INNOVATIVE GREEN MANURE TECHNOLOGIES ON ORGANIC FARMING

Ausra Arlauskiene, Danguole Nemeiksiene, Alvyra Slepetiene
Lithuanian Research Centre for Agriculture and Forestry
arlauskiene.ausra@gmail.com

Abstract. The paper presents the analysis of application of grass biomass in organic manure production using innovative technologies that have not been analysed enough by scientists. The previous green manure technologies were based on incorporation of aboveground biomass of grasses in soil without any additional treatment, so the intensity of mineralization potential and synchronisation of nitrogen released from green manure and the need for nitrogen of cultivated crops were hardly controlled after incorporation of huge content of N. Field experiments with different methods of perennial grasses aboveground mass management (removed from the field, mulching 4 times during the period of vegetation and mixed – first cut removed from the field, second and third – mulching for green manure) were carried out at Joniškėlis Experimental Station of LRCAF. It was defined that during the period of vegetation the mulch of perennial grasses was partially mineralized: the mass was reduced by 51-62 %, N_{total} content – 14-44 %. The greater content of roots and residues of plants was incorporated into the soil if compared to mulch. Late in the autumn the $N_{inorg.}$ content in soil increased the least after application of the aboveground mass of perennial grasses in a combined manner. Mulch of perennial grasses affected the $N_{inorg.}$ content in soil in spring more if compared to the autumn.

Keywords: perennial grasses, mulch technology, mineralization parameters, soil mineral nitrogen.

Introduction

Application of the EU and national support aids, the interest of the consumers in safe products encourage the development of ecologic production farms in Lithuania. The number of such farms increased in 2002-2006; hence this process is dependent upon the financial support, because production of ecologic products is often economically inefficient [1]. Moreover, single-type crop cultivation farms with low variety of crops, inappropriate crop rotation, dominate in Lithuania. It is difficult to deal with problems of crop supply with nutrients, protection from harmful acts and other problems in such ecologic farms. The consequence is low productivity, sometimes insufficient quality of production, low efficiency of application of resources. The base of organic farming should have multi-structural composition with legumes (Leguminosae), cattle and production, oriented towards the closed cycle of nutrient circulation [2]. Organic farming, unlike conventional farming, has complex relationships between different components of the agro-ecosystem and the quantity and quality of the final products depend on the functioning of the entire system [3].

Legumes are one of the most important crop rotation components in ecologic farming. They improve the nutrition of crop rotation crops by nitrogen (due to the ability to fix the atmosphere N_2) and other elements and contribute to improvement of the soil properties, weed choke [4]. Perennial legumes are especially important. However, application of forage legumes in farms with no animal bred is limited. Up to date the surveys have been based on the fact that nitrogen of legumes was indirectly consumed by later cultivated wheat, i.e., after the legume grasses are ploughed up. Therefore, incorporation of a high content of nitrogen by one application sometimes leads to uncontrolled intensity of mineralization; losses of nitrogen as well as insufficient efficiency of N consumption were identified. Decomposition of the biomass of plants is also affected by their quality indicators (C:N, lignin:N, lignin content and etc.). The aboveground mass of delicate plants can be characterised by their rapid mineralization. The need for the development and search for new technologies of applying green manure appears. The aboveground mass of legumes upon the development stage with different specific content has not been widely analysed as well as ways allowing managing the decomposition intensity of the incorporated aboveground mass. Successful further development of ecologic agricultural farming shall depend on the fact how successful application of innovations – new products, technologies, processes – in ecologic production farms will be. The aim of these researches is to assess the effect of application of innovative green manure technologies on mineralization of biomass of perennial grasses as well as on the environmental effect.

Materials and methods

Field experiments were carried out at Joniškėlis Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry (LRCAF) in 2007-2009 on an *Endocalcari – Endohypogleyic*

Cambisol, chemical analysis – in Laboratory of Chemical Researches of Agriculture Institute (LRCAF). The research was conducted in the following sequence of the crop rotation: 2007 spring barley (*Hordeum vulgare* L.) + under-sown perennial grass – 2008 perennial grass – 2009 winter wheat (*Triticum aestivum* L. emend. Fiori et Paol.). Factor A: perennial grass: 1) festulolium (x *Festulolium*) (control, aboveground biomass removed from the field), 2) red clover (*Trifolium pratense* L.), 3) lucerne (*Medicago sativa* L.). Factor B: management methods of aboveground biomass of perennial grass: 1) removed from the field, 2) mixed management, 3) mulching. In the first treatment (B1) of application of the aboveground biomass of perennial grass, the green mass was cut twice at the beginning of flowering: on 10.06.2008 and 25.08.2008 and removed from the field. In the second treatment (B2), the aboveground biomass was used under mixed management: the first grass was cut at the beginning of flowering (10.06.2008) and removed from the field, the second and third cuts were taken during the perennial grass inflorescence growth stage (17.07.2008, 12.08.2008) and mulched on the soil surface. In the third treatment (B3), the green mass was cut every 30-40 days four times (12.05.2008, 13.06.2008, 11.07.2008, 12.08.2008) and mulched on the soil surface. Aboveground biomass for green manure was cut by a self-propelled mower, equipped with a mulching device, then chopped and evenly spread on the plot. In the second half of August, the plots of all treatments were disked and 2 weeks later were ploughed at 25 cm depth. Before sowing, the field was cultivated and harrowed at the same time. Winter wheat (cv. "Tauras") was sown (20.09.2008) at a seed rate of 220 $kg \cdot ha^{-1}$. Ecological winter cereal cultivation technology was applied. Summer 2008 was favourable for the cultivation of perennial grasses. However, the end of summer and the autumn were characterised by excessive precipitation. In August and October the precipitation rate was respectfully 48.6 and 29.8 mm more if compared to the data of the average. Moreover, the average temperature in October was 1.8 ºC higher than usually. Winter of 2009 was warmer and snowier if compared to the data of the average; the spring was warm.

Net (mesh ~1.0 mm) polyvinyl-chloride bags of 20x15 cm were applied for identification of the decomposition intensity of the aboveground mass/mulch of perennials. After every cutting of perennials, the bags with the fixed mass of perennials (20 g.) were laid on the soil surface until the ploughing of perennials in August. The mass of mulch (SM), $C_{org.}$ and N_{total} concentration were defined in bags. Nitrogen (N_{total}) and carbon ($C_{org.}$) in the plant samples were determined by the analyser Vario EL and Carry 50. Soil samples for determination of variation of mineral nitrogen $N_{inorg.}$ ($N–NO_3$ + $N–NH_4$) were taken from 0-60 cm depths in summer before incorporating perennial grass biomass, late in the autumn and early in spring before renewal wheat vegetation.

Results and discussion

The article deals with application of the green mass of perennial legumes for manure by applying the mulch technology. The aboveground mass of perennial grass is mulched in the soil surface 2-4 times during the period of vegetation: it is cut, chopped and spread in order to use the biologic nitrogen, bound by legumes more efficiently, and to save the environment from pollution [5]. Chopped mass of legumes is rich in nitrogen and has a property of rapid mineralization; therefore the free nitrogen is bound by intensively growing perennial grass or is incorporated to the content of organic matters of soil [6]. The mentioned above describes how organic compounds, rich in nitrogen, are formed in soil; they have a feature of slow mineralization and provide cereals with nutrients for several years or may be incorporated to a more stable content of soil organic compounds.

Decomposition of mulch. The most intense decomposition of the biomass of plants is observed in summer and warm autumn. Mineralization can be increased by a shallow incorporation of the biomass as well as other residues of plants by stimulating biological processes in the soil surface [7]. Meanwhile, mulch, spread on the soil surface, is decomposed slower if compared to the one incorporated into soil. Using the combined method of applying the aboveground mass, similar amounts of the aboveground mass of legumes were applied – 4648.6-4948.4 $kg \cdot ha^{-1}$ DM. Upon mulching of all aboveground mass, the mulch content increased 1.5-1.6 times. According to the total content of the aboveground mass, applied for the mulch, perennials can be set in the following order: red clover (8142.1 $kg \cdot ha^{-1}$ DM) > lucerne (6881.7 $kg \cdot ha^{-1}$ DM) > festulolium (4331.4 $kg \cdot ha^{-1}$ DM).

Upon the combined application of the aboveground mass of perennials, during the period of vegetation, mulch of legumes was decomposed the most (54.7-57.9 %), less – festulolium (50.7 %)

(Table 1). The mulch mass of the second cut was reduced more if compared to the third. The ratio of incorporated and decomposed mulch was 0.73-0.97. The greater part of the mass of incorporated mulch was composed from the mulch of the second cut. Upon mulching of all aboveground mass of perennial grasses, the greater amount of mulch was decomposed (53.7-61.8 %) if compared to the cases when the aboveground mass was applied in a combined manner. Mulch of festulolium and red clover from the first and the second cut was decomposed the most intensively as well as the mulch of lucerne of the last two cuts. The ratio of incorporated and decomposed mulch was 0.62-0.86. Upon mulching of all aboveground mass the content of incorporated mulch was from 50.2 to 73.7 % more if compared to the cases when it was applied in a combined manner.

The $C_{org.}$ content of mulch was reduced a bit more than the mass. $C_{org.}$ was more reduced in mulch of festulolium (66.6-69.9 %) than in mulch of legumes (53.7-57.1 %). Within biomass of plants, where C:N >25, microorganisms consume more carbon for nutrition and therefore the energetic input increases.

Table 1

Change of the mass of mulch of perennial grasses and the accumulated nitrogen during the period of vegetation (Joniškėlis, 2008)

Perennial grass (A) and cuts (B)		Management methods of aboveground biomass							
		mixed management				mulching			
		Mass DM kg·ha^{-1}		N_{total} kg·ha^{-1}		Mass DM kg·ha^{-1}		N_{total} kg·ha^{-1}	
		incorpo-rated to soil	decreased	incorpo-rated to soil	decreased	incorpo-rated to soil	decreased	incorpo-rated to soil	decreased
F	first cut	-	-	-	-	603.3	1404.4	15.6	-8.7
	second cut	646.4	-792.0	18.8	-2.9	362.9	629.2	8.6	-1.0
	third cut	306.8	-188.8	7.5	-4.7	357.8	438.4	12.2	-1.5
	fourth cut	-	-	-	-	331.4	204.0	6.8	-1.0
	in total	953.2	-980.8	26.3	-7.6	1655.4	2676.0	43.2	-12.2
RC	first cut	-	-	-	-	469.6	1003.8	23.0	-26.9
	second cut	1172.1	-2222.4	61.0	-29.1	523.7	1115.5	27.2	-28.0
	third cut	909.0	-644.8	44.8	-41.9	1231.8	1534.4	60.7	-23.7
	fourth cut	-	-	-	-	1324.0	933.2	62.4	-1.7
	in total	2081.1	-2867.2	105.8	-71.0	3549.1	4586.9	173.3	-80.3
L	first cut	-	-	-	-	818.2	705.8	32.3	-22.7
	second cut	1374.3	-1737.1	63.5	-45.2	780.6	721.4	36.1	-19.2
	third cut	746.6	-820.5	34.5	-41.3	911.7	1152.4	42.1	-37.5
	fourth cut	-	-	-	-	674.2	1117.0	29.9	-30.0
	in total	2120.9	-2557.7	98.0	-86.5	3184.7	3696.6	140.4	-109.4
LSD_{05} mass A – 396.78; B – 323.97; AB – 561.13; N_{total} A – 15.45; B – 12,62; AB – 21.85									

Note: F – Festulolium; RC – Red clover; L – Lucerne;

The total nitrogen changes in mulch were less significant if compared to the changes of the mass. After the combined application of the aboveground mass of legumess, the N_{total} content was most reduced in mulch of lucerne (34.2 %), less – red clover (28.6 %) and the least – festulolium (13.5 %). Prior incorporation of mulch into the soil, the N_{total} content in mulch of festulolium was 26.3 kg·ha^{-1}, red clover – 105.8 kg·ha^{-1} and medicago sativa – 98.0 kg·ha^{-1}. When all aboveground mass of red clover, lucerne and festulolium was used for the mulch, N_{total} was reduced analogically to the combined manner (respectively 43.8, 31.7 and 22.0 %).

N_{total} was most reduced in mulch of festulolium and red clover of the first cut, while lucerne – of the last two cuts. Upon mulching of all aboveground mass of red clover, N_{total} in mulch was 63.8 %, while in lucerne – 43.3 % more (or incorporated respectively 173.3 and 140.4 kg·ha^{-1}) if compared to the combined application of the aboveground mass. Prior incorporation to the soil, the greater part of the incorporated nitrogen content in the mulch of red clover was composed from the last two cuts, in the mulch of lucerne – nitrogen from almost all cuts similarly. Surveys, carried out in Sweden, indicated that plants cultivated the same year can assimilate 25-28 % of nitrogen from the mulch of perennial grasses (without its incorporation) [8].

Intensity and duration of the decomposition of the biomass of plants depend on the carbon and nitrogen ratio as well as lignin content in the organic material, the consistency of mass. Within the aboveground mass of plants, where the C:N ratio is = 10, the decomposition is implemented very fast. Independently from the aboveground mass application ways, the C:N ratio was most reduced in mulch of festulolium, while in mulch of legumes these changes were smaller. Prior incorporation of mulch of festulolium to soil, the C:N ratio there (respectively to the cut) was the greatest – 14-19, while legumes – much smaller – 10-14. It indicates that composites rich in nitrogen mineralized in mulch. Researchers indicate that amino acids, proteins, glucose, starch decompose rapidly while cellulose, hemicellulose – slower and upon decomposition of lignin for 40-50 days, there were no significant changes of the chemical content [2].

Underground mass of plants. At the end of summer, when perennials are ploughed, microorganisms of the soil affect not only the incorporated aboveground mass, but also the underground mass. The underground mass of perennials was much greater if compared to the mass of mulch. According to average data, the underground mass of festulolium was 7675.0 $kg \cdot ha^{-1}$ DM, red clover – 6771.0 $kg \cdot ha^{-1}$ DM and lucerne – 8551.2 $kg \cdot ha^{-1}$ DM. Meanwhile, the nitrogen content in the underground mass of the mentioned plants was similar as in mulch (respectively 69.4, 156.2 and 180.2 $kg \cdot ha^{-1}$). C:N ratio in the underground mass was wider if compared to the mulch of perennial grasses: festulolium – 72-83, red clover – 21-26 and medicago sativa – 25-29. The underground mass of plants is very diverse and is composed from roots of different sizes, age and chemical composition, fresh or partially decomposed residues of plants. Moreover, after ploughing the soil, a part of mobile organic materials in soil do mineralize.

Soil mineral nitrogen. Prior the ploughing of perennial grasses (04 09 2008) significantly greater $N_{inorg.}$ content was observed in soil where red clover was cultivated (Table 2).

Table 2

$N_{inorg.}$ content ($kg \cdot ha^{-1}$) change dynamics in soil layer 0-60 cm during autumn – spring (Joniškėlis, 2008-2009)

Perennial grass (A)	Indicators	Management methods of aboveground biomass (B)								
		removed from the field			mixed management			mulching		
		04 09 2008	12 11 2008	08 04 2009	04 09 2008	12 11 2008	08 04 2009	04 09 2008	12 11 2008	08 04 2009
F	$N_{inorg.}$	27.1	34.1	37.1	33.6	38.9	37.0	30.6	45.7	44.1
	$^{\Delta}$difference	-	+7.0	+3.0	-	+5.3	-1.9	-	+14.9	-1.5
	NO_3/NH_4	2.3	2.3	1.5	1.9	3.4	1.7	2.3	3.7	2.3
RC	$N_{inorg.}$	40.6*	69.4	49.3	43.2**	50.5	60.3**	38.1*	59.1	57.3*
	difference	-	+28.8	-20.1	-	+7.3	+9.8	3.2	+21.0	-1.9
	NO_3/NH_4	3.2	4.7	2.9*	2.6	3.5	2.7*	-	4.0	3.5**
L	$N_{inorg.}$	34.5	66.5	46.4	37.8	45.1	53.8*	38.5*	77.4*	64.2**
	difference	-	+32.0	-20.1	-	+6.3	+8.7	-	+39.0*	-13.3
	NO_3/NH_4	2.7	5.2*	2.5	2.6	3.3	2.3	4.8**	7.1**	3.7**
LSD_{05} $N_{inorg.(04\ 09\ 2008)}$ A–5.79, B–4.48 AB–10.03; NO_3/NH_4 A–0.67, B–0.52, AB–1.51; $N_{inorg.(12\ 11\ 2008)}$ A–20.51, B–15.89, AB–35.53; difference A–16.58, B–12.84, AB– 28.71; NO_3/NH_4 A–1.60, B–1.24, AB–2.77; LSD_{05} $N_{inorg.(08\ 04\ 2009)}$ A–8.78, B–6.80, AB– 15.20; difference A–19.95, B–15.46, AB–34.56; NO_3/NH_4 A– 0.59, B–0.45, AB–1.02										

Note: F – Festulolium; RC – Red clover; L – Lucerne; $^{\Delta}$difference, compared to previous data;

*differences are statistically significant as compared to the control at $P < 0.05$; **– $P < 0.01$.

If compared to lucerne, the aboveground mass of red clover and especially roots can be characterised by a lower C:N ratio. Mulching of all aboveground mass of lucerne also significantly increased the $N_{inorg.}$ content in soil as well as the part of the nitrate nitrogen in it.

Late in autumn when winter wheat was cultivated after perennials (12.11.2008), the soil $N_{inorg.}$ content increased. It was determined by a warm and rainy autumn, especially favourable for the mineralization of organic materials. After ploughing perennial grasses, the underground mass of legumes mineralized intensively. After red clover and lucerne (with no green manure applied) the $N_{inorg.}$ content in soil was increased, respectively 28.8 and 32.0 kg·ha^{-1}, if compared to the data prior the ploughing of grasses. The $N_{inorg.}$ content was also increased by the mulching of all aboveground mass and after lucerne – significantly. In the soil of the mentioned plots, the greater part of $N_{inorg.}$ content was composed from nitrate nitrogen. Especially high content of nitrogen (especially – nitrate) in soil not during the period of the vegetation of plants can determine the loss of nitrogen – it migrates deeper [9]. Good results were obtained after incorporation of the small mass of mulch (mixed method); the $N_{inorg.}$ content changed a little (6.3-7.3 kg·ha^{-1}) in the soil. It can be explained by the fact that upon incorporation of roots of plants and partially mineralized aboveground mass of plants (mulch), nitrogen in soil could be bound by microorganisms and temporarily became the source of their energy.

In spring after renewal of winter wheat vegetation, the soil $N_{inorg.}$ was dependent upon the ways of applying the aboveground mass. After the aboveground mass of legumes was removed from the field, $N_{inorg.}$ was reduced; in case the combined method was applied – increased; in case of mulching – had a tendency to decrease, especially after lucerne if compared to the data in the autumn. Surveys indicated that after application of the greater aboveground mass of legumes for green manure (the variant – mulched), its decomposition intensity was more affected by unfavourable meteorological conditions.

Prior ploughing of perennials (04.09.2008), the $N_{inorg.}$ content in soil correlated with the C:N ratio of the underground mass (Table 3).

Table 3

Dependability of the mineral nitrogen from the underground mass of perennials and mulch C:N ratio (Joniškėlis, 2008-2009)

$N_{inorg.}$ determina-tion time	**Management methods of aboveground biomass**	**Biomass type**	**Regression equation**
04.09.2008	Mixed management	underground mass	*y* = 44.96 - 0.13*x*; *r* = -0.62*, *n* = 15
		mulch	-
	Mulching	underground mass	*y* = 42.82 - 0.16*x*; *r* = -0.60*, *n* = 15

		mulch	*y* = 56.87 - 1.31*x*, *r* = -0.79*, *n* = 9 (1);
			y = 55.56 - 1.31*x*, *r* = -0.79*, *n* = 9 (2);
			y = 77.01 - 3.12*x*, *r* = -0.80**, *n* = 9 (3);
			y = 52.98 - 1.03*x*, *r* = -0.75*, *n* = 9 (4)

08.04.2009	Mixed management	underground mass	*y* = 66.05 - 0.35*x*, *r* = -0.84**, *n* = 15
		mulch	*y* = 87.12 - 2.82*x*, *r* = -0.74*, *n* = 9 (2); *y* = 129.86 - 6.44*x*, *r* = -0.72*, *n* = 9 (3)
	Mulching	underground mass	*y* = 70.36 - 0.33*x*, *r* = -0.58*, *n* = 15

		mulch	*y* = 97.00 - 3.33*x*, *r* = -0.87**, *n* = 9 (1);
			y = 96.67 - 3.33*x*, *r* = -0.87**, *n* = 9 (2);
			y = 147.16 - 7.85*x*, *r* = -87**, *n* = 9 (3);
			y = 88.44 - 2.72*x*, *r* = -0.86**, *n* = 9 (4)

Note: * – $P < 0.05$; ** – $P < 0.01$; (1), (2) cuts of grasses.

Correlation regression analysis indicated that upon mulching of all aboveground mass, $N_{inorg.}$ of the soil in the autumn was more affected by the aboveground mass of grasses if compared to the application of the part of the aboveground mass. After the C:N ratio of the mulch of perennial grasses was changed by one unit (within 10-19 interval), the soil $N_{inorg.}$ changed towards the different direction averagely from 1.03 to 3.12 kg·ha^{-1}. The stronger inverse link of the soil $N_{inorg.}$ with C:N ratio of mulch if compared to underground mass. Late in the autumn (12.11.2008) dependability of $N_{inorg.}$ on the residues of incorporated plants and the C:N of the mass of green manure was not identified.

In spring (08.04.2009) the C:N ratio of underground mass and mulch of plants had a stronger effect on the soil $N_{inorg.}$ content if compared to the autumn. The soil $N_{inorg.}$ was more intensively affected by the mulch of perennial grasses if compared to the underground mass of grasses. After the combined application of the aboveground mass of perennials, and after its C:N ratio was changed by one unit (within 10-17 interval), $N_{inorg.}$ changed towards the different direction averagely 2.82 and 6.44 kg·ha^{-1} (respectively 2 and 3 cuts). When all aboveground mass was mulched, and its C:N ratio was changed by one unit (within 10-19 interval) $N_{inorg.}$ changed towards the different direction from 2.71 to 7.85 kg·ha^{-1} (depending from the cut). In cases the aboveground mass was applied in a combined manner or mulched, the mulch of the third cut had a greater effect on the soil $N_{inorg.}$

Conclusion

During the period of vegetation, the aboveground mass of perennial grasses, mulched on the surface of the soil was partially decomposed. The mass was reduced by 50.7-61.8 %, the nitrogen content in it – 13.5-43.8 %, C:N ratio – up to 10-19. Biomass of legumes was decomposing more intensively if compared to festulolium. After ploughing of perennial grasses together with mulch, the underground mass of perennials affecting further mineralization of the mulch in the soil is also decomposed. In the autumn, favourable for the mineralization of organic materials, the incorporated mulch of the underground mass of plants or mulch of perennials with a low C:N ratio, determines the increase of the $N_{inorg.}$ content in soil. It is purposeful to apply the aboveground mass of perennials in a combined manner from the environmental approach. Mulch of perennials affects the soil $N_{inorg.}$ content in spring more than in the autumn.

References

1. Arlauskienė A., Nemeikšienė D., Šlepetienė A., Maikštėnienė S. Aplinkosauginiai ir agronominiai veiksniai lemiantys ekologiškų maistinių kviečių kokybę [Environmental and agronomic factors influencing quality of ecological wheat grain (summary)] . Ekonomika ir vadyba: aktualijos ir perspektyvos, vol. 19, nr 3 (19), 2010, pp. 150-158.
2. Osono T., Takeda H. Organic chemical and nutrient dynamics in decomposing beech leaf litter in relation to fungal in growth and succession during 3-year decomposition processes in a cool temperate decduoud forestin Japan. Ecological Research, vol. 16, 2001, pp. 649-670.
3. Watson C. A., Atkinson D., Gosling P. et al. Managing soil fertility in organic farming systems. Soil Use and Management, no. 18, 2002, pp. 239-247.
4. Peoples M. B., Rockwell J., Herridge D. F. et al. The contributions of nitrogen-fixing crop legumes to the productivity of agricultural systems. Symbiosis , vol. 48, 2009, pp. 1-17 .
5. Dreymann S., Loges R., Taube F. Einfluss der Kleegrasnutzung auf die N-Versorgung und Ertragsleistung marktfähiger Folgefrüchte unter Berücksichtigung einer variierten organischen Düngung. Ökologischer Landbau der Zukunft: Beiträge zur 7. Wissenschaftstagung zum Ökologischen Landbau. Austria, German, 2003, S. 89-92.
6. Schäfer W., Väisänen J., Pihala M. Technique of green mulch spreading. Agricultural Engineering Research, no. 79, 2001, pp. 56.
7. Dryšlova T., Prochazkova B. Effect of olifferent soil tillage and straw management on soil nitrogen content under winter wheat. Curent Trends in the Research of Soil Environments Precedings of International Conference. Brno, 2002, pp. 89-94.
8. Bath B., Malgeryd J. Stintzing A.R., Akerhielm H. Surface mulching with red clover in white cabbage production. Nitrogen uptake, ammonia losses and the residual fertility effect in ryegrass. Biological agriculture and horticulture, vol. 23, 2006, pp. 287-304.
9. Tripolskaja L. Organinės trąšos ir jų poveikis aplinkai. Akademija (Kėdainių r.), 2005, pp. 205.
10. Kustermann B., Christen O., Hulsbergen K. J. Modelling nitrogen cycles of farming systems as basis of site- and farm-specific nitrogen management. Agriculture, Ecosystems and Environment, vol. 135, 2010 pp. 70-80.