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The changes of mineral nitrogen content in clay loam *Cambisol* in sustainable and organic agriculture

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Abstract. Experiments were conducted in the Joniskelis Experimental Station of the Lithuanian Institute of Agriculture in 2006–2008 on the clay loam *Gleyic Cambisol*. The aim of the research – to estimate changes of amount of mineral nitrogen in several humus content soils under influence of fertilization systems with a catch crop of green manure – combinations of white mustard (S*inapis alba* L.), oil radish (*Raphanus sativus* L.), narrowleaf lupin (*Lupinus angustifolius* L.), buckwheat (*Fagopyrum esculentum* MOENCH.) in sustainable and organic farming systems. Experiments showed that in late autumn, before incorporation of different catch crops biomass, the lowest amount of mineral nitrogen – 6.21-6.31 mg kg^{-1} in the soil layer of 0–40 cm was found in the organic farming system. In the sustainable farming system growing white mustard and using nitrogen at low rates – N_{30} for more intensive straw mineralization, the amount of mineral nitrogen in the soil was significantly – 17.0-15.2% - higher. The highest content of mineral nitrogen – 8.04 mg kg^{-1} in the soil was found in the fields without catch crops, where N_{30} was also applied for straw mineralization.

Key words: clay loam, organic and sustainable farming system, winter wheat, straw, green manure

INTRODUCTION

In intensive farming fertilization systems for harvest increase is based on the plant nutrition needs, but little attention is paid to the maintenance of ecosystem productivity (Hoffmann & Johnsson, 2000; Nieder et al., 2003; Lützow et al., 2006). Nitrogen is one of the most important nutritional elements determining productivity of agrocenosis. During cultivation of the main crops nitrogen in the soil is utilised for 3-4 months. But, after their harvest, in late summer or early autumn, the risk of nutrient leaching rises again (Stopes & Philipps, 1994). Use of nitrogen fertilizer for straw mineralization and its rapid migration raises the risk of groundwater contamination. In order to reduce nutrient losses, and at the same time to protect the soil from direct influence of the atmosphere for a longer period, it is advisable to grow catch crops in monocrops or in combinations after the main crop (Tripolskaja, 2005). The development of different plant species in agrophytocenoses is determined by various factors. One of the most important plant nutrition problems in sustainable and ecological agrosystems is optimization of the balance of soil conditions without use of mineral fertilizers. Greater attention to the use of organic fertilizers and reduction or abandonment of the quantity of mineral fertilizers increases organic carbon in the soil, but raises a complex plant nutrition problem (Molina et al., 1997; Bhogal et al., 2000; Magid & Kjaergaard 2000; Maiksteniene et al., 2008).

The catch crops are important in organic farming agrosystems as their biomass is one of the main sources of organic fertilizers. Another important function: to accumulate the nutritional elements - nitrogen, phosphorus, potassium, calcium, magnesium – remaining in the soil in the phytomass, after the main crop has been harvested. Also catch crops, with the help of roots, lift nutrient elements from the deeper soil layers to the topsoil and reduce the risk of nitrogen leaching. E. Hansen (1994) stated that growing catch crops reduced nitrate leaching by 39 % compared to only ploughing. Other authors reported that catch crops for green manure reduced nitrogen leaching by 94.9% as compared with soil without a catch crop (Marcinkeviciene et al., 2008).

These investigations seek to determine the possibility to compensate plant nutrition needs by growing various catch crops for green manure in organic and sustainable farming systems in soils of varying humus content and to estimate their influence on the changes of mineral nitrogen in the soil.

METHODS AND MATERIALS

To estimate the changes of basic parameters of the soil in sustainable or organic farming systems of different soil fertility, investigations were carried out in the soil of different fecundity, described as glacial lacustrine-clay loam on silty clay, lying under morainic sandy loam, *Gleyic Cambisol* (Rdg4 – K_2). The influence of different fertilization systems in sustainable and organic farming systems was investigated in a four-course crop rotation: perennial grasses of the 1st year, winter wheat (*Triticum aestivum* L.), peas (*Pisum sativum* L.), and spring barley (*Hordeum distichon* L.). The soil was grouped into two groups (low and medium humus content) based on the data of several authors (Pestriakov, 1977; Mazvila, 1998).

Experiment design:

Factor A. Level of soil humus content:

1. Low content of humus (2.01–2.09) in soil (A1);
2. Medium content of humus (2.38–2.43) in soil (A2).

Factor B. Farming and fertilisation systems:

1. Organic I – straw of winter wheat (*Triticum aestivum* L.) + narrowleaf lupin (*Lupinus angustifolius* L.) & oil radish (*Raphanus sativus* L.),
2. Organic II – straw of winter wheat + white mustard (*Sinapis alba* L.),
3. Sustainable I – straw of winter wheat + N_{30} + white mustard & buckwheat (*Fagopyrum esculentum* MOENCH.),
4. Sustainable II – $N_{60}P_{60}K_{60}$ for winter wheat + straw +N_{30}.

The experiments were performed in a randomised block design with 4 replications. Winter wheat seed – 5 million per hectare of germs, narrowleaf lupin and buckwheat (150 + 20 kg ha^{-1}), white mustard monocrops – 15 kg ha^{-1}, and their mixture with buckwheat (10 + 80 kg ha^{-1}).

Research methods. Soil samples for mineral nitrogen estimation were taken from each plot at twenty positions, from the soil layer of 0–40 cm, taking average samples. Samples were taken in autumn, after the shallow winter wheat straw and before catch crops biomass incorporation and again in spring before the sowing of peas. Ammonia nitrogen ($N\text{-}NH_4$) in the soil was determined spectrometrically with a Carry 50 instrument, nitrate nitrogen ($N\text{-}NO_3$) by ionometric technique.

Statistical analysis. Data statistical analysis was performed using ANOVA for two-factor experiment from the program package „Selekcija" (Tarakanovas & Raudonius, 2003).

Meteorological conditions. In July of 2006 precipitation was 40.7 mm less, and the temperature was 3.7°C higher than the yearly average, therefore development of winter wheat was weak. August was rainy; precipitation was 71.9 mm higher. Winter wheat was sown in the soil of moderate humidity; the development and germination of plants was normal. April 2007 was dry, precipitation 24.6 mm lower than the yearly average. Although June and July were rainy, precipitation was only respectively 8.3 and 37.8 mm higher than the early average, but the winter wheat harvest was average. During September, catch crops developed weakly due to lack of moisture.

RESULTS AND DISCUSSION

After the winter wheat harvest, to maintain fecundity of soil with different humus content, the straw was also incorporated with the plants grown with catch crops with different biological characteristics or their mixtures (Table 1). Significantly higher dry matter (DM) content accumulated in the biomass of different crops compositions than in that of monocrops. The aboveground biomass of catch crops grown in soil of medium humus content was significantly lower than in soil of low humus content.

Table 1. Aboveground biomass and content of nutrients in catch crops grown during post harvest period of winter wheat, 2007.

Farming and fertilisation systems (B)	DM kg ha^{-1}	Nutrients kg ha^{-1}		
		N	P	K
Low content of humus in soil (A1)				
Organic I - straw + narrowleaf lupin + oil radish	495	9.8	1.7	9.6
Organic II – straw + white mustard	345	7.7	1.2	10.2
Sustainable I – straw + N_{30} + white mustard +buckwheat	655	13.2	2.3	139
Sustainable II - NPK for winter wheat + straw + N_{30}	-	-	-	-
Average of A1	498	10.2	1.74	11.2
Medium content of humus in soil (A2)				
Organic I - straw + narrowleaf lupin + oil radish	275*	4.1*	0.9*	4.4*
Organic II - straw+ white mustard	355	7.2	1.6	7.9
Sustainable I - straw+ N_{30}+ white mustard +buckwheat	460	10.3	2.4	10.9
Sustainable II - NPK for winter wheat + straw+N_{30}	-	-	-	-
Average of A2	363*	7.2*	1.64	7.7*
Average of factor B				
Organic I - straw + narrowleaf lupin + oil radish	385	6.9	1.3	7.0
Organic II – straw + white mustard	350	7.5	1.4	9.0
Sustainable I - straw+ N_{30} + white mustard +buckwheat	558*	11.7*	2.4*	12.4*
Sustainable II - NPK for winter wheat + straw + N_{30}	-	-	-	-
LSD_{05} fact. A	114.7	2.42	0.47	2.79
LSD_{05} fact. B	140.4	2.96	0.57	3.41
LSD_{05} fact. AB	198.6	4.19	0.81	4.82

* – significant at $P < 0.05$

Table 2. The effect of straw and catch crops on the amount of $N_{min.}$ in soil layer of 0–40 cm in autumn before the incorporation of catch crops biomass, 2007.

Farming and fertilisation systems (B)	Low content of humus in soil (A1)	Medium content of humus in soil (A2)	Average of factor B
	$N_{min.}$mg kg^{-1}		
Organic I - straw + narrowleaf lupin + oil radish	6.38	6.03	6.21
Organic II – straw + white mustard	5.29*	7.32*	6.31
Sustainable I - straw+ N_{30}+ white mustard +buckwheat	6.10	8.44*	7.27*
Sustainable II - NPK for winter wheat + straw + N_{30}	7.42*	8.65*	8.04*
Average of factor A	6.30	7.61*	
LSD$_{05}$ fact. A			0.318
LSD$_{05}$ fact. B			0.450
LSD$_{05}$ fact. AB			0.636

*– significant at P<0.05

Average data shows that the concentration of nutrients in the biomass of catch crop was significantly higher in the sustainable agricultural system, where N_{30} was used for mineralization of straw. In the biomass of white mustard and buckwheat mixture the content of phosphorus and potassium was (P < 0.05) significantly higher compared with that of the white mustard monocrop grown in soils of different humus content. On average, 41% more nitrogen accumulated in the mixture of white mustard and buckwheat compared to the narrowleaf lupine and oil radish mixture or by 36 % more than in the white mustard monocrop. M. Torstensson (2006) has reported that N leaching in a crop rotation with a catch crop was reduced as compared with an identical crop rotation without a catch crop.The highest amount of phosphorus and nitrogen was incorporated with white mustard and buckwheat mixture biomass. That is respectively 46 and 42% more than with the mixture of narrowleaf lupine and oil radish and white mustard monocrop. The trend of potassium accumulation in the biomass of the catch crops remained the same as nitrogen and phosphorus. The content of potassium was respectively 44 and 27% higher. These data are consistent with that of other researchers. It is stated that buckwheat, with the help of specific roots exudates, is capable of assimilating various forms of phosphorus; therefore it can accumulate more biomass and also enrich the soil with nutrients which will be used by plants grown subsequently (Freyer, 2003; Marcinkonis et al., 2007).After the winter wheat harvest and before the incorporation of catch crop biomass, the changes of mineral nitrogen content in soil depended on soil humus content and the properties of the plants grown for the catch crops (Table 2). After the winter wheat crop, growing various catch crops and before incorporation of their biomass, the lowest content of mineral nitrogen in soil in autumn occurred after the narrowleaf lupine and oil radish mixture - 6.21 mg kg^{-1}. In those fields where low doses of mineral fertilizers N_{30} were applied for straw mineralization, the content of N_{min} was 17.1 and 29.5% higher. Mineral nitrogen N_{30} in the form of ammonium nitrate was applied to promote straw mineralization in late autumn, therefore it was not included in organic compounds, hence it posed a threat of leaching into the deeper layers and contaminating the groundwater (Wallgren & Lindén, 1994; Tripolskaja, 2005).

In spring 2008, before the sowing of spring crops, according to average data, the amount of mineral nitrogen in the soil was higher in plots which had incorporated straw and green nmanure in autumn than in plots where mineral nitrogen N_{30} for straw mineralization was applied (Table 3).

Table 3. The effect of straw and catch crops on the amount of N_{min} in soil, in spring, 2008.

Farming and fertilisation systems (B)	Low content of humus in soil (A1)	Medium content of humus in soil (A2)	Average of factor B
	$N_{min.}$mg kg^{-1}		
Organic I - straw + narrowleaf lupine +oil radish	7.18	6.81	6.99
Organic II - straw+ white mustard	6.49	7.29	6.89
Sustainable I - straw+ N_{30}+ white mustard +buckwheat	7.02	7.73	7.38
Sustainable II - NPK for winter wheat + straw+N_{30}	6.26	7.95	7.11
Average of factor A	6.74	7.45	
LSD_{05} fact.A			0.949
LSD_{05} fact.B			1.342
LSD_{05} fact.AB			1.898

After application of mineral fertilizers – $N_{60}P_{60}K_{60}$ for winter wheat and N_{30} for straw mineralization, the content of N_{min} in the soil in spring was – 11.6 % lower than before the winter. The content of mineral nitrogen in spring increased the most as compared with that in the previous autumn, in plots where biomass of narrowleaf lupine and oil radish mixture or white mustard was incorporated accordingly by 12.6 or 9.2 %. Processes of straw mineralization stop during the winter period, because temperatures fall below zero, therefore unused mineral nitrogen in early spring leaches into the deeper layers (Buciene, 2003). The soil, in which biomass of various plants was incorporated and its nitrogen released, created better nutrition conditions for spring crops.

CONCLUSIONS

Higher amounts of dry matter and nutrients in biomass accumulated when plants with different biological properties were grown in combinations as catch crops than in monocrops. By growing different catch crops after winter wheat and before their biomass incorporation in autumn, the lowest amount of mineral nitrogen in both medium and low humus content soils was found in the organic system after the mixture of narrowleaf lupin and oil radish or white mustard monocrop.

In the sustainable farming system, for promotion of winter wheat straw mineralization using nitrogen N_{30} at low rates, in late autumn it was not incorporated into organic substances and the amount of N_{min} in the soil remained significantly higher than where it was used in combination with catch crops.

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