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Effect of horn shaving and horn core powder fertilizers on the dynamics of mineral nitrogen in the soil of organic farm

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Research on the effect of horn shavings and horn core powder fertilizers, produced from cattle horn waste, on mineral nitrogen and its forms in soil layers of 0–30 and 30–60 cm was carried out in 2008–2010 on the farm of organic production in the Centre of Agroecology at Aleksandras Stulginskis University in Kazliškės village, Kaunas region. Organic winter wheat was grown for this research. Before sowing and in the stage of tillering organic winter wheat was treated with fertilizers of horn shavings and horn core powder, which resolved in the period of autumn–spring and spring–summer. During the period of winter wheat tillering (BBCH 21–23) and at the end of vegetation in the period of complete maturity (BBCH 89) soil layer of 0–30 cm contained an increased amount of nitrogenous compounds. Intensity of degradation was different in different years as it depended on meteorological conditions during the period of winter wheat vegetation. In the event of warm and humid weather more compounds of mineral nitrogen were formed and this increase due to fertilization was essential. Leaching of nitrogen compounds into the deeper layer of 30–60 cm was different in different years and depended on the meteorological conditions during the vegetation period of winter wheat. In the event of higher weather temperature and more humid air during vegetation period of winter wheat horn shavings and horn core powder significantly increased amount of nitrogen compounds in this soil layer. Additional treatment of winter wheat in tillering stage (BBCH 21–23) with different rates of horn shavings increased the amount of mineral nitrogen compounds in soil, though this amount was different in different years. In 2008–2009 strong correlation between horn shavings rates and the amount of nitrate nitrogen in 0–30 cm layer of soil was found, while correlation with the amount of ammonium and mineral nitrogen was found to be very strong. Meanwhile in 2009–2010 no correlation between nitrate nitrogen and fertilizer rates was determined, while correlation with amounts of ammonium and mineral nitrogen was weak. In 2008–2009 in the deeper layer of 30–60 cm correlation between horn shaving rates and nitrate nitrogen was found to be weak, while correlation with amounts of ammonium and mineral nitrogen was found to be moderate. In 2009–2010 correlation between fertilizer rates and forms of mineral nitrogen was found to be weak.

Key words: organic farming, horn shavings, horn core powder, soil, mineral nitrogen, winter wheat

INTRODUCTION

European Commission has established that only 68% of bird, 62% of pig, 54% of cattle and 52% of sheep or goat mass is used in food production. Each year, European Union (EU) produces more than 15 million tons of animal by-products. Animal by-products are used to produce gelatin, animal feed, cosmetics, medicines and diagnostic medical devices. As subproducts of animal origin are rich in proteins, after certain processing they could be used as nitrogen source in the process of growing different plants (Swisher, 2006; Gaskell, Smith, 2007; Mondini et al., 2008).

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Commission Regulation (EC) No. 889/2008 of 5 September 2008, which determines the detailed rules for implementation of Council Regulation (EC) No. 834/2007 on organic production and labeling and control of organic produce, contains Annex No. 1 “Fertilizers and soil conditioners mentioned in Part 1 of Article 3” which implies that organic production could use blood meal, hoof and horn shavings, meat powder, bone meal, bone meal without gelatin, etc. as soil conditioners (Commission Regulation (EC) No. 889/2008, 2008). Presently there are fertilizers, certified in the system of organic production, based on processed subproducts of animal origin. Such fertilizers and soil conditioners are applied to agricultural plants especially in worked-out land with small content of organic materials (Van-Camp et al., 2004; Pekarskas, 2008). Research has shown that fertilizers of animal origin resulted in increased amounts of nitrogen in soil superior to those produced by fertilizers of plant origin; however, larger rates of these fertilizers significantly increased the amount of NH_4^+ in soil which resulted in temporary decrease of biomass of microorganisms (Cayuela et al., 2009).

Bone tissue in soil decomposes significantly more slowly than other animal subproducts suitable for application as fertilizers. Fertilizers and soil conditioners made from animal bone tissues could be used as slow-release nitrogen fertilizers. In slow-release nitrogen fertilizers nutrients are gradually released therefore decreasing the extent of leaching and improving efficiency of nitrogen usage. It is rather complicated to research biodegradability of organic materials and release of mineral nitrogen into soil because the amount of mineral nitrogen changes due to other factors as well. Accumulation of mineral nitrogen and its dynamics in soil depends on soil texture, humus, conditions of plant vegetation period, type of plant grown, agricultural technologies, mineral and organic fertilizers used, their rates and method of application (Mary et al., 1998; Mosier et al., 1998; Antil et al., 2005; Loges et al., 2006; Dambreville et al., 2008; Miller et al., 2008).

There is a continuous metabolism going on in soil and due to biochemical processes taking place in soil residues of animal and plant origin are decomposed to simpler organic derivatives and mineral compounds which in their turn repeatedly get into metabolic cycle of nutrients (Kandeler, Gerfried, 1993; Grigaliūnienė et al., 2003). To provide themselves with energy and elements of nutrition, microorganisms require a certain ratio of materials for building their tissue. When amounts of organic and mineral materials change in soil, an increase or decrease in numbers of microorganisms as well as succession of their breeds are observed (Cavigelli et al., 1998; Brady, Weil, 1999; Bending et al., 2002; Bengtson et al., 2003). Microorganisms of many different physiological groups take part in decomposition of organic materials. In the beginning stages of degrading organic residues spores non-forming bacteria take part, later spore-forming bacteria join in and finally micromycetes (Lukošiūnienė et al., 1997; Montgomery, 1998).

The amount of mineral nitrogen in soil changes noticeably throughout the year, depending on the qualities of the soil, agrotechnology used, fertilization and meteorological conditions. In spring, when temperature rises, more intensive mineralization and nitrification take place as a result of which a sharp increase in the amount of non-organic nitrogen is observed. If this increased amount of nitrogen corresponds in time to the needs of agricultural plants, they manage to appropriate it. The process of mineralization becomes more active as the soil gets warmer and reaches 10 °C and it is at its most intensive pace during the summer with the greatest amounts of nitrogen produced at soil temperature of 25–35 °C (Nicolardot et al., 1994).

In 2001–2004 at the Vėžaičiai branch of the Lithuanian Institute of Agriculture experiments on prevalence of microorganisms participating in transformation of nitrogen in soil were carried out. The possible nitrate depression was determined in June while valuating the succession of microorganisms transforming nitrogen compounds. The activity of microorganisms was high and the content of nitrogen was low. Later on, after 10–15 weeks of plant vegetation (in July–September), the content of nitrogen in the soil increased again. At the end of the period plant vegetation stops. Moreover, a decrease of microorganisms was determined. Therefore, the possibility of nitrate pollution occurs 20 weeks following the beginning of plant vegetation (in September and October) (Piaulokaitė-Motuzienė, Končius, 2006).

It is very important to predict the speed of mineralization in soil when choosing rates of fertilization in the period of vegetation for economic and environmental purposes. High levels of fertilisation reduce the possibilities to appropriate nitrogen and increase leaching of nitrates (Benbi, Richter 2002; Jagadamma et al., 2007; Mengel et al., 2006).

There are two main factors determining transformations of nitrogenous compounds in soil. The first factor is the amount of potentially mineralizable nitrogenous compounds. It depends on the processes of mineralization–fixation, which in their turn are connected to C:N ratio in the organic part of soil. A certain kind of organic nitrogen (waste, plant residues, soil humus) is also a factor affecting the amount of potentially mineralizable nitrogen in soil. The second factor is the speed of mineralization. This factor depends on characteristics of soil, environmental conditions and the quality of organic fertilizers in soil. Humidity of soil, amount of oxygen, pH and temperature are some of the environmental conditions affecting the speed of mineralization (Schimel, Bennett, 2004).

Fertilizers, especially nitrogen ones, are one of the means in solving problems of supplying inhabitants with food. However, ineffective use of nitrogen fertilizers may cause nitrates leach into ground water and pollute rivers as well as other water clusters (Jensen, Hauggaard-Nielsen, 2003; Dobermann, Cassman, 2004; Eisman et al., 2005). Efficiency of nitrogenous fertilizers differs greatly throughout the years of research and is greatly dependent on the humidity and warmth in the spring and summer period. Nitrogenous fertilizers were the most efficient in wet years, while in the years of moderate humidity their efficiency declined by 30–6% and in dry years by 35–62% (Janušauskaitė, Šidlauskas, 2004).

It has been established that hydrothermal conditions of period of vegetation are closely connected to nutrients appropriated by plants which inevitably leads to changes in chemical composition of plants (Alaru et al., 2003).

Research carried out in south-eastern Lithuania demonstrated that decomposition speed of organic materials and migration of mineralized chemical elements in soil depend primarily on hydrothermal regime. Approx. 36.9% of annual filtration were measured at spring time while in autumn and winter soil water filtration was lower – 22.8% and 26.3%, respectively. In summer time most of soil water evaporated or was assimilated by plants (Tripolskaja, Šidlauskas, 2010).

Loss of biogenic elements due to leaching is connected not only with agrarian use of soil, but also with climatic factors, namely amount of precipitation and air temperature. Annually Lithuanian territory on average gets 675 mm of precipitation with average air temperature of 6.2 °C, which preconditions filtration of atmospheric precipitation and certain leaching of chemical elements form arable layer of soil (Galvonaitė et al., 2007).

Research carried out at the Lithuanian Institute of Agriculture only found reliable correlation between meteorological conditions (hydrothermal regime) in vegetation period and nitrate concentration in water when growing sugar beat as well as annual and perennial grasses, while correlation with amount of ammonium in water was found when growing winter wheat, annual grasses and barley. More nitrates leached when plants of annual sowing were grown. In case of perennial plants lesser amounts of nitrates leached (Adomaitis et al., 2004).

The article is focused on mineral nitrogen dynamics influenced by horn shavings and horn core powder. Such cattle waste can be used as organic fertilizer increasing the amount of mineral nitrogen in soil. Moreover, this would solve cattle horn waste management problem.

The aim of this study was to investigate the effect of cattle horn fertilizers, such as horn shavings and horn core powder, on mineral nitrogen content in different layers of soil at different stages of ecologically grown winter wheat growth.

MATERIALS AND METHODS

Research on the effect of organic fertilizers made from biodegradable waste of cattle horns, horn shavings and horn core powder on nitrogen dynamics in soil was carried out in 2008–2010 in the organic farm of Agroecology Centre at Aleksandras Stulginskis University, Kazliškės village, Kaunas region (54°52’ N, 23°51’ E). In the area of research soils were characterized as silty clay loam (dp) *(Endohypogleyi-Eutric Planosols – PLe-gln-w)*.

Powder of horn core and horn shavings are made from the waste of cattle horns, accumulated in the process of meat production in Lithuania. Fertilizers are rich in organic matter and microelements (Table 1).

Table 1. **Properties of horn shavings and horn core powder fertilizers**

Fertilizer	Organic materials %	Total nitrogen %	Phosphorus %	Potassium %	Calcium %	Magnesium %
Horn shavings (RD)	97	5.82	0.047	0.03	0.125	0.011
Horn core powder (RGM)	39.72	6.43	9.41	0.08	21.8	0.443

In 2008–2009 and 2009–2010 the soil of the experimental area was neutral to light alkaline, moderately phosphorus rich, moderately potassium rich. Considerably more humus and total nitrogen was found in 2009–2010 (Table 2).

Organically grown winter wheat was treated with horn shavings and horn core powder prior to sowing by cultivating it into the ground. Fertilizers were applied at a nitrogen rate of 30 kg ha^{-1} and in spring at the stage of tillering (BBCH 21–23) at a nitrogen rate of 50 kg ha^{-1}. In spring the fertilizers were spread on organically grown winter wheat, but not inserted into soil. Rates of horn shavings were spread in spring on growing winter wheat only.

During the horn fertilizer test, total (bruto) experimental site area was 40 m^2 (4 × 10 m), neto area – 22 m^2 (2.2 × 10 × 3 m). In 2008–2009 during the test of horn shaving rates, bruto area was 30 m^2 (3 × 10), neto area – 17.6 m^2 (2.2 × 8), in 2009–2010 21 m^2 (3 × 7) and 11.0 m^2 (2.2 × 5), respectively. Fertilizer rates tested were N_{14}, N_{28} and N_{42}.

The test was carried out in four replications. Winter wheat variety '*Širvinta* 1' was sown with seed rate of 250 kg ha^{-1} of viable seeds. Winter wheat was grown after mixture of peas and oats for seed. No means of plant protection were used during the period of the test, plants were not treated with potassium and phosphorus fertilizers.

Soil samples to test agrochemical properties of soil (pH, phosphorus, potassium, humus and total nitrogen) were taken from the test area with a soil drill from the depth of 0–20 cm in 8–12 different test places and a composite soil sample of 500 g was created. In total, for analysis three soil samples were taken from the test area. Soil samples were taken before sowing winter wheat. Agrochemical properties were determined in the Lithuanian Centre of Agrarian and Forestry Sciences Branch Laboratory of Agrochemical Research. Soil pH_{KCl} was determined by potentiometric method (ISO 10390), amount of active phosphorus and potassium by A-L method, humus – by the method of dry burning (ISO 10694) (amount of organic carbon X 1.724), amount of total nitrogen – by Kjeldahl method.

According to the test design, in the research site of horn shavings and horn core powder (test on forms of horn fertilizers) soil samples to determine amount of nitrogen in soil were taken with a soil drill from the depth of 0–30 and 30–60 cm in 5–8 different places of neto area in four replications. Soil samples were taken in autumn before sowing, at the stage of winter wheat tillering (BBCH 21–23) and complete maturity (BBCH 89). Amount of mineral nitrogen ($N–NO_3$, $N–NH_4$ and N_{min}) was determined in the Laboratory of Environmental Sciences at Aleksandras Stulginskis University. During the research on the rates of horn shavings, the amount of mineral nitrogen was determined twice: at the tillering stage of winter wheat and at the stage of complete maturity. Tests were carried out in the Laboratory of Institute of Environment at Aleksandras Stulginskis University. The amount of mineral nitrogen was determined by colorimetric method.

The data obtained was statistically evaluated by the method of correlation and variance analysis using ANOVA and STAT_ENG.

Table 2. **Agrochemical properties of experimental test site soil**

Year	pH	Phosphorus mg kg^{-1}	Potassium Mg kg^{-1}	Humus %	Total nitrogen %
2008–2009	7.2–7.4	118–155	108–124	1.84–2.28	0.109–0.122
2009–2010	7.4	134–147	100–140	3.17–3.34	0.184–0.213

RESULTS AND DISCUSSION

Low positive temperatures that usually prevail in late autumn, winter and spring do not inhibit activity of microorganisms; however affect their abundance and mobility. Soil's organic materials are further decomposed and nitrogenous compounds liberate, in spring they are more abundant than in autumn. When the temperature rises, microorganism activity becomes more significant, organic materials are decomposed more intensively and more mobile nitrogenous compounds liberate (Marion, Black, 1987; Tripolskaja et al., 2002). The amount of precipitation and temperature has a great effect on liberation of mineral nitrogen from organic compounds. In spring when the weather becomes warmer this process intensifies. Periodical processes of warming–cooling taking place in winter and spring could also affect the amount of nitrogen as they enhance leaching of nitrogen (Sierra, 1997; Dalias et al., 2002; Sierra, 2002; Wang et al., 2006; Germane et al., 2008; Ptil et al., 2010).

In different years of research different meteorological conditions prevailed during vegetation period of winter wheat. Those meteorological conditions had an essential effect on degradation of cattle horn waste fertilizers, horn core powder and horn shavings as well as nitrogenous compounds liberating in soil. In 2008 cattle horn fertilizers were applied on September 18. The mean annual precipitation was 176.3 mm in 2008. It is less than annual average, moreover, warm weather compared to annual temperatures prevailed. In 2009 fertilizers were applied on September 10. Comparing weather conditions in autumn of 2008, there was 73.7 mm more precipitation, but the weather was cooler by 0.6 °C. Meteorological conditions in the period of winter–spring played a decisive role for the amount of mineral nitrogen in soil. In January–March 2009, before soil samples were taken in the stage of winter wheat tillering, there was 44.0 mm more precipitation than in the same period in 2010 and the weather was significantly warmer. Essential effect was made by extremely cold weather in January and February 2010. This slowed down mineralization of nitrogen fertilizers in soil. The amount of mineral nitrogen in soil in spring and summer months was also affected by the amount of precipitation and air temperature. In the stages of winter wheat tillering and complete maturity in 2010 there was 109.5 mm more precipitation and the average daily temperature was by 1.42 °C higher than that at the same time in 2009. In 2010 meteorological conditions were far more favorable for horn fertilizer decomposition than in 2009 (Figs. 1 and 2).

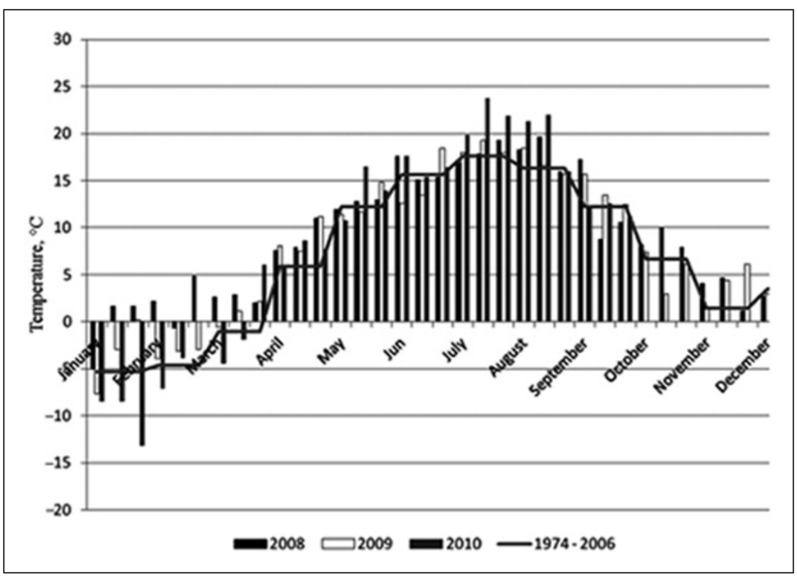

Fig. 1. Average temperature during the period of winter wheat vegetation. Data from Kaunas meteorological station

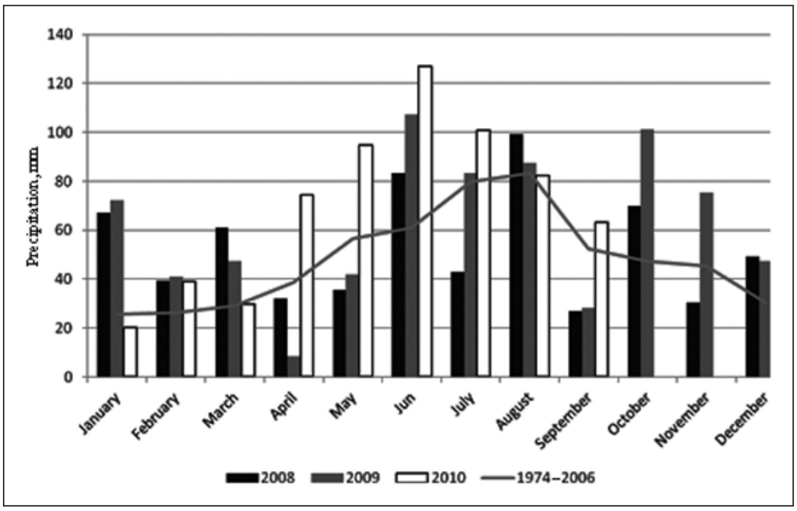

Fig. 2. Amount of precipitation during the period of winter wheat vegetation. Data from Kaunas meteorological station

A reliable correlation with 95% confidence interval has been established between mineral nitrogen in soil and meteorological conditions of twenty days consisting of air temperature and amount of precipitation. Mineral nitrogen is dependent on air temperature with correlation resilience at $r = 0.41–0.45$; $n = 60$, while it is dependent on precipitation with correlation coefficient resilience at $r = 0.66–0.71$; $n = 60$. Calculating dependence of amount of mineral nitrogen on air temperature according to equation of polynomial regression, the relation has been found to be moderate $r = 0.41–0.45$; $n = 60$ (Mažvila et al., 2006).

Horn shavings and horn core powder inserted into the soil in autumn were decomposed due to soil humidity and activity of microorganisms, resulting in the increase of the amount of mineral nitrogenous compounds. Increase was not significant as fertilizers of cattle origin are long-term fertilizers and under the effect of different factors they are decomposed slowly and nitrogenous compounds are liberated by time. Fertilizers produced from cattle horn waste decompose much more slowly than other organic fertilizers (manure, composts) and this is why in spring at the stage of winter wheat tillering no significant increase in the amount of nitrate nitrogen was observed.

In pre-sowing period treating organically grown winter wheat with organic fertilizers made from biodegradable waste of cattle horn, horn shavings and horn core powder evoked an increase of nitrate nitrogen in soil layers of 0–30 and 30–60 cm in early spring at the stage of winter wheat tillering (BBCH 21–23) compared to the amounts in autumn before sowing winter wheat (Fig. 3).

0–30 cm layers of unfertilised soil in autumn of 2008 contained 6.88 mg kg^{-1} of nitrate nitrogen and in 2009 9.26 mg kg^{-1} of nitrate nitrogen. In spring during the period of tillering on winter wheat nitrate nitrogen in soil increased by 1.31 and 1.37 mg kg^{-1} respectively. Having been inserted into soil before sowing winter wheat, horn shavings and horn core powder degraded during autumn, winter and spring therefore increasing nitrogen supply in soil. Under the effect of horn shavings, nitrate nitrogen in soil increased by 1.62 and 2.39 mg kg^{-1} while as a result of treatment with horn core powder, there was a 1.73 and 2.83 mg kg^{-1} increase in nitrate nitrogen. As a result of treatment with cattle horn fertilizers, during the period of tillering nitrate nitrogen in soil increased by 0.64–0.83 mg kg^{-1} and 0.14–1.14 mg kg^{-1} or from 1% to 11% compared with unfertilised plants. This increase in nitrate nitrogen was statistically insignificant ($p < 0.05$). There was noticed a trend that treatment with such fertilizers results in increase of nitrate nitrogen in 0–30 layer of soil. The amount of nitrate nitrogen increased more by treating soil with horn core powder than horn shavings (Fig. 3).

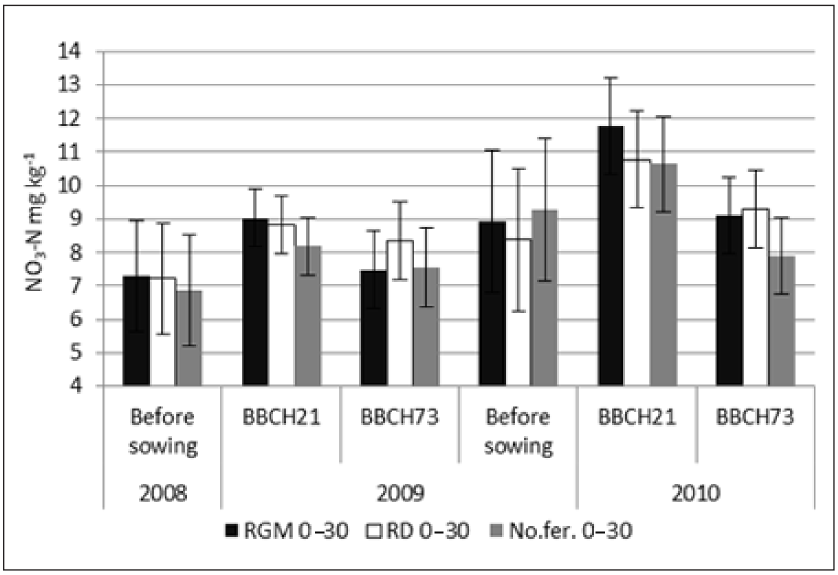

Fig. 3. The amounts of nitric nitrogen (NO_3–N) in soil top layer (0–30 cm) in 2008–2010. Error bars are the least significant difference (LSD_{05}). RGM – horn core powder, RD – horn shavings (horn meal), No. fer. – no fertilization. The farm of organic production in the Centre of Agroecology at ASU, 2008–2010

At the end of vegetation of winter wheat, at the stage of complete maturity (BBCH 73) there was less nitrate nitrogen in 0–30 layer of soil compared to the period of tillering. Having treated soil with horn shavings resulted in decrease of nitrate nitrogen (0.48 mg kg^{-1} in 2008–2009 and 1.48 mg kg^{-1} in 2009–2010). Application of horn core powder resulted in 1.54 and 2.66 mg kg^{-1} decrease respectively and unfertilised soil had a decrease in nitrate nitrogen of 0.65–2.73 mg kg^{-1}. Comparing unfertilised winter wheat with that treated with organic fertilizers, at the end of vegetation period of 2008–2009 in 0–30 cm layer no differences in the amount of nitrate nitrogen were observed, while in 2009–2010 treatment with horn shavings and horn core powder resulted in essential increase ($p < 0.05$) in nitrate nitrogen in soil (Fig. 3).

Winter wheat use great amounts of nitrogen in their process of growth. Consequently, the decrease in the amount of soil can be observed at the end of the vegetation period. Treatment with horn shavings and horn core powder resulted in the increased yield of winter wheat and this increase had effect due to plant capability to use nutrients from fertilizers applied (Žibutis et al., 2011). In summer and spring of 2009–2010 meteorological conditions were much more favorable for decomposition of horn fertilizers than those in 2008–2009, as this period was slightly warmer and more humid. This creates more favorable conditions for microorganism activity and solution of fertilizers themselves.

Less amount of nitrate nitrogen was found in the layer of 30–60 cm compared with 0–30 cm layer. The application of horn shavings increased the amount of nitrate nitrogen by 1.15–2.55 mg kg^{-1} in 30–60 cm soil layer, the treatment with horn core powder resulted in 1.23–2.46 mg kg^{-1} increase, and the unfertilised soil had an increase of 0.36–2.36 mg kg^{-1} (Fig. 4). Fertilizers compared to unfertilised winter wheat did not have essential effect ($p < 0.05$) on the amount of nitrate nitrogen in the soil layer of 30–60 cm during the period of winter wheat tillering.

Another research of horn fertilizers is in progress at the Centre of Agroecology in Aleksandras Stulginskis University. The results show that cattle horn fertilizers decomposed slowly and liberated nitrate nitrogen was appropriated by growing winter wheat and could not intensively leach to deeper mineral soil layers.

Comparing the amount of nitrate nitrogen in 30–60 cm soil layer at the period of winter wheat tillering and at the end of vegetation period, it was determined that in 2008–2009 its values decreased, while in 2009–2010 the treatment with horn shavings resulted in the increase of nitrate nitrogen in this soil layer by 0.92–1.07 mg kg^{-1} (Fig. 4). Comparing unfertilized winter wheat with those treated with organic fertilizers at the end of vegetation period in 2009 no essential differences in the amount of nitrate nitrogen were observed. While in 2010 the treatment with horn shavings and horn core powder resulted in essential increase of nitrate nitrogen ($p < 0.05$), however, if compared between themselves, the two kinds of organic fertilizers produced no essential differences. Application of horn shavings resulted in a greater increase of nitrate nitrogen than the treatment with horn core powder (Fig. 4).

Due to damp and warm weather in spring–summer 2010, horn waste fertilizers decomposed more effectively and as a result greater amounts of nitrate nitrogen accumulated in 0–30 cm soil layer. This amount could not be fully appropriated by winter wheat and resulted in nitrate nitrogen leaching into deeper soil layer of 30–60 cm. For this reason the amount of nitrate nitrogen in this layer increased. In 2009 during vegetation period there was less precipitation and later leaching of nitrate nitrogen decreased significantly. It has been determined that leaching of nitrate nitrogen from arable layer into deeper layers of soil is different in different years and usually nitrogen is leached in the form of nitrates (Errebhi et al., 1998; Owens et al., 2000).

Forms of ammonium nitrogen in soil were less abundant than those of nitrate. Comparing the amount of ammonium nitrogen in soil layer of 0–30 cm in autumn and in the stage of winter wheat tillering it has been determined that horn shavings increased by 0.26 and 0.96 mg kg^{-1} (Fig. 5). Application of horn core powder resulted in the increase of ammonium nitrogen by 0.39 and 0.52 mg kg^{-1}, while unfertilised soil had an increase of 0.10 and 0.44 mg kg^{-1}. At BBCH 21–23 changes of ammonium nitrogen in 0–30 cm soil layer were different in different years. In 2008–2009 after treating soil with horn shavings there was much more ammonium nitrogen ($p < 0.05$) found than in an unfertilised site and the site treated with horn core powder. In 2009–2010 during vegetation period no essential difference in the amount of ammonium nitrogen content was found. It can be explained by differences in meteorological conditions. Comparing the amount of soil ammonium nitrogen in the stage of winter wheat tillering and at the end of vegetation period it can be seen that ammonium nitrogen in 0–30 cm soil layer decreased. In 2009–2010 during vegetation period after treating winter wheat with horn shavings there was higher ammonium nitrogen content than in unfertilised site while in 2008–2009 no significant differences in the amount of ammonium nitrogen were found (Fig. 5).

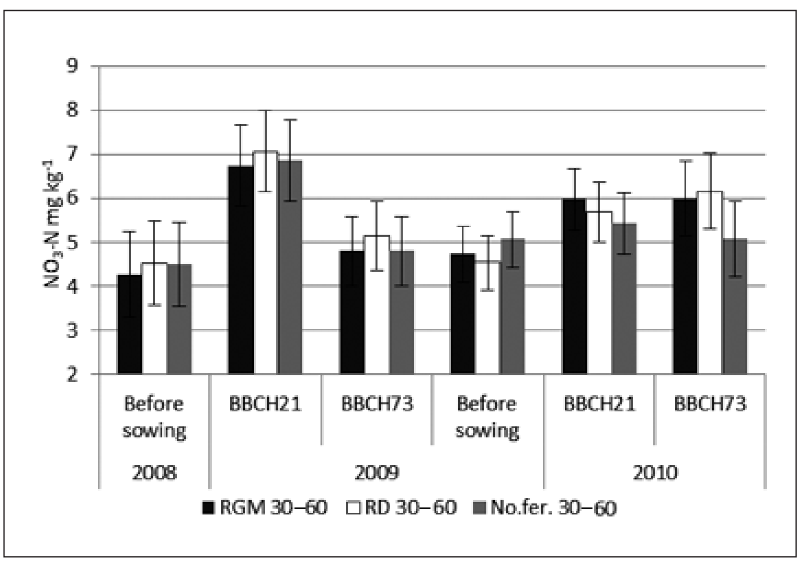

Fig. 4. The amounts of nitric nitrogen (NO_3–N) in a deeper soil layer (30–60 cm) in 2008–2010. Error bars are the least significant difference (LSD_{05}). RGM – horn core powder, RD – horn shavings (horn meal), No. fer. – no fertilization

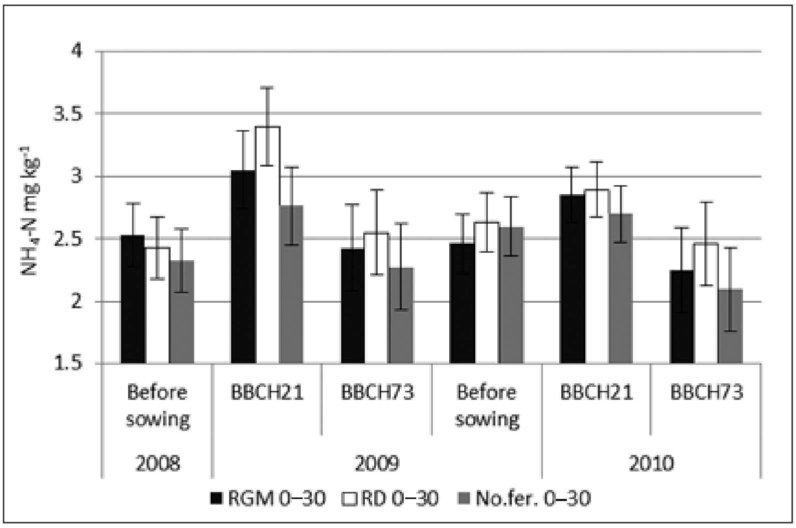

Fig. 5. The amounts of ammoniacal nitrogen (NH_4–N) in soil top layer (0–30 cm) in 2008–2010. Error bars are the least significant difference (LSD_{05}). RGM – horn core powder, RD – horn shavings (horn meal), No. fer. – no fertilization

Ammonium nitrogen content in 30–60 cm soil layer was lower than in 0–30 cm. Comparing the amount of ammonium nitrogen in tillering stage (BBCH 21–23) with its amount in autumn it was determined that the treatment with horn shavings resulted in 0.46–1.72 mg kg^{-1} increase in N–NH_4 content, the treatment with horn core powder increased it by 0.42–1.38 mg kg^{-1}, while unfertilised site demonstrated merely 0.16–1.36 mg kg^{-1} increase (Fig. 6). In 2008–2009 application of horn shavings resulted in a significantly greater amount of ammonium nitrogen in soil ($p < 0.05$) than in the unfertilised site as well as in the site fertilized with horn core shavings. Comparing the amount of ammonium nitrogen in soil in tillering stage with its amount at the end of vegetation period it can be seen that the amount of ammonium nitrogen in 30–60 cm layer of soil decreased. In 2009–2010 during vegetation period horn core shavings resulted in a significant increase in the amount of ammonium nitrogen than it was found in unfertilized site and in 2008–2009 no significant differences in the amount of ammonium nitrogen were found (Fig. 6).

The treating organically grown winter wheat with organic fertilizers made from biodegradable waste resulted in the increase of mineral nitrogen in soil layer of 0–30 cm (Fig. 7). In spring in tillering stage (BBCH 21–23) there was 1.75 and 1.47 mg kg^{-1} of mineral nitrogen in unfertilised soil. Soil with horn shavings had 2.58 and 2.66 mg kg^{-1} more nitrogen than before sowing, while application of horn core powder resulted in mineral nitrogen increase of 2.26 and 3.22 mg kg^{-1}. In different years under the effect of soil mineral nitrogen in winter wheat tillering stage there was an increase of 1.12–1.27 mg kg^{-1} or 10.23–11.60 per cent and 0.34–1.29 mg kg^{-1} or 2.55–9.68 per cent. In 2008–2009 in winter wheat tillering stage (BBCH 21–23) application of horn shavings and horn core powder resulted in an essential increase of the amount of mineral nitrogen in 0–30 cm soil layer compared with unfertilised winter wheat. In 2009–2010 differences in the amount of mineral nitrogen were statistically insignificant. In the stage of total maturity (BBCH 89) compared with tillering stage the amounts of mineral nitrogen in 0–30 cm soil layer decreased. Application of horn shavings resulted in mineral nitrogen decrease of 1.32–1.92 mg kg^{-1}, application of horn core powder resulted in decrease of 2.17–3.26 mg kg^{-1}, while unfertilised sites had a decrease of 1.14–3.3 mg kg^{-1}. Comparing unfertilised winter wheat at the end of vegetation in 0–30 cm soil layer in 2008–2009 no significant differences in the amount of mineral nitrogen were observed, while in 2009–2010 the application of horn shavings resulted in an essentially greater

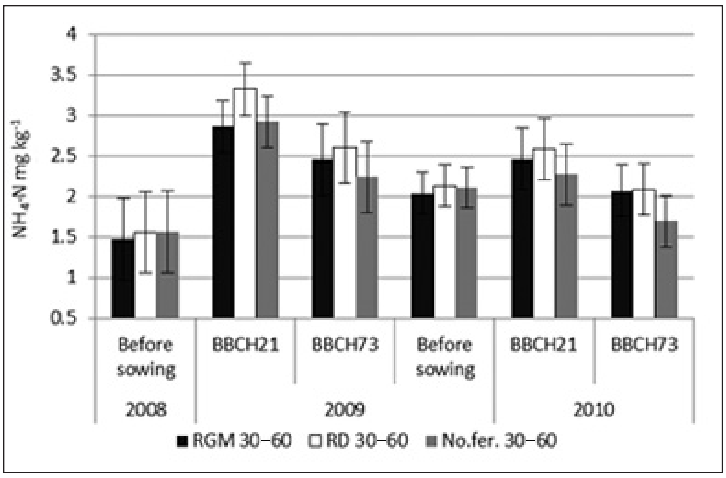

Fig. 6. The amounts of ammoniacal nitrogen (NH_4–N) in deeper soil layer (30–60 cm) in 2008–2010. Error bars are the least significant difference (LSD_{05}). RGM – horn core powder, RD – horn shavings (horn meal), No. fer. – no fertilization

increase ($p < 0.05$), comparing to unfertilised soil. Comparing fertilizers between themselves no significant differences were found. Application of horn core shavings resulted in a greater increase than application of horn core powder (Fig. 7).

Comparing the amount of mineral nitrogen in tillering stage (BBCH 21) with its amount in 30–60 layer of soil found in autumn it was determined that application of horn shavings increased the amount of mineral nitrogen by 1.61–4.31 mg kg^{-1}, the application of horn core powder resulted in an increase of 1.65–3.85 mg kg^{-1}, while unfertilised sites had an increase of 0.52–3.72 mg kg^{-1} (Fig. 8). Fertilizers when compared with unfertilised winter wheat did not have any essential effect ($p < 0.05$) on the amount of mineral nitrogen in 30–60 cm layer in the stage of winter wheat tillering. Comparing the amount of mineral nitrogen in soil in tillering stage with its amount at the end of plant vegetation it was determined that its amount in 30–60 cm soil layer decreased. Application on horn shavings resulted in a decrease of 0.04–2.65 mg kg^{-1}, the application of horn core shavings decreased the amount of mineral nitrogen by 0.36–2.35 mg kg^{-1}, while unfertilised soil had a decrease of 0.93–2.74 mg kg^{-1}. In 2009–2010 during vegetation period after application of horn shavings and horn core powder to winter wheat there was significantly more mineral nitrogen ($p < 0.05$) found in soil at the end of vegetation than in the soil of unfertilised winter wheat, while in 2008–2009 no significant differences in the amount of mineral nitrogen were found. Application of horn shavings resulted in greater amounts of mineral nitrogen in soil than application of horn core powder (Fig. 8).

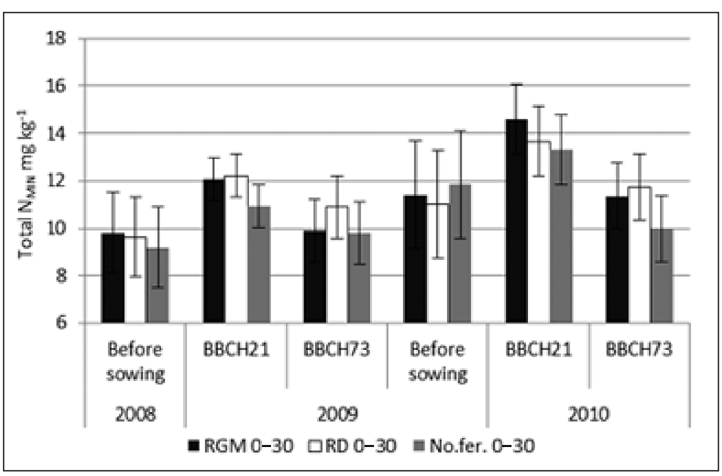

Fig. 7. The amounts of mineral nitrogen (N_{MIN}.) in soil top layer (0–30 cm) in 2008–2010. Error bars are the least significant difference (LSD_{05}). RGM – horn core powder, RD – horn shavings (horn meal), No. fer. – no fertilization

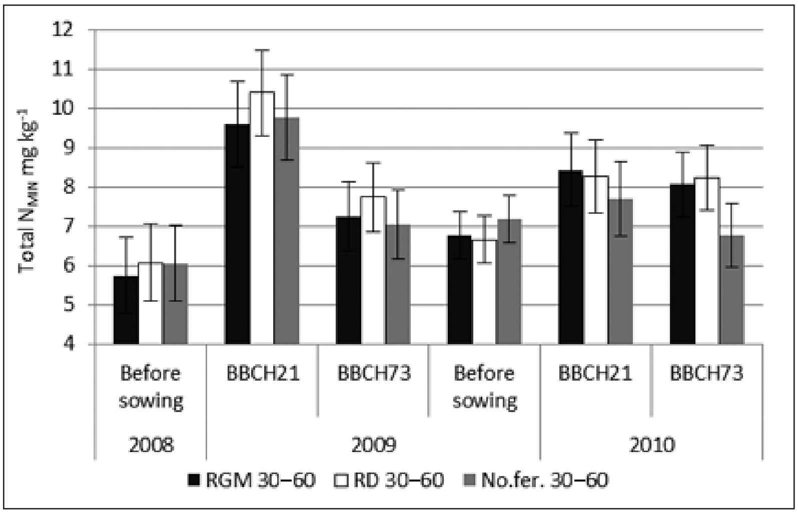

Fig. 8. The amounts of mineral nitrogen (N_{MIN}) in deeper soil layer (30–60 cm) in 2008–2010. Error bars are the least significant difference (LSD_{05}). RGM – horn core powder, RD – horn shavings (horn meal), No. fer. – no fertilization

Having investigated the effect of horn shavings rates on the amount of nitrate nitrogen in 0–30 layer of soil, it has been determined that in different years it had a different effect (Figs. 7–10). If in 2008–2009 during the period of vegetation there was a strong correlation (r = 0.75) determined between fertilizer rates and the amount of nitrate nitrogen ($N–NO_3$) (Fig. 7), in 2009–2010 none interrelationship was weak (r = –0.02) (Fig. 8). A very strong correlation (r = 0.93) was found between horn shavings rates and the amount of ammonium nitrogen ($N–NH_4$) in 0–30 cm layer of soil in 2008–2009. However, in 2009–2010 there was only strong positive correlation (r = 0.70). Assessing the dependence of mineral nitrogen (N_{min}) on treatment with different horn shavings rates in 0–30 cm layer of soil it was determined that in 2008–2009 there was a very strong correlation (r = 0.95) between horn shavings rates and the amount of mineral nitrogen in soil while in 2009–2010 the correlation was weak (r = 0.39) (Figs. 9 and 10).

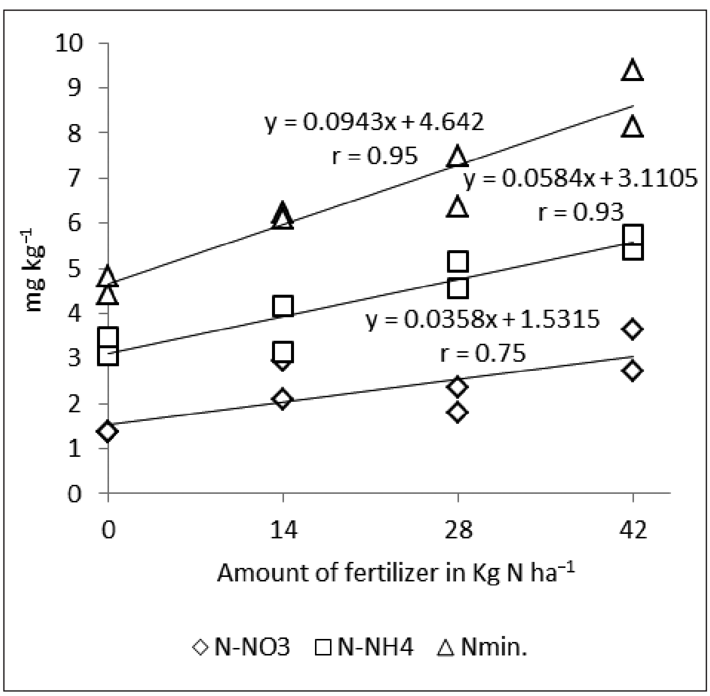

Fig. 9. Dependence of the amount of nitrate, ammonium and mineral nitrogen in 0–30 cm layers of soil on horn shavings rates. Farm of organic production in the Centre of Agroecology at ASU, 2008–2009

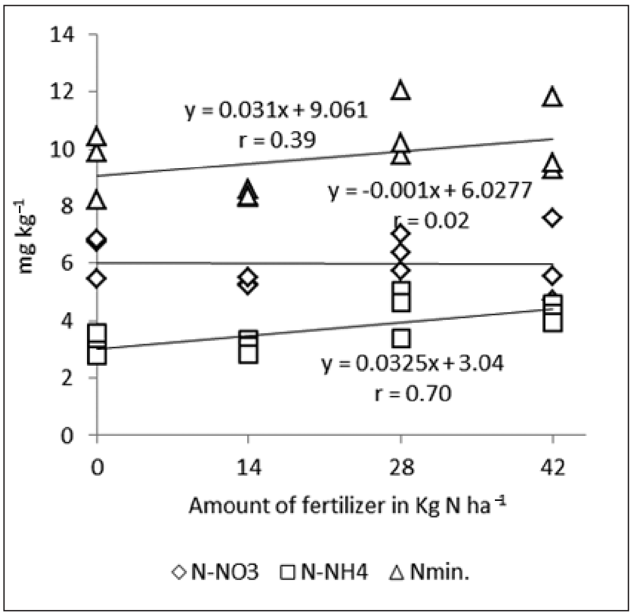

Fig. 10. Dependence of the amount of nitrate, ammonium and mineral nitrogen in 0–30 cm layers of soil on horn shavings rates. Farm of organic production in the Centre of Agroecology at ASU, 2009–2010

After the research of the effect of horn shavings rates on the amount of nitrate nitrogen in a deeper 30–60 cm soil layer it was determined that fertilizers had a different effect on nitrate nitrogen in different years. In 2008–2009 during the wheat vegetation period there was a strong positive correlation (r = 0.77) determined between horn shavings rates and nitrate nitrogen (N–NO_3) while in 2009–2010 the correlation was weak (r = 0.29). In 2008–2009 there was a moderate correlation (r = 0.61) determined between horn shavings rates and the amount of ammonium nitrogen (N–NH_4) while in 2009–2010 it was weak (r = 0.45). Assessing the dependence of mineral nitrogen (N_{min}) on application of different fertilizer rates in 30–60 cm soil layer in 2008–2009 during the period of winter wheat vegetation a positive correlation of moderate strength (r = 0.77) was determined, while in 2009–2010 it was weak (r = 0.47) (Figs. 11 and 12).

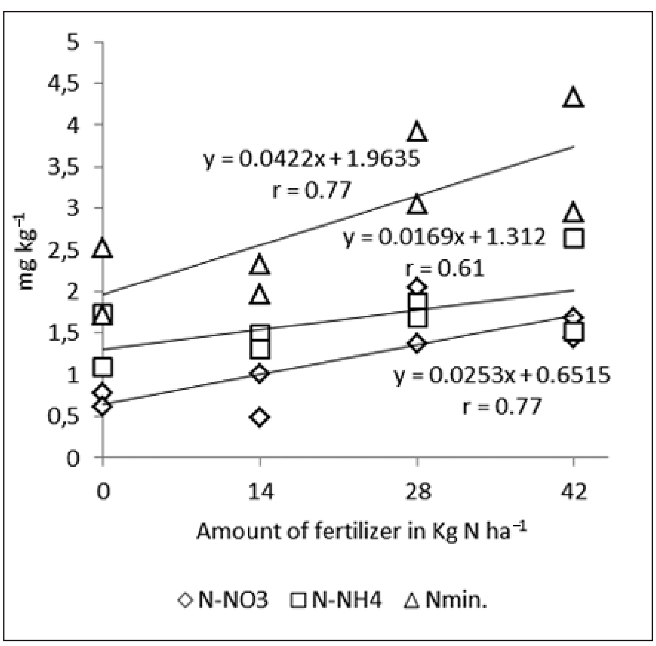

Fig. 11. Dependence of the amount of nitrate, ammonium and mineral nitrogen in 30–60 cm layers of soil on horn shavings rates. Farm of organic production in the Centre of Agroecology at ASU, 2008–2009

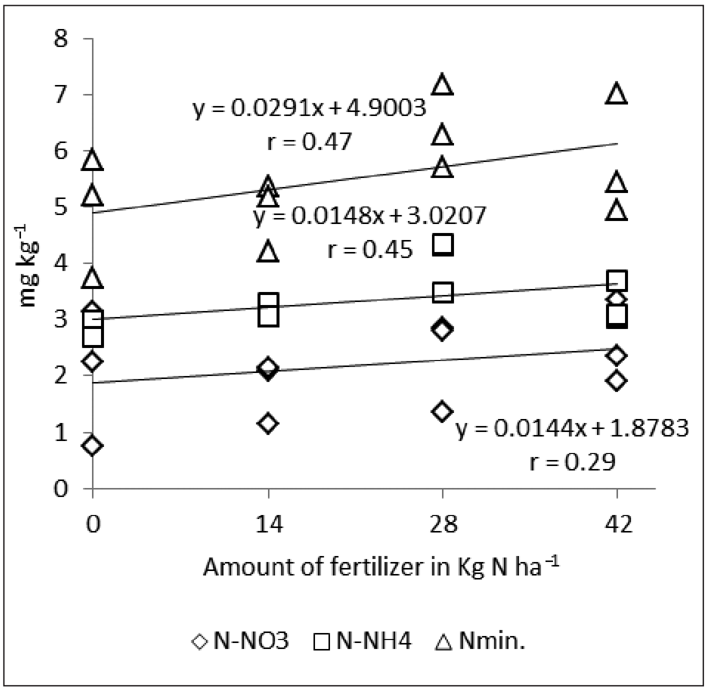

Fig. 12. Dependence of the amount of nitrate, ammonium and mineral nitrogen in 30–60 cm layers of soil on horn shavings rates. Farm of organic production in the Centre of Agroecology at ASU, 2009–2010

CONCLUSIONS

Organically grown winter wheat treated with fertilizers from cattle horn shavings and horn core powder decomposed during the periods of autumn–spring and spring–summer. Therefore the amount of mineral nitrogen compounds increased in 0–30 cm soil layer. Intensity of decomposition was different in different years depending on meteorological conditions in the period of wheat vegetation. In the event of warm and damp weather more mineral compounds formed and due to fertilization their increase was essential.

Leaching of mineral compounds into a deeper 30–60 cm layer was different in different years and depended on meteorological conditions of wheat growth period. Due to higher temperature and greater humidity, horn shavings and horn core powder significantly increased the content of mineral nitrogen compounds in this layer.

Additional treatment of winter wheat with different rates of horn shavings in tillering stage increased the content of mineral nitrogen compounds which was different in different years. In 2008–2009 in 0–30 cm soil layer there was a strong correlation between horn shaving rates and nitrate nitrogen content. At the same time in 2009–2010 no relationships were found between fertilizer rates and soil nitrate nitrogen contents. Correlation between ammonium and mineral nitrogen was weak. In 2008–2009 in the deeper 30–60 cm soil layer the correlation between fertilizer rates and contents of nitrate nitrogen was weak, while that between ammonium and mineral nitrogen was of moderate strength. In 2009–2010 the correlation between fertilizer rates and forms of mineral nitrogen was weak.

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RAGŲ DROŽLIŲ IR RAGŲ GELUONIŲ MILTŲ TRĄŠŲ, PAGAMINTŲ IŠ GALVIJŲ RAGŲ ATLIEKŲ, POVEIKIS MINERALINIO AZOTO KAITAI EKOLOGINIO ŪKIO DIRVOŽEMYJE

Santrauka

Tirtas galvijų ragų drožlių ir ragų geluonių miltų poveikis mineraliniam azotui ir jo formoms 0–30 ir 30–60 cm dirvožemio sluoksniuose. Bandymams auginti ekologiški žieminiai kviečiai. Tyrimai vykdyti 2008–2010 m. Kauno rajono Kazliškių kaime, Aleksandro Stulginskio universiteto Agroekologijos centro ekologinės gamybos ūkyje. Žieminiai kviečiai prieš sėją bei krūmijimosi metu buvo patręšti galvijų ragų trąšomis. Krūmijimosi tarpsniu (BBCH 21–23) ir vegetacijos pabaigoje pasiekus visišką brandą (BBCH 89) 0–30 cm dirvožemio sluoksnyje nustatyti didesni mineralinio azoto junginių kiekiai. Skirtingais metais skaidymosi intensyvumas buvo nevienodas – tikėtina, jog tai lėmė meteorologinės sąlygos kviečių vegetacijos metu. Esant šiltesniems ir drėgnesniems orams, tręšimas mineralinio azoto junginių kiekį dirvožemyje padidino iš esmės. Mineralinio azoto junginių išsiplovimas į gilesnį, 30–60 cm, sluoksnį atskirais metais buvo skirtingas. Esant didesnei temperatūrai bei drėgnesniam orui, kviečių vegetacijos metu ragų drožlės ir ragų geluonių miltai reikšmingai padidino mineralinio azoto junginių kiekį šiame dirvožemio sluoksnyje. Papildomas žieminių kviečių tręšimas krūmijimosi tarpsniu (BBCH 21–23) skirtingomis ragų drožlių normomis didino mineralinio azoto junginių kiekį dirvožemyje, kuris skirtingais metais buvo nevienodas. 2008–2009 m. 0–30 cm dirvožemio sluoksnyje tarp ragų drožlių normos ir nitratinio azoto kiekio nustatytas stiprus, o tarp amoniakinio ir mineralinio azoto kiekio – labai stiprus koreliacinis ryšys. 2009–2010 m. tarp trąšų normos ir nitratinio azoto kiekio koreliacinio ryšio nenustatyta, o tarp amoniakinio ir mineralinio azoto kiekio jis buvo silpnas. Gilesniame, 30–60 cm, dirvožemio sluoksnyje 2008–2009 m. tarp ragų drožlių normos ir nitratinio azoto kiekio nustatytas silpnas, o tarp amoniakinio ir mineralinio azoto kiekio – vidutinio stiprumo koreliacinis ryšys. 2009–2010 m. tarp trąšų normos ir mineralinio azoto formų nustatytas tik silpnas koreliacinis ryšys. Skirtingais metais gauti rezultatai rodo, kad trąšos turi teigiamą poveikį mineralinio azoto kiekiui dirvožemyje, tačiau jų efektyvumas priklauso nuo meteorologinių sąlygų.

Raktažodžiai: ekologinis ūkininkavimas, ragų drožlės, ragų geluonių miltai, dirvožemis, mineralinis azotas, žieminiai kviečiai