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INFLUENCE OF MINERAL FERTILIZERS OF DIFFERENT FORM ON THE LEACHING OF BIOGENIC ELEMENTS

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Abstract

The experiment "Influence of mineral fertilizers of different form on the leaching of biogenic elements and nitrogen regime in sandy loam soils" was carried out in lysimeter facilities of Voke Branch of the Lithuanian Research Centre for Agriculture and Forestry (LRCAF) in 2008 – 2011.

The aim of the experiment – to assess the effect of solid and liquid fertilizers and their impact on surface water contamination with biogenic elements.

Precipitation filtration in fertilized soil was by 11.9-14.7 % lower than in untreated soil. Granular PK fertilizer induced the migration of calcium and potassium, and the concentration of these elements in lysimeter leachate increased compared to soil treated with liquid fertilizer Lyderis 9-9-9. However, the use of Lyderis 9-9-9 activated phosphorus leaching, and its concentration in the leachate was higher than in soil treated with granular fertilizers.

Key words: *mineral fertilizers, leaching, biogenic elements*

INTRODUCTION

The last decade in the Lithuanian agriculture has been witnessing an increasing use of liquid fertilizers. With the improvement of mineral and organic fertilizer production methods, a wide variety of complex fertilizer technologies have been mastered for basic and additional fertilization of plants. It is stated that liquid fertilizers reduce environmental pollution because plants may be fertilized with regard to their consumption in accordance with the ontogenesis stages. Liquid fertilizers have less unnecessary chemical additives and their production consumes less energy.

A wide range of agro technical measures applied to enhance the agricultural crop yield may increase the volume of chemical element leaching as well as negatively affect the quality of groundwater basins and reservoirs (Kutra et. al 2006; Baigys 2010).

A comparative study of granulated and liquid fertilizer effectiveness generally suggests that the efficiency is similar if fertilization of plants is applied under equal rates and at one and the same time, although it may vary under different soil and weather conditions (Staugaitis and others 2006, Lubomir 2003). Different form of granulated and liquid fertilizers allows efficient use of liquid fertilizers periodically during the plant growing season. This increases the nutrient absorption coefficient from fertilizers and reduces their leaching losses (Broschat 1995).

An important criterion of the fertilizer use is leaching of nutrients from the arable soil layer. The earlier research carried out at the Voke branch of the LAI using 15N labelled isotope shows that, under the Lithuanian conditions of sandy soils, on the average, from 2,24 to 4,76 % of nitrogen leaching occurs from fertilizers and 24,8 to 34,9 % is immobilized in the soil (Tripolskaja, Panamarioviene 1995). During re-mineralization of immobilized nitrogen, the plants still take 2,3 to 4,3 % of fertilizer nitrogen. The research was carried out with granulated nitrogen fertilizers. Transformation and immobilization of nitrogen compounds of liquid fertilizers in the soil may have a different nature and affect the leaching volume accordingly. The volume of fertilizer nitrogen mobilization also depends on the extent of hydrothermal conditions during the growing season. Using isotope15N labelled fertilizers in the research carried out at Vokė branch of the LAI, it was found out that, on the average, from 24,5 to 38,5 % of nitrogen from fertilizers is immobilized in sandy soils by microorganisms, although immobilization significantly increased (from 52,6 to 80,0 %) due to the lack of moisture in the soil (Tripolskaja, Panamariovienė 1997).

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In light-textured soils an important criterion for the efficiency of fertilizers is leaching of nitrogen and other nutrients from arable soil layer. Nitrogen (N) in fertilizer solutions is available mainly in three forms: Ammonium**–N**: that has a positive electric charge (cation); Nitrate–N: that has a negative electric charge (anion); Urea–N: that is a non-charged molecule. These nitrogen compounds encounter a highly complex environment when they come in contact with the soil. The ammonium cation is adsorbed to the negatively charged clay particles and is slowly oxidized by soil bacteria to nitrate-N. The nitrate-N enters the soil under the dripper into a water saturated zone, devoid of oxygen, which contains soil bacteria that actively seek an oxygen source to meet their respiratory demands. Another part of the nitrate moves with the water and accumulates to a very high concentration at the boundary between the wet and dry soil zones. Urea, the noncharged molecule, is able to travel considerable distances in the soil with the moving water. Once in contact with the ubiquitous soil enzyme urease, however, this molecule is rapidly converted to carbon dioxide (CO_2) and ammonia (Schimel, Bennett 2004, Kafkafi, Tarchitzky. 2011). This way, nitrogen fertilizers of different chemical composition may have various effects on nitrogen leaching and environmental pollution.

The experiments carried out in England showed that under different climatic conditions of various years nitrogen uptake and leaching from liquid and granulated urea and ammonium nitrate were different (Readman et al. Al. 2002). One year, more nitrogen was taken by plants from liquid fertilizers while the other year there was no difference. Only once in a three-year period, there was a decrease in nitrogen leaching when the plants were fertilized with liquid urea. Timmons and Dylla (1981) report that, in the irrigated fields, liquid nitrogen fertilizers, compared to granulated ones, allow reducing nitrogen leaching due to the fact that they are used several times irrigating plants with water during the growing season.

After applying nitrogen fertilizers, the nitrogen compound emission may increase for a short period. The more NO_3 form ions there are in a nitrogen fertilizer, the larger gaseous nitrogen losses are, compared with ammonium fertilizers. Linzmeier and others (2001) report that the nitrogen compound emission from fertilizers amounts to 20 % on the average, while granulated fertilizer losses were smaller, compared to liquid ones. Thus, the use of liquid nitrogen fertilizers is superior to granulated ones because it allows reducing nitrogen unproductive losses as well as environmental pollution with biogenic elements.

The lysimeter experiment carried out at the Voke branch of the LAI showed that, under the East Lithuanian climatic conditions, higher biogenic element leaching takes place in autumn, winter, and spring period (Romanovskaja 2005). Therefore, the extension of the length of these periods of time due to climate warming may give rise to the increased surface water contamination with these elements.

Experimental technique

The experiment was carried out at the Voke branch of the LRCAF in 2008 - 2011 in stationary cylindrical lysimeters of reinforced concrete. One lysimeter area – 1,75 m2, the research soil layer – 0,60 m. The lysimeters were filled with the typical eastern Lithuania zone soil - sandy loam *Haplic Luvisol*.
The aim of this work. The experiment goal - to assess the granular fertilizer and liquid fertilizer efficiency and their effect on the surface water contamination with biogenic elements.

Experiment objectives:

1. To compare the impact of granular solid and liquid fertilizers on the crop yield as well as nitrogen aggregation;
2. To assess the difference of nitrogen in the soil treatment through the fertilization of plants with granular and liquid fertilizers;

3. To determine the nitrogen leaching dynamics from liquid and granular fertilizers in the run of the year;

4. To determine biogenic element leaching losses from the fertilizers intended for the essential fertilization of plants;

5. To assess the impact of the rainfall intensity on nutrient losses.

Experimental scheme:

1. Without fertilizers;

2. Single-component NPK granular fertilizers (ammonium nitrate, superphosphate gr., potassium chloride);

3. Lyderis 9-9-9 liquid fertilizer;

4. UAN 32 liquid fertilizer and PK granular fertilizer (superphosphate gr., potassium chloride).

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Fertilizer characteristics:

Ammonium nitrate (NH_4NO_3) – a granulated nitrogen fertilizer (34,7 % N), ammonium and nitrate ion form nitrogen, hygroscopic granules;

Granulated superphosphate ($Ca(H_2PO_4)_2x\ H_2O + CaSO_4x2H_2O$) – a phosphorus fertilizer (19-20% P_2O_5), phosphorus acid, water soluble, granules;

Potassium chloride (KCl) – a granulated potassium fertilizer (60 % K_2O), crystals, hygroscopic; UAN 32 ($CO(NH_2)$ x nNH_4NO_3) – an urea ammonium nitrate solution, contains amide, nitrate and ammonium nitrogen, a liquid fertilizer;

Lyderis 9-9-9 – NPK liquid fertilizer, contains nitrogen of amide and ammonium form, phosphorus and potassium; the nutrient ratio 9-9-9.

General conditions of the experiment

The research was carried out by the lyzimeter experience methodology.

The impact of different form mineral fertilizers on the biogenic element migration was investigated in the next chain: barley - potato (repeated 2 times). The plants were fertilized: barley - $N_{90}P_{60}K_{90}$, potatoes - $N_{120}P_{90}K_{120}$.

Under the test scheme, the fertilizers were applied in the lysimeters 2-4 days before sowing or planting. In accordance with the fertilizer rate, the physical fertilizer quantity was estimated for each type fertilizer.

Barley was sown in the third decade of April, the seeding rate - 200 kg ha^{-1} seeds “Aura” variety. Between rows - 12 cm. Potatoes were planted in the third decade of April by 9 pcs. per the lysimeter “Goda” variety.

Crop maintenance work was carried out according to the condition of the crop (weeds, pests, and plant diseases).

The plant yield calculations were performed at the full maturity stage. Harvesting was done manually. Barley grain and straw yield, tuber yield and fractional composition as well as grain and tuber quality indicators were determined.

To assess the fertilizer efficiency, two different botanical groups of plants were chosen - potatoes and barley. Potatoes belong to the group of row crops. They are planted in wide row spacing, loosened by 4-6 times during the growing season and have a weak root system. Barley is a cereal, has a well-developed root system, and is sown in narrow row spacing. All these differences affect the nutrient uptake of plants and their leaching into the subsoil horizon.

Infiltration water calculation.

On the territory of Lithuania hydrological year period runs from March 1 to March 1. Respectively, duration of the seasons is: spring– from 1st March to 31st May, summer – from 1st June until 31st August, autumn – from 1st September until 30th November, winter – from 1st December until 28th February. Therefore, the amount of atmospheric precipitation filtrate was calculated from 1st March of the current year to 28th February of the following year (12 months), and the duration of the experiment was from 1st March 2008 to 28th February 2012. Precipitation filtrate was measured according to the intensity of atmospheric precipitation. Amount of leachate per month, season of the year and per year was calculated.

Nitrate concentration in lysimeter water (NO_3 mg L^{-1}) was determined each month. The weight NO_3 concentrations of separate months, seasons of the year and each year were estimated. The weight concentration was calculated according to the formula:

$$K_{weight} = (K_1 \text{ x } V_1 + K_2 \text{ x } V_2 + K_3 \text{ x } V_3)/(V_1 + V_2 + V_3),$$

where:

$K_{1,\ 2,\ 3}$ – nitrate concentration mg $NO_3^- L^{-1}$ in leachate of one lysimeter of a corresponding variant (1, 2, 3 – replications) for a certain period of time (month, season of a year);

$V_{1,\ 2,\ 3}$ – amount of atmospheric precipitation filtrate L m^{-2} of one lysimeter of a corresponding variant for a certain period of time (month, season of a year);

The concentration of nitrate (mg NO_3 L^{-1}) in the filtrate was determined by the colorimetric method.

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The obtained data were processed by methods of variance and correlation regression analyses with ANOVA program and MS Excel.

Meteorological conditions at the time of the experiment. During the years of the meteorological conditions were characterized by major deviations from the standard climate norm (SCN). Air temperature of spring months throughout the whole period of the experiment was by 0.1-3.2 °C higher than the climate norm (Table. 1). The summer of 2010 was very warm; the temperature exceeded the climate norm by 1.0-4.9 °C. Temperature conditions of winter periods varied: in 2008-2009 air temperature during the winter months exceeded the SCN by 1.2-2.7 °C, while in 2009-2010 and 2011-2012, on the contrary, air temperature was by 0.2-4.6 °C lower than the SCN.

Table 1. Temperature deviations from the standard climate norm (SCN) during the period of the experiment (Data of Vilnius Meteorological Station)

Month	Year							
	2008		2009		2010		2011	
	^{0}C	Deviations from SCN	^{0}C	Deviations from SCN	^{0}C	Deviations from SCN	^{0}C	Deviations from SCN
January	-1,5	4,5	-3,8	2,2	-10,4	-4,3	-3,3	2,8
February	1,1	5,9	-3,6	1,2	-4,1	0,7	-7,5	-2,6
March	1,8		0,5	1,1	0,2	0,8	-0,2	0,4
April	8,9	3,2	8,7	3,0	7,6	1,9	8,7	3,0
May	11,4	-1,0	12,4	0,0	14	1,5	12,9	0,4
June	15,8	0,0	14,9	-0,9	16,7	0,9	18,3	2,5
July	17,8	0,9	18	0,5	21,8	4,8	19,6	2,7
August	17,6	1,4	16,4	0,1	19,8	3,5	17,3	1,0
September	11,9	0,3	13,6	1,9	11,5	-0,2	13,3	1,7
October	8,4	1,8	4,8	-1,8	4,4	-2,2	6,6	0,0
Nowember	2,3	1,1	3,3	2,1	3,7	2,5	2,9	1,7
December	-0,2	2,6	-3,1	-0,2	-7,5	-4,6	1,2	4,1

Regarding precipitation, summer of 2010 can be distinguished as rainfall was by 49-130 mm above the SCN throughout the whole season. June and July of 2009 were also rainy (Table 2).

Table 2. Precipitation deviations from the climatic norm during the period of the experiment (Data of Vilnius Meteorological Station)

Month	Year							
	2008		2009		2010		2011	
	mm	Deviations from SCN	mm	Deviations from SCN	mm	Deviations from SCN	mm	Deviations from SCN
January	61	149	46	112	23	56	43	105

February	49	129	28	74	44	116	37	96
March	63		40	103	47	121	13	34
April	62	135	6	13	37	80	32	68
May	104	168	46	79	113	182	79	127
June	69	90	129	168	142	184	40	52
July	58	74	107	137	208	267	155	199
August	55	76	68	94	117	163	101	144
September	31	48	60	92	80	123	62	96
October	60	113	109	206	42	84	13	25
Nowember	34	60	72	126	54	95	16	28
December	42	76	70	127	56	102	46	83
Hydrological year ∑	652	98,2	774	116,6	976	147,0	636	93

RESULTS

It was found out that the form of fertilizers (granulated or liquid) had no significant differences in yield enhancement. Compared with the control option (no fertilizer), barley grain yield has almost doubled (from 113,4 to 123,4 %) and potato tuber yield – 66,8 to 84,2 %.

Table 3. Different fertilizer impact on potato tuber yield and quality

Fertilization	Potato tuber yield		Major (> 6 cm) tuber %	Tuber quality indicators		
	kg m^{-2}	%		Starch %	Ascorbic acid %	NO_3 mg kg-1
Without fertilizers	2,18	100,0	30,8	16,6	1,71	30,1
Single-component NPK granular fertilizers	4,64	213,4	60,6	17,0	1,61	42,6
Lyderis 9-9-9 liquid fertilizer	4,11	189,2	42,1	17,2	1,81	44,3
UAN 32 liquid fertilizer and PK granular fertilizer	4,87	223,8	58,2	16,8	1,67	51,6
R_{05}	0,570		7,87			

In a rainy growing season, impact of liquid fertilizers on the crop yield may be lower than of granulated ones. The Lyderis 9-9-9 fertilizer increasingly drives the accumulation of starch in potato tubers and the granular fertilizers - nitrogen levels in barley grain and potato tubers.

The quantity of mineral nitrogen in the soil during the growing season was changing depending on the hydrothermal treatment and the form of fertilizers. According to the research average data, in the intense growing season (June) of the plant vegetative mass, a higher mineral nitrogen concentration occurred in the soil fertilized with granular fertilizers. At the pant full maturity stage (August), the mineral nitrogen deposit did not differ significantly.

The atmospheric precipitation filtration in the fertilized soil was 11,9 to 14,7 % lower than in the unfertilized one. This is related to the plant vigour, extensive root system, and increased transpiration. The fertilizer form did

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not affect the filtration intensity. The variations of the chemical element (N, P, K, Ca) concentration in the lysimetric water depended on the intensity of the hydrothermal conditions, nutrient uptake by plants, and fertilizer form.

Table 4. Different fertilizer impact on barley yield and quality

Fertilization	Grain yield		Grain and straw ratio	Biogenic elements in grain, %		
	kg m^{-2}	%		N	P	K
Without fertilizers	0,201	100,0	1,42	1,56	0,505	0,861
Single-component NPK granular fertilizers	0,429	213,4	1,80	1,95	0,412	0,829
Lyderis 9-9-9 liquid fertilizer	0,449	223,4	1,70	1,79	0,426	0,831
UAN 32 liquid fertilizer and PK granular fertilizer	0,429	213,4	1,58	1,85	0,397	0,775
R_{05}	0,017					

Table 5. Impact of different form fertilizers on the major plant nutrient concentration in the filtrate and leaching

Fertilization	N		K^+		Ca^{2+}	
	mg L^{-1} or kg ha^{-1}	%	mg L^{-1} orkg ha^{-1}	%	mg L^{-1} or kg ha^{-1}	%
	Concentration in the filtrate mg L^{-1}					
Without fertilizers	61,1	100,0	3.06	100	32,4	100,0
Single-component NPK granular fertilizers	98,7	161,5	3.44	112.4	58,8	181,5
Lyderis 9-9-9 liquid fertilizer	87,3	142,9	2.89	94.4	43,7	134,9
UAN 32 liquid fertilizer and PK granular fertilizer	121,9	199,5	3.93	128.4	63,8	196,9
	Leaching kg ha^{-1}					
Without fertilizers	48,56	100,0	13,25	100,0	128,8	100
Single-component NPK granular fertilizers	52,18	107,5	10,99	82,9	187,0	145,2
Lyderis 9-9-9 liquid fertilizer	54,36	111,9	11,61	87,6	145,3	112,8
UAN 32 liquid fertilizer and PK granular fertilizer	57,22	117,8	15,92	120,2	192,4	149,4

According to the average data, a higher nitrate concentration in the filtrate was determined in the plants fertilized with a granulated fertilizer, although the concentration variations were dependent considerably on the period of time after the last fertilization. The PK granulated fertilizer stimulated calcium and the potassium migration and concentration of these elements in the Lysimeter filtrate and increased when compared with the soil fertilized with the liquid fertilizer Leader 9-9-9. However, when using Lyderis 9-9-9 phosphorus, leaching became more active and its concentration in the filtrate was higher than of the soil fertilized with granulated fertilizers.

CONCLUSIONS

Effect on plants:

• Granulated NPK, Lyderis 9-9-9 liquid fertilizer, and KAS 32 had actually the same effect on the crop yield;
• The Lyderis 9-9-9 fertilizer efficiency was reduced if, during the plant intensive growth phase (June), there were more rainfalls against the norm;

• Compared with the NPK granulated fertilizers and KAS 32, fertilization with Lyderis 9-9-9 reduces the accumulation of nitrogen in plants.

Impact on biogenic element leaching:

• Due to the use of the nitrogen fertilizer, the concentration of the filtrate increased from 38,6 to 55,2 % while nitrogen leaching losses were from 7,5 to 17,8 %;
• The nitrate concentration of the filtrate was further enhanced by ammonium nitrate and KAS 32 rather than Lyderis 9-9-9;
• Leaching losses were increased substantially (17,8 %) by the KAS 32 fertilizer;
• Potassium leaching increased insignificantly due to the fertilizer use, more (20,2 %) when applying a combination of the KAS 32 fertilizer and gran. PK;
• Leaching of calcium was increased by the calcium-based fertilizers (superphosphate gr.). Compared with the untreated soil, calcium leaching increased 45-49 %, while its concentration in the filtrate – 83-99 %.

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