ISSN 1392-3196
Zemdirbyste-Agriculture, vol. 97, No. 2 (2010), p. 41–52
UDK 631.445.15:631.51.01:631.582:631.51.01:631.83./85

The influence of various organic fertilizers and catch crops on the balance of biogenic elements in the agrosystems

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Abstract

Field experiments were conducted during the period 2005–2009 at the Lithuanian Institute of Agriculture's Joniškėlis Experimental Station on a clay loam *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*). The objective of this study was to estimate the effects of organic and sustainable farming systems on the balance of biogenic elements in the soil with a low (1.98–2.01%) and medium (2.10–2.40%) humus content, fertilized with farmyard manure, cereal straw, pea vines and biomass of various catch crops. The crop rotation, expanded in time and space, consisted of perennial grasses – red clover (*Trifolium pretenses* L.) and meadow fescue (*Festuca pratensis* Huds.), winter wheat (*Triticum aestivum* L.), pea (*Pisum sativum* L.) and spring barley (*Hordeum vulgare* L.) with grasses as an undersown crop. The investigated measures were assessed in a grass-cereal sequence: perennial grasses → winter wheat + catch crops → pea. In the sustainable farming systems, to promote straw mineralization mineral nitrogen fertilizers N_{30} were used in the form of ammonium nitrate.

It was found that in the catch crop the highest dry matter mass and the amount of nutrients were accumulated in the white mustard grown with buckwheat or white mustard grown as a monocrop. The balance of the main nutrients (NPK) was negative in the organic farming system in both humus backgrounds, using only green manure for fertilization. NP balance (and K – significantly) was positive in the organic farming system, where green manure and farmyard manure were incorporated. NPK balance was positive in the soil low in humus content when farmyard manure was used for winter wheat and N_{30} for straw mineralization in the sustainable farming system. Only the nitrogen balance was negative in the soil with medium humus content because of the better growth conditions for crops and higher removal with the wheat yield. Unlike green manure, farmyard manure incorporated for winter wheat in the organic agrosystem secured a positive balance of NPK. However, due to the low mineralization rate in clay loam *Cambisol*, farmyard manure increased the yield of the second rotation member – pea more effectively than that of winter wheat.

Key words: *Gleyic Cambisol*, organic and sustainable farming systems, catch crops, green manure, farmyard manure, nutrient balance.

Introduction

Anthropogenic activity has a clear effect on ecosystems, because it stimulates the domination of components, useful for human beings. In intensive farming, fertilization systems targeted at yield increase are based on the plant nutrition needs, but little attention is paid to the maintenance of ecosystem productivity (Hoffmann, Johnsson, 2000; Nieder et al., 2003; Lutzow et al., 2006; Liaudanskienė, 2009). Intensive use of chemical plant protection products and mineral fertilizers intended for crop productivity enhancement results in the atrophy of natural, self-regulatory processes in the soil (Bučienė, 2003). Rational soil management in combination with maintenance of ecological balance helps to increase crop fertility and to keep its potential productivity. In order to reduce environmental pollution and to maintain safe environment, it is important to select prevention means appropriately by including nutrients, not absorbed by plants, into biological circulation (Eitminavičiūtė, 1994; Di et al., 2002; Kriaučiūnienė, 2008; Arlauskienė et al., 2009). Anthropogenic activity must be directed towards the increase of stability in an agrosystem by improving the state of crops and fauna (Bučienė, 2003). The process of biologization in agriculture is one of the main factors, maintaining the natural productivity of soil as well as stability of ecosystem (Shaxson, 1998; Bučienė, 2003; Maikštėnienė et al., 2008).

In order to protect the ecosystems from the effects of chemical means, alternative agricultural systems are being developed. However, these agricultural systems must often solve the problems of nutrient balance, because the issue of versatile plant nutrition arises. Mineral fertilizers help in forming an appropriate balance of nutrient ratio more easily than in the cases when sustainable and organic farming is applied, where plant nutrition is solved by organic manure and limited content of mineral fertilizers (Gale, Gilmour, 1988; Bhogal et al., 2000; Deng, Motore, 2000). Seeking to preserve nutrients, especially readily migrating nitrogen, in the ploughlayer, to reduce nutrient leaching losses and to provide as long as possible protection of the soil surface from the direct adverse effects of the atmospheric phenomena, promoting soil degradation, we cultivated catch crops after the main crops in the agrosystems (Tripolskaja, 2005). Under Lithuania's conditions, during the warm period, the soil is covered with crops for only 3–4 months a year, while in the autumn with a prolonged rainy period, the risk of nutrient leaching during main crops' post-harvest arises. Catch crops accumulate in their phytomass the nutrients that are left in the soil after the main crops, and what is the most important, keep nitrogen in the topsoil layer (Stopes, Philipps, 1994; Marcinkevičienė et al., 2008). Literature sources indicate that some plants, cultivated as catch crops, such as buckwheat, with the help of specific root exudates are capable of assimilating various forms of phosphorus; therefore it can accumulate more biomass, also enrich the soil with nutrients which will be used by plants, grown subsequently. Having incorporated the phytomass of catch crops as green manure, nutrients are released during the process of mineralization and can be assimilated by subsequent main crops (Tripolskaja, 2005; Maikštėnienė, Arlauskienė, 2007; Tausojamoji žemdirbystė…, 2008). It is important to form combinations of main and catch crops from plants with different biological properties for symbiosis between them (Hoffmann, Johnsson, 2000; Bučienė, 2003). There is little research into the effects of technologies used on nutrient, especially nitrogen, immobilization in the soil after harvesting of the main crops, when the soil during the post-harvest period stays bare for a long time.

The study was designed to ascertain the effects of fertilization systems and catch crops on the balance of the main biogenic elements in a clay loam *Gleyic Cambisol* with a different humus content in organic and sustainable farming systems.

Materials and methods

Field experiments were conducted at the Lithuanian Institute of Agriculture's Joniškėlis Experimental Station during 2005–2009 on a clay loam *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*).

The field experiment was arranged according to the following design: soil humus content based on the humus content scale developed by several authors (Пестряков, 1977; Lietuvos dirvožemių…, 1998; Amacher et al., 2007) – factor A: 1) – low (1.98–2.01%) and 2) – medium (2.10–2.40%). Farming systems – factor B: organic I, organic II, sustainable I and sustainable II, are presented in Table 1. In topsoil (0–25 cm) mobile P_2O_5 in the soil with a low humus content amounted to 75–101 mg kg^{-1}, with a medium humus content to 111–134 mg kg^{-1} and K_2O 207–235 and 221–240 mg kg^{-1}, respectively. The experiment was performed in a four-course crop rotation expanded in time and space: perennial grasses – red clover (*Trifolium pretense* L.) and meadow fescue (*Festuca pratensis* Huds.), winter wheat (*Triticum aestivum* L.), peas (*Pisum sativum* L.) and spring barley (*Hordeum vulgare* L.) with undersown perennial grasses. The influence of different fertilization systems in sustainable and organic farming was investigated in the grass-cereal sequence: perennial grasses → winter wheat + catch crop → peas.

In organic I – after winter wheat, applied with aftermath of perennial grasses as green manure catch crops, narrow-leafed lupine (*Lupinus angustifolius* L.) and oil radish *Raphanus sativus* L. var. *oleiformis* Pers.) mixture was cultivated, in organic II – after winter wheat, farmyard manure (FYM), white mustard (*Sinapis alba* L.) as a monocrop was cultivated. In sustainable I farming system – after winter wheat, applied with FYM, white mustard was cultivated in a mixture with buckwheat (*Fagopyrum esculentum* Moench.) as green manure. In sustainable II – winter wheat, manured with aftermath of perennial grasses and applied with mineral fertilizers $N_{60}P_{60}K_{60}$ and $N_{10}P_{40}K_{60}$ – for peas. Cereal straw and pea vines were used as fertilizer (Table 1).

Table 1. Crop sequence and fertilization in the farming systems

Crops	Farming systems (factor B)			
	Organic I	Organic II	Sustainable I	Sustainable II
	Fertilization			
Perennial grass	–	–	–	$P_{60}K_{60}$
Winter wheat	Aftermath of perennial grass for green manure	40 t ha^{-1} FYM + aftermath of perennial grass for green manure	40 t ha^{-1} FYM	Aftermath of perennial grass for green manure + $N_{60}P_{60}K_{60}$
Pea	Straw + narrow-leafed lupine + oil radish	Straw + white mustard	Straw + N_{30} + white mustard + buckwheat	Straw + N_{30} + $N_{10}P_{40}K_{60}$

Crop analysis. After emergence of crops, four micro-field squares of 0.25 m^2 for record were marked in every field. Composite samples were taken at harvesting of the main crops in every field in main and secondary produce as well as the samples of over-ground biomass of catch crops. Dry matter (DM) content and concentrations (%) of the main nutrients – nitrogen, phosphorus and potassium (NPK) were determined in the samples and recalculations of the accumulated nutrients into kg ha^{-1} were performed. Nitrogen was determined by Kjeldahl method in the biomass of main and secondary produce of the rotation crops as well as in catch crops' biomass, while phosphorus was measured by colorimetric method and potassium by a flame photometer.

Statistical analysis. The statistical analysis of data was performed using *Anova* for a two-factor experiment from the program package *Selekcija* (Tarakanovas, Raudonius, 2003).

Meteorological conditions. In 2005, the growing season of the main crops was characterised by less rainfall in July compared with the long-term mean, therefore cereals matured early. In 2005, after cereal harvesting, September and October were warmer and wetter than usual.

In 2006, during the growing season of the main crops (May–July), when cereals grow intensively and utilize nutrients from the soil, there was also a shortage of moisture. The rainfall that fell during that period accounted for only 38.9% of the long-term mean. Meanwhile the mean daily temperature in June and July was by 0.7 and 3.7°C higher, respectively. The yield of the main crops was low. However, the growing season of catch crops (August–October 2006) was the most favourable for catch crops' growing compared with the other growing seasons. Minimal daily temperature dropped below 10°C only in the second half of September. Moreover, in August, September and October the mean daily air temperature exceeded the long-term mean by 1.5, 2.9 and 3.1°C. During the growing season of catch cops the amount of precipitation exceeded the long-term mean by 85.5 mm; there was a lot of rainfall in August and October.

After a dry year 2006, the growing season of the main crops (May–July 2007) was relatively warm and wet. As a result, conditions were especially favourable for cereal growing. Catch crops sown after cereal harvesting grew poorly. In August, September, and October the mean daily temperature was higher than the long-term mean, the minimal daily air temperature dropped below 10°C already at the end of August and persisted such all through September, although the days were relatively warm. Poor plant emergence and establishment was caused by a droughtier first half of August, heavier rain occurred only on August 20.

In 2008, the mean daily air temperature during the main crops' growing season differed little from the long-term mean; however, this period was one of the driest. The plants were short of moisture already at early growth stages – May and June. This impeded plant nutrient uptake from the soil. Catch crops' growing season was rather wet. However, precipitation distributed very unevenly. In August, the rainfall exceeded the long-term mean by 48.6 mm; in October by 29.3 mm. September was extremely dry (rainfall amounted to as little as 6.5 mm).

Dry weather in 2009 April and May suppressed germination and establishment of the main crops. However, June and July were very wet.

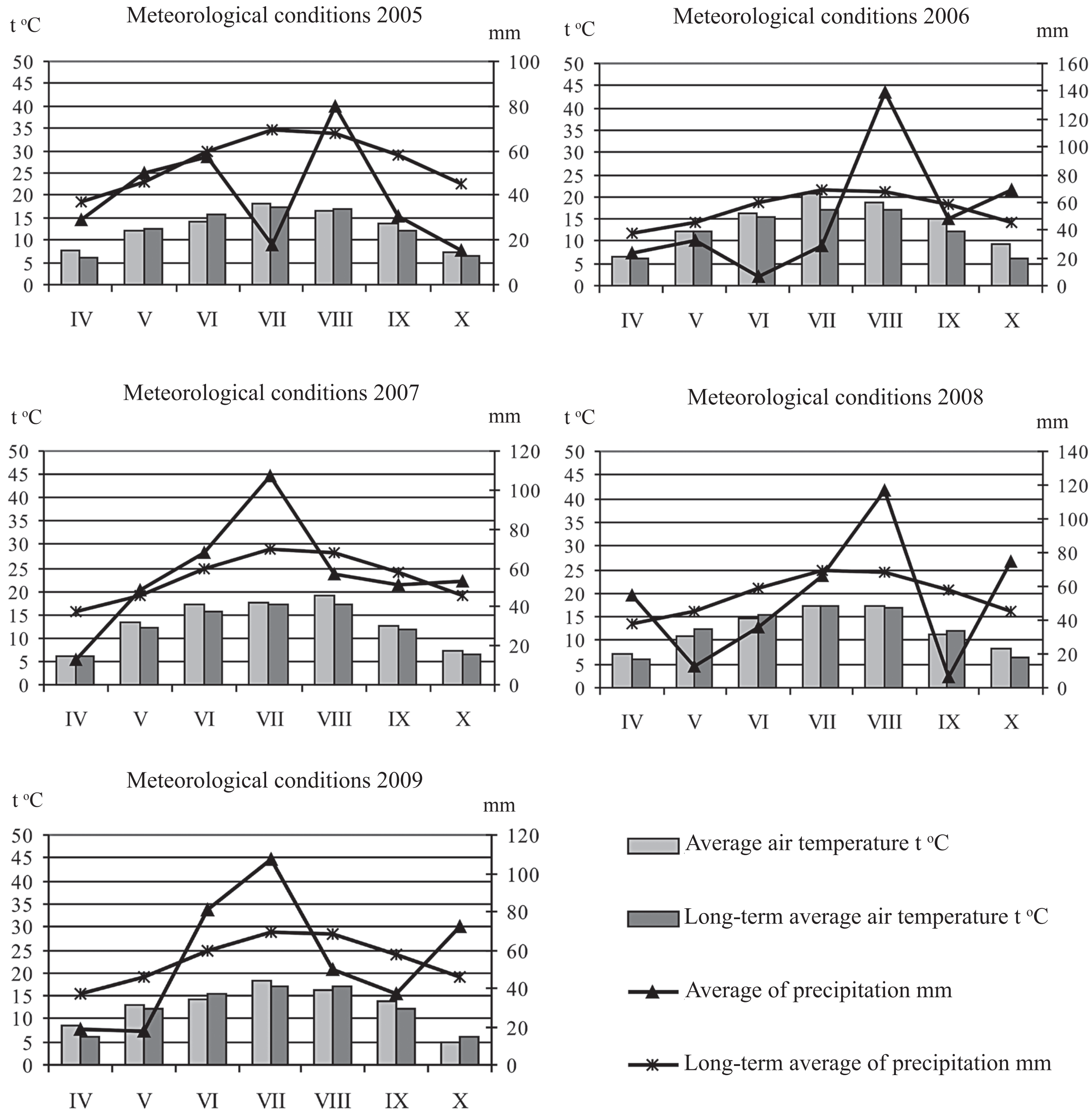

Figure. Meteorological conditions in the experimental periods

Results and discussion

In intensive agriculture, mineral fertilization intended to meet plant nutritional needs poses a threat to ecological balance. However, there is little research into the effects of technologies used on nutrient, especially nitrogen immobilization in the soil after harvesting of the main crops, when the soil during the post-harvest period stays bare for a long time. Numerous research and recommendations have indicated catch crops to be the best source of nutrients (Bučienė, 2003; Tripolskaja, 2005; Marcinkevičienė et al., 2008). Perennial grasses have a common complex of environmental factors for accumulation of nutrients (Karlsson-Strese et al., 1998; Snapp et al., 2005). Some authors suggest that grasses produce much biomass and restore organic matter more rapidly.

In our research, the data averaged over 4 rotation fields showed that in the soil with low and medium humus content, the lowest DM and nutrient contents for winter wheat were incorporated with aftermath of perennial grasses in organic I farming system (Table 2).

Table 2. DM and nutrient content, incorporated into the soil with aftermath of perennial grasses, FYM and mineral fertilizers for winter wheat

2006–2008

Farming systems (B)	Type of organic matter (OM)	Incorporation of DM and nutrients			
		DM	N	P	K
		t ha^{-1}	kg ha^{-1}		
Low humus content in the soil					
Organic I	Aftermath of perennial grasses	**2.08**	**50.35**	**5.13**	**35.49**
Organic II	Aftermath of perennial grasses	1.84	42.64	4.11	31.75
	40 t ha^{-1} FYM	6.65	136.10	58.21	208.01
	Total	**8.49**	**178.74**	**62.30**	**239.78**
Sustainable I	40 t ha^{-1} FYM	6.65	136.10	58.18	208.01
	N_{30} for straw		30.00		
	Total	**6.65**	**166.10**	**58.18**	**208.01**
Sustainable II	Aftermath of perennial grasses	2.02	49.74	4.91	37.97
	NPK		70.00	100.00	120.00
	Total	**2.02**	**119.74**	**104.91**	**157.97**
Medium humus content in the soil					
Organic I	Aftermath of perennial grasses	**2.19**	**55.89**	**5.42**	**39.73**
Organic II	Aftermath of perennial grasses	2.05	49.78	5.05	38.08
	40 t ha^{-1} FYM	6.65	136.10	58.21	208.01
	Total	**8.70**	**185.88**	**63.23**	**246.09**
Sustainable I	40 t ha^{-1} FYM	6.65	136.10	58.18	208.01
	N_{30} for straw		30.00		
	Total	**6.65**	**166.10**	**58.18**	**208.01**
Sustainable II	Aftermath of perennial grasses	1.89	46.03	4.79	38.26
	NPK		70.00	100.00	120.00
	Total	**1.89**	**116.03**	**104.79**	**158.26**

In organic II system, significantly higher content of DM and nutrients was determined by FYM 40 t ha^{-1}. In this system, in the soil low and medium in humus content, incorporation of nitrogen with FYM and aftermath of perennial grasses was by 3.5 and 3.3 times higher, phosphorus 12.1 and 11.7 times, potassium 6.8 and 6.2 times as compared with organic I farming system. With the application of FYM 40 t ha^{-1} in organic II farming system and aftermath of perennial grasses and mineral fertilizers in sustainable II farming system, appropriate reserves of the main nutrients – nitrogen, phosphorus and potassium – for optimal yields of winter wheat were incorporated.

In organic I farming system, with the application of only aftermath of perennial grasses as green manure, the yield of winter wheat was rather low, not typical of productive soils and totalled 3.0 t ha^{-1} of DM, therefore the amount of nutrients, removed from the soil was slightly lesser (Table 3). According to the averaged data of 4 crop rotation fields, FYM application on a clay loam soil did not increase winter wheat yield significantly due to the slow mineralization of organic matter. The highest grain yield was produced in more intensive sustainable II farming system, where green manure was applied together with mineral fertilizers for wheat. In this system, the grain yield in the soil low and medium in humus was by 35.7 and 29.7% respectively higher than in organic I farming system and by 32.6 and 21.2% higher than in sustainable I farming system without application of mineral fertilizers. In different fertilization systems in the soil with higher humus content, winter crop grain yield tend to increase inappreciably: throughout all farming systems the grain yield was significantly (11.2%) higher than in the soil with low humus content.

In organic farming systems with the application of green manure, rather low contents of main biogenic elements, especially phosphorus and potassium, were removed from the soil with grain yield, on average in both soil levels – 11.29 and 17.81 kg ha^{-1}, respectively. Application of FYM had no significant effect on grain yield increase, and accumulation of biogenic elements was not significantly higher than that when only aftermath of perennial grasses was applied as green manure. Significantly higher content of accumulated biogenic elements in the main production of winter wheat was observed in sustainable II farming system, when average NPK rates were applied N – 43.9%, P – 28.8% and K – 28.3% more than in the cases when only aftermath of perennial grasses was applied as green manure. In the soil with medium humus content, significantly higher yield of winter wheat was produced; therefore higher contents of nutrients were accumulated and removed from the soil, N – 13.7%, P – 14.3% and K – 11.7%, respectively.

Table 3. Nutrients accumulated in winter wheat grain yield and removed from the soil 2006–2008

Soil humus content (factor A)	Farming system (factor B)				
	Organic I	Organic II	Sustainable I	Sustainable II	Mean A
			DM t ha^{-1}		
Low	3.00	3.02	3.07	4.07	**3.29**
Medium	3.30	3.53	3.53	4.28	**3.66**
Mean B	**3.15**	**3.28**	**3.30**	**4.18**	
	LSD$_{05}$: A – **0.285**, B – **0.403**, AB – **0.569**				
			N kg ha^{-1}		
Low	49.26	48.48	50.10	72.31	**55.04**
Medium	54.20	58.84	60.67	76.56	**62.57**
Mean B	**51.73**	**53.66**	**55.38**	**74.44**	
	LSD$_{05}$: A – **6.395**, B – **9.043**, AB – **12.789**				
			P kg ha^{-1}		
Low	10.56	9.92	10.72	13.95	**11.29**
Medium	12.01	11.46	12.20	15.91	**12.90**
Mean B	**11.29**	**10.69**	**11.46**	**14.93**	
	LSD$_{05}$: A – **1.336**, B – **1.889**, AB – **2.672**				
			K kg ha^{-1}		
Low	16.55	16.36	16.88	22.58	**18.09**
Medium	19.07	19.33	19.28	23.11	**20.20**
Mean B	**17.81**	**17.85**	**18.08**	**22.85**	
	LSD$_{05}$: A – **1.972**, B – **2.789**, AB – **3.944**				

Averaged over both humus backgrounds, significantly higher winter wheat yield was obtained if the crop had been applied with NPK fertilizers and aftermath of perennial grasses compared with that when only aftermath of perennial grasses was applied in organic I farming system, where the yield was lower by 1.03 t ha^{-1}, or 24.6%. Averaged over both humus environments, during all crop rotation with the application of FYM in sustainable I farming system and application of FYM and aftermath of perennial grasses as green manure in organic II farming system, the yield was by 4.8 and 4.1% higher respectively, compared to organic I farming system.

Averaged data indicate that throughout all crop rotation, averaged over both humus levels, significantly highest content of main biogenic elements in the main production of winter wheat was determined in the treatments producing higher grain yield, i.e. in sustainable II farming system with the application of minimal NPK rates and was N – 43.9%, P – 32.2%, and K – 28.3% more compared to aftermath of perennial grasses application as green manure. With the application of FYM as well as FYM with aftermath of perennial grasses, the content of biogenic elements in grain yield was higher than in the control, when aftermath of perennial grasses was applied as green manure.

The trends of changes in winter wheat straw yield as well as accumulated biogenic elements were identified to be similar to those of grain yield (Table 4). In the first year of FYM effects straw and grain yield insignificantly increased compared with the treatments applied with green manure only. The highest accumulation of DM in straw biomass was identified in sustainable II farming system, where average rates of mineral fertilizers were applied together with green manure, however, compared to organic farming systems, a significant difference –

17.1% – was observed only in the soil, with medium humus content. Accumulation of the main biogenic elements in straw, depending on organic manure application, varied less. Significantly higher contents of nitrogen and potassium in the soil with low and medium humus content, 27.4 and 18.6% respectively as well as 48.9 and 37.8% were accumulated when winter wheat had been cultivated in sustainable II farming system with the application of mineral fertilizers as compared to organic farming system. Low content of phosphorus was accumulated in straw and there were no significant differences between farming systems. Soil humus content had a significant effect only on the accumulation of nitrogen in straw: if wheat was cultivated in the soil with medium humus content, accumulated nitrogen content was 14.9% higher than in the soil with low humus content. Soil humus content did not have any significant effect on the accumulation of phosphorus and potassium in straw.

Table 4. Nutrients accumulated in winter wheat straw yield 2006–2009

Soil humus content (factor A)	Farming system (factor B)				
	Organic I	Organic II	Sustainable I	Sustainable II	Mean A
	DM t ha^{-1}				
Low	2.89	2.82	2.76	3.43	**2.98**
Medium	3.16	3.47	3.37	3.70	**3.43**
Mean B	**3.03**	**3.15**	**3.07**	**3.57**	
	LSD_{05}: A – **0.592**, B – **0.725**, AB – **1.026**				
	N kg ha^{-1}				
Low	18.35	17.78	17.62	23.38	**19.28**
Medium	19.36	20.94	21.20	27.13	**22.16**
Mean B	**18.86**	**19.36**	**19.41**	**25.26**	
	LSD_{05}: A – **12.967**, B – **15.881**, AB – **22.459**				
	P kg ha^{-1}				
Low	3.59	3.44	4.02	3.56	**3.65**
Medium	4.12	4.75	4.66	3.78	**4.33**
Mean B	**3.86**	**4.10**	**4.34**	**3.67**	
	LSD_{05}: A – **2.319**, B – **2.841**, AB – **4.017**				
	K kg ha^{-1}				
Low	23.97	24.23	23.95	35.70	**26.96**
Medium	26.08	29.98	29.55	35.95	**30.39**
Mean B	**25.03**	**27.11**	**26.75**	**35.83**	
	LSD_{05}: A – **22.791**, B – **27.913**, AB – **39.475**				

Our data support the findings obtained by other authors who maintain that higher effect of green manure is achieved with straw incorporation. The researchers suggest that under favourable conditions the biomass of catch crops incorporated into the soil with straw start to decompose in the autumn (Lahti, Kuikman, 2003). Scientists of many countries indicated that incorporation of catch crops biomass for green manure has a different positive effect (Abdallahi, N'Dayegamiye, 2000; Deng, Motore, 2000; Kara, Penezoglu, 2000). Researchers have reported that with straw incorporated together with nitrogen-rich aboveground mass of catch crops not only excess of mineral nitrogen in the soil, but also soil humus is restored (Stumpe et al., 2000; Arlauskienė et al., 2009). After main crops cultivation during their post-harvest period, in order to keep the remaining nutrients in the soil from migrating to deeper layers, catch crops are cultivated, which are the main source of organic fertilizer (Tripolskaja, 2005; Tausojamoji žemdirbystė…, 2008). Catch crops, especially lupin, that fix nitrogen from the atmosphere, should be the reserve for enrichment of soil by nitrogen (Arlauskienė, Maikštėnienė, 2007). In our research, analysis of catch crops, cultivated during the post-harvest period as well as analysis of accumulated biogenic elements in them indicated that for both humus backgrounds the lowest content of accumulated DM and biogenic elements in catch crops' biomass was observed in the mixture of narrow-leafed lupine and oil radish (Table 5). This was determined by a genetic property of the plants (narrow-leafed lupine) – long vegetation, because of which late in the autumn, with the days becoming shorter, they accumulated lower biomass content compared with the plants characterised by short vegetation (white mustard).

Significantly more, on average for both humus backgrounds, 72.4% of DM in biomass was accumulated by white mustard, cultivated in mixture with buckwheat in sustainable I farming system compared to organic I system. Moreover, this effect resulted from mineral N_{30} application for straw mineralization. In the soil with medium humus content accumulation of biogenic elements in catch crops biomass was more intensive, however the differences were not significant, compared to the soil with low humus content.

Table 5. Biomass of catch crops, cultivated after winter wheat and biogenic elements, accumulated in it 2006–2008

Soil humus content (factor A)	Farming system (factor B)				
	Organic I	Organic II	Sustainable I	Sustainable II	Mean A
DM t ha^{-1}					
Low	1.07	1.09	1.82	–	**1.33**
Medium	1.03	1.35	1.80	–	**1.39**
Mean B	**1.05**	**1.22**	**1.81**	–	
LSD_{05}: A – **0.592**, B – **0.725**, AB – **1.026**					
N kg ha^{-1}					
Low	29.41	30.23	41.15	–	**33.60**
Medium	27.91	36.17	41.84	–	**35.31**
Mean B	**28.66**	**33.20**	**41.49**	–	
LSD_{05}: A – **12.967**, B – **15.881**, AB – **22.459**					
P kg ha^{-1}					
Low	7.89	4.78	4.89	–	**5.86**
Medium	3.78	10.09	8.16	–	**7.34**
Mean B	**5.84**	**7.44**	**6.53**	–	
LSD_{05}: A – **2.319**, B – **2.841**, AB – **4.017**					
K kg ha^{-1}					
Low	38.15	40.91	55.86	–	**44.97**
Medium	28.73	50.01	53.60	–	**44.11**
Mean B	**33.44**	**45.46**	**54.73**	–	
LSD_{05}: A – **22.791**, B – **27.913**, AB – **39.475**					

Winter wheat straw was incorporated into the soil and mineral fertilizer N_{30} in the form of ammonium nitrate was spread for its mineralization in sustainable farming system; cultivation of peas afterwards in organic farming system led to low grain yield. This could be influenced by straw, incorporated into the soil with high levels of lignin, which is characterised by slow mineralization (Table 6).

More positive significant effect on grain yield was exerted by white mustard, cultivated in the soil with medium humus content, whose biomass together with straw was incorporated into the soil, compared with organic I farming system. Similar yield changes were observed in sustainable I farming system, where white mustard was cultivated in a mixture with buckwheat. The highest DM content in peas was observed in sustainable II farming system in the soils with low and medium humus content and was 43.0 and 46.0%, respectively, as compared to crops, cultivated in organic I farming system. Medium humus content in the soil in all farming systems had a significant (33.9%) positive effect on grain yield compared to that in the soil with low humus content. Accumulation of biogenic elements in pea grain yield and their removal from soil were significantly influenced by pre-crop fertilization and catch crops only in the soil with medium humus content, where higher yield was obtained.

On average for both humus backgrounds, significantly higher content of phosphorus and potassium was accumulated in pea grain yield where white mustard was cultivated as monocrop or in mixture with buckwheat, compared with other catch crops. The highest contents of biogenic elements were accumulated in the yield of peas, cultivated in sustainable II farming system; the difference, as compared to organic I farming system, was N – 44.6%, P – 45.7% and K – 40.6%.

Table 6. Nutrients accumulated in the pea yield

2006–2008

Soil humus content (factor A)	Farming system (factor B)				
	Organic I	Organic II	Sustainable I	Sustainable II	Mean A
DM t ha^{-1}					
Low	1.21	1.03	1.09	1.73	**1.27**
Medium	1.39	1.71	1.66	2.03	**1.70**
Mean B	**1.30**	**1.37**	**1.38**	**1.88**	
LSD_{05}: A – **0.179**, B – **0.253**, AB – **0.358**					
N kg ha^{-1}					
Low	40.46	32.25	33.77	56.13	**40.65**
Medium	45.17	49.83	52.55	67.69	**53.81**
Mean B	**42.82**	**41.04**	**43.16**	**61.91**	
LSD_{05}: A – **8.070**, B – **11.413**, AB – **16.141**					
P kg ha^{-1}					
Low	4.68	4.13	4.38	6.83	**5.01**
Medium	5.77	7.26	7.10	8.40	**7.13**
Mean B	**5.23**	**5.70**	**5.74**	**7.62**	
LSD_{05}: A – 0.**744**, B – **1.052**, AB – **1.488**					
K kg ha^{-1}					
Low	17.86	14.23	15.42	23.74	**17.81**
Medium	20.05	24.75	23.86	29.55	**24.55**
Mean B	**18.96**	**19.49**	**19.64**	**26.65**	
LSD_{05}: A – **2.176**, B – **3.078**, AB – **4.353**					

Changes of DM content in biomass of pea vines were similar to those in the yield of pea grain. On average 17.9% higher content of DM was accumulated in the soils with medium humus content, than in the soils with low humus content (Table 7).

Incorporation of white mustard as monocrop or in mixture with buckwheat, cultivated as catch crops, increased DM content in pea vines in more productive soil, with medium humus content, the differences were significant. The highest content of DM accumulated in sustainable II farming system, where mineral fertilizer $N_{10}P_{40}K_{60}$ was spread together with organic manure. The content of biogenic elements, accumulated in pea vines was rather low, nitrogen and potassium – a little higher (Table 7). On average, in the soils of both humus levels in sustainable II farming system, the content of accumulated nitrogen and potassium in pea vines was significantly 53.7 and 62.9% respectively higher as compared to organic I farming system; the differences of phosphorus were not significant.

Nutrient balance. Balance of nutrients incorporated and removed with the yield varied in different farming systems. In organic I farming system in both soils with different contents of humus and with the application of only aftermath of perennial grasses as green manure, not considering low removal with yields of winter wheat and peas, the NPK balance of main nutrients was negative; mainly there was a lack of nitrogen for crops (Table 8).

In organic II farming system, where green manure and FYM were incorporated in both humus content environments, NP balance in the soil was positive. Potassium balance in this system was significantly surplus because of incorporation of FYM containing high levels of potassium together with green manure affected its total content and it surpassed the nutrient content removed with crop production.

With the application of FYM in sustainable I farming system for winter wheat and N_{30} for straw mineralization in the soil low in humus content, PK balance was significantly positive, nitrogen balance was insignificantly positive and in the soil medium in humus content due to better crop growth conditions and due to 15.0 and 52.3% higher yield of DM of winter wheat and peas, respectively; as well as due to higher removal, the balance was negative. In sustainable II farming system in both humus environments winter wheat yield was the highest due to more readily available nutrients from mineral fertilizers and made up on average 4.18 t ha^{-1}; the content of biogenic elements removed with the yield determined negative nitrogen balance, while P and K balance was insignificantly positive.

Table 7. Nutrients accumulated in the biomass of pea vines
2006–2009

Soil humus content (factor A)	Farming system (factor B)				
	Organic I	Organic II	Sustainable I	Sustainable II	Mean A
			DM t ha^{-1}		
Low	0.57	0.67	0.57	0.88	**0.67**
Medium	0.62	0.86	0.83	0.86	**0.79**
Mean B	**0.60**	**0.77**	**0.70**	**0.87**	
	LSD$_{05}$: A – **0.088**, B – **0.125**, AB – **0.177**				
			N kg ha^{-1}		
Low	5.86	6.65	5.45	8.86	**6.71**
Medium	6.14	7.98	8.28	9.59	**8.00**
Mean B	**6.00**	**7.32**	**6.87**	**9.22**	
	LSD$_{05}$: A – **1.066**, B – **1.508**, AB – **2.133**				
			P kg ha^{-1}		
Low	0.77	0.80	0.69	1.04	**0.83**
Medium	0.89	1.43	1.39	1.06	**1.19**
Mean B	**0.83**	**1.12**	**1.04**	**1.05**	
	LSD$_{05}$: A – **0.407**, B – **0.576**, AB – **0.815**				
			K kg ha^{-1}		
Low	5.93	6.61	6.00	9.92	**7.12**
Medium	6.47	9.45	8.67	10.28	**8.72**
Mean B	**6.20**	**8.03**	**7.34**	**10.10**	
	LSD$_{05}$: A – **1.060**, B – **1.498**, AB – **2.119**				

Table 8. Balance of nutrients, incorporated in the soil and removed with the yield in the crop rotation of perennial grasses, winter wheat and peas
2006–2008

Soil humus content (factor A)	Farming system (factor B)				
	Organic I	Organic II	Sustainable I	Sustainable II	Mean A
			Nitrogen balance +/–		
Low	−93.95	53.76	32.03	−66.84	**−18.75**
Medium	−103.91	12.54	−8.45	−94.45	**48.57**
Mean B	**−98.93**	**33.15**	**11.79**	**−80.65**	
	LSD$_{05}$: A – **26.656**, B – **37.697**, AB – **53.312**				
			Phosphorus balance +/–		
Low	−16.45	44.13	38.59	76.56	**35.70**
Medium	−19.3	36.95	31.58	72.92	**30.54**
Mean B	**−17.88**	**40.54**	**35.09**	**74.74**	
	LSD$_{05}$: A – **11.976**, B – **16.937**, AB – **23.952**				
			Potassium balance +/–		
Low	−45.93	171.75	134.98	45.87	**76.67**
Medium	−56.34	142.36	104.2	37.44	**56.92**
Mean B	**−51.14**	**157.06**	**119.59**	**41.66**	
	LSD$_{05}$: A – **29.976**, B – **42.393**; AB – **59.952**				

Conclusions

1. In a *Gleyic Cambisol* low (1.98–2.01%) and medium (2.10–2.40%) in humus content, in the organic system with the application of green manure only and aftermath of perennial grasses for winter wheat, straw and catch crops' biomass for peas, the NPK balance was negative, despite the low removal with low crop yields.

2. Significantly highest contents of DM and biogenic elements in the biomass was accumulated by white mustard, cultivated as a catch crop in a

monocrop or in a mixture with buckwheat as compared to narrow-leafed lupine and oil radish mixture with a longer growing season.

3. In the organic agro-system, the application of the green manure and 40 t ha^{-1} of FYM for winter wheat and catch crops biomass for peas, the yield, due to specific properties of clay loam and slow mineralization did not increase significantly; in the soils, low and medium in humus content, NP balance was positive, while that of K was high surplus.

4. In the sustainable farming system, the application of 40 t ha^{-1} of FYM for winter wheat and N_{30} in the form of ammonium nitrate for straw mineralization, as well as catch crops' biomass for peas, NPK balance in the soil low in humus content, was positive and in the soil medium in humus content the nitrogen balance was negative, due to the better conditions for crop growth in the soil with a higher humus status and higher removal with wheat yield.

5. In the sustainable farming system, with the application of integrated fertilization system, incorporation of aftermath of perennial grasses as well as $N_{60}P_{60}K_{60}$ for winter wheat and $N_{10}P_{40}K_{60}$ for peas, the wheat yield and accumulated content of biogenic elements in it for both humus environments were the highest; however the nitrogen balance was positive, while that of PK was insignificantly positive.

6. Unlike green manure, FYM incorporated for winter wheat in the organic agrosystem secured a positive NPK balance. However, due to low mineralization in a clay loam Cambisol, it increased the yield of the second rotation member (peas) more effectively, than that of the first rotation member (winter wheat).

Received 19 03 2010
Accepted 10 05 2010

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ISSN 1392-3196
Žemdirbystė-Agriculture, t. 97, Nr. 2 (2010), p. 41–52
UDK 631.445.15:631.51.01:631.582:631.51.01:631.83./85

Įvairių organinių trąšų ir tarpinių pasėlių poveikis agrosistemų biogeninių elementų balansui

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Santrauka

Lauko bandymai atlikti 2005–2009 m. Lietuvos žemdirbystės instituto Joniškėlio bandymų stotyje sunkaus priemolio giliau karbonatingame giliau glėjiškame rudžemyje (Rdg4-k2), *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*). Tyrimų tikslas – mažo (1,98–2,01 %) ir vidutinio (2,10–2,40 %) humusingumo dirvožemyje ištirti ekologinės bei tausojamosios žemdirbystės sistemų poveikį biogeninių elementų balansui, trąšai naudojant mėšlą, žieminių kviečių šiaudus, žirnių virkščias ir įvairių tarpinių pasėlių biomasę. Sėjomaina išskleista laike ir erdvėje – daugiametės žolės (raudonasis dobilas (*Trifolium pratense* L.) bei tikrasis eraičinas (*Festuca pratensis* Huds.)), žieminis kvietys (*Triticum aestivum* L.), sėjamasis žirnis (*Pisum sativum* L.), miežis (*Hordeum vulgare* L.) su įsėliu. Tirtos priemonės įvertintos javų ir žolių grandyje: daugiametės žolės → žieminiai kviečiai + tarpiniai pasėliai → žirniai. Tausojamojoje žemdirbystės sistemoje šiaudų mineralizacijai skatinti panaudotos amonio nitrato formos mineralinės azoto trąšos (N_{30}).
Nustatyta, kad tarpinių pasėlių biomasėje daugiausia sausųjų medžiagų ir didžiausias joje sukauptų biogeninių elementų kiekis buvo baltąsias garstyčias auginant kartu su sėjamaisiais grikiais arba jų monopasėlį. Ekologinėje žemdirbystės sistemoje, esant abiem humusingumo fonams ir tręšimui panaudojus tik žaliąją trąšą, pagrindinių mitybos elementų NPK balansas buvo neigiamas. Tręšimui panaudojus žaliąją trąšą bei mėšlą ir esant mažam netekimui su derliumi, dirvožemyje NP balansas buvo teigiamas, o K – ryškiai perteklinis. Tausojamoje žemdirbystės sistemoje, žieminius kviečius patręšus mėšlu ir šiaudų mineralizacijai – N_{30}, mažo humusingumo dirvožemyje NPK balansas buvo teigiamas, o vidutinio humusingumo dirvožemyje dėl augalų aktyvesnio augimo ir didesnio netekimo su kviečių derliumi tik azoto balansas buvo neigiamas. Kitaip nei žalioji trąša, ekologinėje žemdirbystės sistemoje žieminiams kviečiams įterptas mėšlas užtikrino teigiamą NPK balansą, tačiau dėl lėtos mineralizacijos sunkaus priemolio rudžemiuose efektyviau padidino kito sėjomainos nario žirnių, o ne žieminių kviečių derlių.

Reikšminiai žodžiai: glėjiškas rudžemis, ekologinė ir tausojamoji žemdirbystė, mėšlas, tarpiniai augalai, žalioji trąša, NPK balansas.