.3	3.3	13.9	12.4	11.3
Manure (50 t ha^{-1})+NPK every year	13.9	10.0	16.2	17.2	18.2	12.6	6.0	2.9	14.4	12.6	12.1

Table 8. Soil moisture in the second four-year rotation (%)

Object	Terms of soil sampling from										
	cabbage plots			onion plots		red beet plots			cabbage plots		
	I	II	III	I	II	I	II	III	I	II	III
No fertilization	9.9	13.4	15.6	7.4	5.2	6.2	7.9	13.0	12.8	8.3	11.2
NH_4NO_3 (N)	9.8	11.8	15.2	9.0	5.6	5.2	7.6	13.3	12.1	8.3	10.4
Organic-mineral fertilizer (6 t ha^{-1}+N)	10.5	12.5	15.0	8.5	5.6	5.1	7.3	12.6	12.8	7.8	10.2
Organic-mineral fertilizer (12 t ha^{-1}+N)	11.2	12.5	16.7	9.8	6.1	5.1	7.6	13.0	12.6	7.8	10.1
Organic-mineral fertilizer (18 t ha^{-1}+N)	11.3	12.8	16.1	9.9	5.6	5.2	7.1	12.5	12.4	7.4	9.7
Manure (50 t ha^{-1})+NPK every year	10.2	12.2	15.4	9.3	6.6	5.2	7.5	11.8	12.8	7.1	10.2

been fertilized with manure or various doses of organic-mineral fertilizer contained similar amounts of $N-NO_3^-$ (Fig. 1).

The content of $N-NH_4^+$ in the soil fertilized with various doses of organic-mineral + N or with farm manure did not differ during the 4-year experiment (Fig. 2).

The soil content of nitrates depended to a great extent on its moisture (Tables 1-3, 7). The average $N-NO_3^-$ content was highest in soil of the largest moisture (Tables 1-3 and 7-9).

The content of the ammonium form in the years of large rainfall, was highest in soil of cabbage and red beet plots, and lowest in that of onion (Tables 4-9).

Table 9. Soil moisture in the third four-year rotation (%)

Object	Terms of soil sampling from										
	cabbage plots			onion plots		red beet plots			cabbage plots		
	I	II	III	I	II	I	II	III	I	II	III
No fertilization	6.2	2.8	8.9	5.8	9.5	15.6	6.7	9.1	8.9	11.9	6.7
NH_4NO_3 (N)	6.4	2.5	9.0	6.5	10.2	15.3	6.0	9.7	9.3	11.3	6.4
Organic-mineral fertilizer (6 t ha^{-1}+N)	6.4	2.7	9.0	5.8	10.1	15.4	6.1	10.0	7.6	10.3	6.5
Organic-mineral fertilizer (12 t ha^{-1}+N)	6.7	2.6	9.2	6.7	10.9	15.6	6.1	9.8	8.7	10.8	6.0
Organic-mineral fertilizer (18 t ha^{-1}+N)	7.0	2.5	9.2	6.4	10.6	15.9	5.8	9.6	7.7	10.4	6.3
Manure (50 t ha^{-1})+NPK every year	6.4	2.4	9.6	6.4	10.7	15.6	5.6	9.3	8.1	11.6	6.7

Table 10. Influence of organic-mineral fertilization the $N-NH_4^+$: $N-NO_3^-$ ratio in soil (means of 3 years)

Object	Terms of soil sampling from										
	cabbage plots			onion plots		red beet plots			cabbage plots		
	I	II	III	I	II	I	II	III	I	II	III
No fertilization	1:3.0	1:3.4	1:2.3	1:2.6	1:2.2	1:1.4	1:1.2	1:0.6	1:1.7	1:1.2	1:2.1
NH_4NO_3 (N)	1:4.4	1:4.4	1:4.2	1:8.4	1:8.9	1:3.9	1:2.6	1:4.7	1:3.8	1:4.4	1:3.4
Organic-mineral fertilizer (6 t ha^{-1}+N)	1:4.7	1:7.6	1:3.5	1:6.7	1:6.9	1:1.8	1:2.7	1:1.2	1:3.2	1:2.4	1:4.8
Organic-mineral fertilizer (12 t ha^{-1}+N)	1:5.8	1:6.9	1:3.9	1:9.9	1:9.3	1:5.0	1:3.2	1:1.7	1:2.5	1:3.2	1:5.2
Organic-mineral fertilizer (18 t ha^{-1}+N)	1:6.3	1:8.3	1:4.3	1:6.6	1:7.8	1:4.3	1:2.9	1:1.3	1:3.8	1:3.5	1:4.9
Manure (50 t ha^{-1})+NPK every year	1:5.7	1:4.5	1:6.6	1:10.4	1:8.9	1:8.6	1:3.5	1:1.9	1:4.7	1:4.1	1:4.6
Means	1:5.0	1:5.8	1:4.1	1:7.4	1:7.3	1:4.2	1:2.7	1:.1.	1:3.3	1:3.2	1:4.2

Considering the sampling times, connected with the various stages of the plant growth and development it was found, that the content of nitrates in the soil varied greatly according to the soil sampling time.

The lowest levels of this N-form were found in soil sampled after harvest, whereas the highest - at the first stage of cabbage growth (head formation), onion and red beet (5-6 leaves). The contents of $N-NH_4^+$ did not differ much, independently of the plant kind. Taking into account the impact of growing doses of the organic-mineral fertilizer on the relation of nitrates to ammonium N it was found that in the first and fourth year after application, this ratio was broadest

(Table 10) in soil which had been fertilized with 18 t ha^{-1}+N. In the other years, such broad ratio was found after application of 12 t ha^{-1}+N. The tightest ratio of the two N forms was found on plots fertilized with 6 t ha^{-1}+N. Comparing the results pertaining to the influence of organic-mineral fertilization +N and manure + NPK on the nitrate: ammonium ratio it has been found that in the first year after application of 18 t ha^{-1} + N the widest proportion was found, and in the second year - if 12 t ha^{-1} +N were applied.

In the third and fourth year (of all analysed objects), this ratio was broadest on plots fertilized with manure. During all years of the experiment the proportions between N-NH_4^+ and N-NO_3^- varied accordingly to the soil sampling dates. In the first year of the crop rotation the broadest average ratio of N-NH_4^+:N-NO_3^- was in the soil of the second sampling. In the second year, these ratios were highest and rather equal, in the third year the ratios went down (1:4.1, 1:2.7, 1:1.9). The last year was characterised by the widest N-NH_4^+:N-NO_3^- ratio in the soil sampled at the III term, and this ratio was identical (but less than in the first term) in the soil sampled at the I and II terms. As compared to the first year of the experiment, the proportions of these ions in the fourth year were at each sampling date almost by 40% narrower.

The soil moisture also influence the ratio of N-NH_4^+ to N-NO_3^- in the soil solution. The analysis of these ratios has shown that in soil of low moisture content, the N-NH_4^+:N-NO_3^- ratio was broadest. In a moist soil this ratio was twice or three-fold wider.

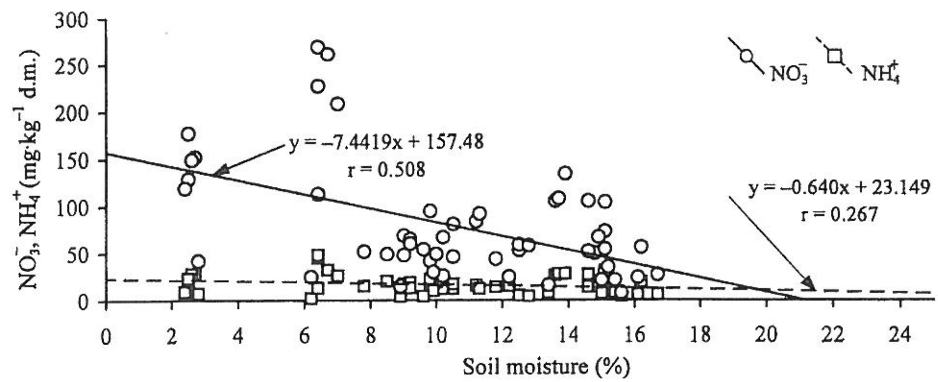


Fig. 3. Correlation of N – NO_3^- and N – NH_4^+ content depending on soil moisture (first-year of rotation, means of 3 years).

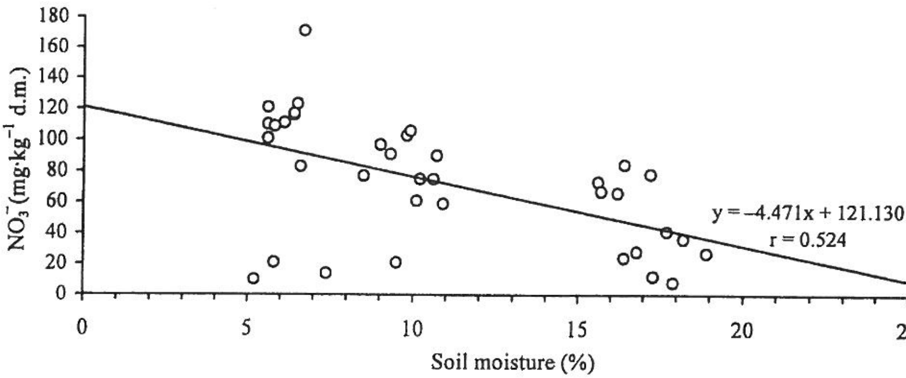


Fig. 4. Correlation of $N-NO_3^-$ content depending on soil moisture (second-year of rotation, means of 3 years).

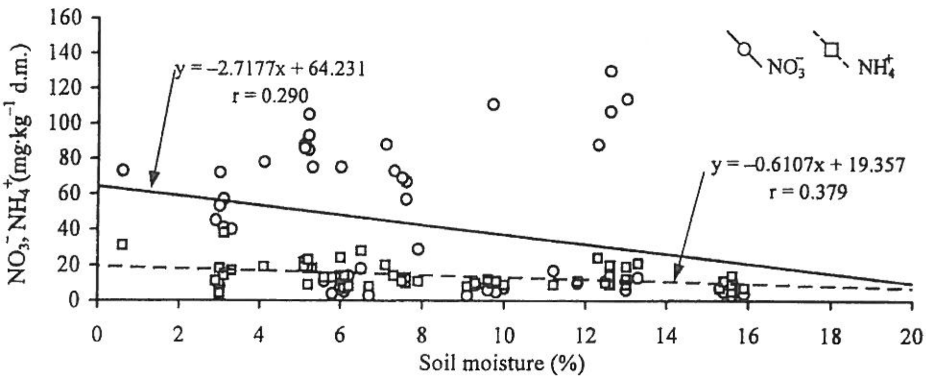


Fig. 5. Correlation of $N-NO_3^-$ and $N-NH_4^+$ content depending on soil moisture (third-year of rotation, means of 3 years).

From the calculated correlations can be seen a significant dependence of both nitrogen forms on the soil moisture in the first and second year of the crop rotation, of nitrates and soil moisture in the second year, and in the fourth year a significant correlation was found between the $N-NH_4^+$ content and soil moisture (Figs. 3-6).

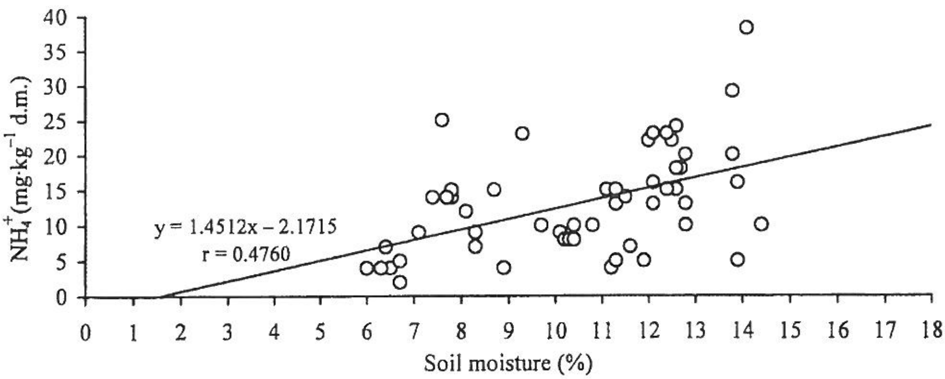


Fig. 6. Correlation of $N-NH_4^+$ content depending on soil moisture (fourth-year of rotation, means of 3 years).

DISCUSSION

The results obtained have shown that the content of nitrates in the soil depended significantly on the doses of organic-mineral fertilizer and manure contrary to the content of N-NH_4^+. The 12 t ha^{-1}+N organic-mineral fertilizer dose caused a high content in the soil, compatible with the 50 t ha^{-1} dose of manure, applied every year. Also Mazur [9] found that the application of manure combined with NPK causes an increase of mineral nitrogen forms, that of N-NO_3^- to greater extent than N-NH_4^+. In this experiment the content of ammonium did not significantly differ, independently on the fertilizer dose. The thermal and precipitation conditions, affecting the moisture content in the soil contributed to changes of the content of nitrogen mineral forms in the soil. The highest levels of nitrates were found in the dryest soil, whereas the ammonium form contents varied accordingly to the plant species. This was caused by various density of the plant cover, depending on the plant size. The soil of the onion plots was very much exposed to sun, which caused a decreased moisture content. These plots contained very small amounts of ammonium N, particularly in dry years. The soil sampled from these plots during intense onion growth (II sampling, II crop rotation) contained almost no N-NH_4^+. Cieślewicz *et al.* [3] also noticed a specific influence of plants on the soil content of various N compounds. These authors have also found a greater influence of soil moisture than that of fertilizer on the content of the two forms of nitrogen in the soil. A similar relationship was also described by Popławski and Filipiak [12]. Independently of the soil moisture, the N compounds dynamics (particularly N-NO_3^-) was related mostly to the plant development stages.

The soil sampled during the first growth periods of white cabbage, onion, and red beet contained the greatest amounts of nitrates, whereas at the harvesting time, the content of nitrates decreased. Similar results were reported by Dechnik and Wiater [4] who reported an increased $N-NO_3^-$ content in soil at wheat heading stage.

Considering the contents of both forms of nitrogen in the soil it was found that the N-NO_3^- content was always higher than that of N-NH_4^+. This corresponds with western literature [1], and also with the research of Mazur *et al.* [8] who also found that the soil containes more nitrates than ammonium. A different result was described by Łabędowicz and Rutkowska [6] who explained it by saying that in Poland are specific conditions, particularly on light soils, which limit nitrification.

CONCLUSIONS

1. The 12 t ha^{-1} dose of organic-mineral fertilizer +N caused the greatest increase of N-NO_3^- content in the soil. The content of $N-NH_4^+$ did not significantly vary in the years of the experiment, independently of the fertilizer dose.

2. The content of nitrates in the soil depended on the moisture content. Soil of the least moisture contained the highest amount of N-NO_3^-. The concentration of $N-NH_4^+$ was in dry years highest in soil of the cabbage and red beet plots, and lowest in the onion plots.

3. The soil moisture content had a greater impact on the content of mineral nitrogen than the fertilization applied.

4. Chemical analyses have shown a systematic decrease of the nitrate content with the growth and development of the plants, which indicates a steady uptake of the N-NO_3^- during the growth season. No such relations were found for N-NH_4^+, which content in the soil was stable.

5. The content of nitrate forms in the soil was in the course of the whole experiment higher than that of ammonium form.

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