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Residual effects of perennial grasses as green manure on soil agrochemical properties and spring barley

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Abstract

Field experiments were carried out at the Vėžaičiai Branch of the Lithuanian Institute of Agriculture on an *Albi-Endohypogleyic Luvisol* (*LVg-n-w-ab*). The study was aimed to explore the residual effect of phytomass of differently-managed perennial grasses, as green manure, on the improvement of soil properties and on the productivity and phytopathological condition of spring barley grown in a crop rotation in the second year of effect. The greatest amounts of plant residues were found to be left in the soil after differently-managed lucerne (19.48 and 17.29 t ha^{-1}) and red clover of the 2nd year of use (13.06 t ha^{-1}). With phytomass, the soil received 294.6, 262.6 and 228.2 kg ha^{-1} of nitrogen, 31.0, 26.5 and 24.8 kg ha^{-1} of phosphorus, and 154.2, 133.6 and 129.3 kg ha^{-1} of potassium, respectively. The C:N ratio of the aboveground mass of perennial grasses was the lowest and more favourable for a more rapid decomposition (10.0–14.0) than in the residues (roots and stubble) (20.0–36.0). Nutrients, released during mineralization of phytomass of perennial grasses of the second year of use, had a positive effect on spring barley grown in the second year of effect after green manure incorporation. The correlation of spring barley total stem number, productive stem number and grain yield with the content of organic carbon formed by perennial grasses was moderately strong and strong (r = 0.504*, 0.640** and 0.727**, respectively). The correlation of spring barley productive stem number and grain yield with the content of available phosphorus formed by perennial grasses was moderately strong and strong (r = 0.506* and 0.790**, respectively). Available potassium content in the soil influenced only barley grain yield r = 0.548*.
The severity of spring barley foliar diseases significantly depended on the growing conditions: $P < 0.05$. A 1.1–1.2-time higher foliar disease incidence and severity was recorded in the agrocenoses of spring barley after legumes of the 2nd year of use, especially after lucerne. The total and productive stem number of spring barley significantly increased the severity of foliar diseases at barley booting and milk maturity stages (r = 0.455*, 0.502*, 0.905** and 0.834**). However, the severity of foliar diseases did not exert any significant impact on barely grain yield and 1000 grain weight.

Key words: perennial grasses, phytomass effects, spring barley, productivity, diseases.

Introduction

One of the challenges now is to develop a widely applicable scheme with measures to maintain or increase soil quality and decrease nutrient losses from grass-arable rotations under different conditions, using the ideas and results of studies from different countries. One requirement should be to optimize the length of the grass and arable period in a rotation, according to production needs and environmental considerations (Vertès et al., 2007).

Organic fertilizers play the central role in sustaining soil fertility and crop productivity in organic farming. In specialised crop farms where the use of animal manure is limited, green manures provide the most effective way to improve the nitrogen supply for succeeding crops (Leinonen, 2000; Thorup-Kristensen et al., 2003). The inclusion of perennial leys in crop rotations is regarded as an important tool to increase soil fertility due to the positive effect of leys on soil organic matter (SOM) (Persson et al., 2008). Cultivation of legumes results in an increased mobility of phosphorous compounds in the soil and enriches the soil with organic matter too (Tripolskaja, 2005). The largest amount of organic matter is left in the soil with the residues of perennial grasses (Maiksteniene, Arlauskiene, 2004).

The productivity of cereals depends on soil properties, meteorological factors, fertilisation, and particularly humus content in the soil. When the soil is poor in humus, crop yield is even more dependent on the natural conditions – heavy-textured soils in wet years tend to become lumpy, whereas light-textures soils in dry years become moisture-deficient more rapidly and plants are prone to wilting (Tripolskaja, 2005).

Seeking to achieve a balanced functioning of agrocenoses, it is vital to maintain a high productivity level of the crops grown using organic management practices, whose major problem is yield losses to diseases. The concept of disease tolerance is very different as it describes decreased crop yield loss under the same level of disease and is strongly influenced by environmental conditions (Newton et al., 2000). Sustainable control of some diseases in barley needs to integrate major-gene-mediated resistance, partial resistance and other strategies such as customized fungicide programmes, species or cultivar rotation, fertilization, resistance gene deployment, clean seed and cultivar mixtures, etc. (Zhan et al., 2008). Whilst an important tool in combating barley foliar diseases, some management practices do not necessarily provide complete protection and are less effective in reducing the overall size of disease populations. The disease population can change rapidly so that new barley resistance genes and fungicides become ineffective after several seasons of widespread commercial use (Newton et al., 2001). Yet little is known about how individual resistance mechanisms of cereals are determined. Clearly, there is no single mechanism or approach that will provide sustainable control of disease epidemics on barley crops. Nevertheless, use of cultivars with both partial resistance in diversification strategies which include mixtures, supplemented with customized fungicide spray programmes when necessary, clean seed, preceding crops and good crop husbandry, is likely to be a sustainable strategy.

Nearly 40% of the soils in Lithuania are insufficiently fertile (Tripolskaja, idlauskas, 2010); soil degradation is observed, especially in the western part of Lithuania. Ecologically sensitive automorphic moderately podzolized sod-podzolic soil on moraine loam (till) is prevailing in Western Lithuania. This soil is very acid (pH_{KCl} 3.9–4.2) in whole profile to the 160 cm depth and the amount of toxic mobile aluminium is very high both in the topsoil and subsoil (100–300 mg kg^{-1}, respectively). The deficiency in clay (<0.002 mm), cations of Ca, Mg and organic colloids, is the main factor that influences the stability of structure in the soil. All these reasons hamper the formation of food, water and warmth regime for the best usage of genotype potential in the soil. The improvement and conservation of this soil fertility are the strategic directions of research. It is important to maintain nutrient reserves in the soil with organic matter (Ozeraitiene, 2002).

The objective of the study was to explore the residual effect of phytomass of differently-managed perennial grasses, as green manure, on the improvement of soil properties and on the productivity and phytopathological condition of spring barley grown in a crop rotation in the second year of effect.

Materials and methods

Site description and soil. The field experiments were conducted in Western Lithuania at the Vėžaičiai Branch of the Lithuanian Institute of Agriculture (central coordinates: 55º43′24 N, 21º27′24 E) during 2002–2007. Two analogous experiments were set up in 2002 and 2003. The field experiments were done following the multi-factorial method. The total plot size was 96.0 m^2 (6.0 × 16.0 m), harvested area of legumes and timothy 22.4 m^2 (1.4 × 16.0 m), and harvested area of cereals 36.8 m^2 (2.3 × 16.0 m). The experimental treatments were replicated four times and were arranged randomly. The soil of the experimental site was *Albi-Endohypogleyic Luvisol* (*LVg-n-w-ab*), light loam on medium heavy loam. The ploughlayer's agrochemical characteristics were as follows: pH_{KCl} – 6.0–6.1, mobile P_2O_5 and K_2O – 104–99 and 120–66 mg kg^{-1} soil, respectively, N_{total} 0.08–0.11%, C_{org} 0.90–1.05%.

Experimental design. The experiments were conducted in the following crop rotation sequence: spring barley undersown with perennial grasses → perennial grasses → winter triticale → spring barley. Perennial grasses included red clover (*Trifolium pratense* L.) cv. 'Vyliai', white clover (*Trifolium repens* L.) cv. 'Sūduviai', lucerne (*Medicago sativa* L.) cv. 'Birutė', timothy (*Phleum pratense* L.) cv. 'Gintaras II'. Cereals included winter triticale (*Triticosecale* Wittm.) cv. 'Tevo' and spring barley (*Hordeum vulgare* L.) cv. 'Ūla'.

In the first experimental year (2002 and 2003), spring barley (*Hordeum vulgare* L.) cv. 'Ūla' was undersown with perennial grasses in compliance with the experimental design.

The experimental area was divided into two plots, because perennial grasses plouged-in as green manure were of different year of development.

In the first plot, perennial grasses were grown for two years. First year – sowing year, in the second year of development of perennial grasses (2003 and 2004) – 1st crop for forage, second crop – for green manure: R – ploughed-in only residues, aboveground mass removed from field; R + A – ploughed-in total phytomass. Perennial grasses: 1) timothy (R), 2) red clover (R + A), 3) red clover (R), 4) white clover (R + A), white clover (R). Perennial grasses were preceding crops for winter triticale (in 2004 and 2005); spring barley was grown after winter triticale (in 2005 and 2006).

In the second plot, perennial grasses were grown for three years. First year – sowing year, in the second year of development of perennial grasses – 3 cuts, in the third year of development of perennial grasses (2004 and 2005) – 1st crop for forage, second crop – for green manure: R – ploughed-in only residues, aboveground mass removed from field; R + A – ploughed-in total phytomass. Perennial grasses: 1) timothy (R), 2) lucerne (L + A), 3) lucerne (R), 4) red clover (R + A), 5) white clover (R + A). Perennial grasses were preceding crops for winter triticale (in 2005 and 2006), spring barley was grown after winter triticale (in 2006 and 2007).

The phytomass was chopped and shallowly incorporated at the beginning of flowering of legumes and beginning of ear emergence of timothy, and after two weeks deeply ploughed in (25 cm). Seeking to determine the ecological value of different preceding crops no mineral fertilisers and plant protection products were used. Timothy was chosen for the control treatment, because it is best adapted to Lithuania's natural conditions.

Plant and soil analyses. Plant residue mass was determined by the Katchinski monolith washing method (Lapinskiene, 1986). We considered the following as plant residues: stubble (10 cm in length), undecomposed plant parts present on the soil surface and roots present at the 25 cm depth. The mass of all plant residues and aboveground mass were re-calculated into dry matter. Having determined the concentration of major nutrients, we calculated the content of nutrients (kg ha^{-1}) incorporated into the soil. The content of phosphorus in the phytomass of perennial grasses and their plant residues was determined by colorimetry and potassium by flame photometry methods, total nitrogen by Kjeldahl, organic carbon by a mineraliser "Heraeus" (Germany).

Spring barley crop population density and number of productive stems were established in each plot, in two places 0.25 m^2 in size. Grain samples for analyses were taken from each plot after pre-cleaning. The data on 1000 grain weight and yield were adjusted to 15% moisture content.

Soil agrochemical characteristics in the 0–20 cm soil layer were determined before trial establishment and before sowing of spring barley using the following methods: pH_{KCl} by electrometric method, available P_2O_5 and K_2O by A-L method, total nitrogen by Kjeldahl, organic carbon by a mineraliser "Heraeus".

Diseases assessment. Foliar disease assessments on spring barley were carried out in 2005–2007 at booting stage (BBCH 37–39) and milk maturity stage (BBCH 73–75). Fifty plants were collected from ten locations per each plot, in each treatment. Foliar fungal diseases were diagnosed using visual (according to external symptoms) and microscopy methods.

The disease-affected leaf area was estimated in percent according to the scale recommended by the European Plant Protection Organisation (EPPO). This scale is included in the EPPO standards. To assess foliar diseases EPPO guidelines were used, for net blotch and spot blotch – PP 1/29(2). Disease severity (R) was calculated according to the formula, having added percent of affected leaf area of each leaf and having divided the sum by the number of assessed leaves (Agriculture pest diseases…, 2002):

$$R = \frac{\sum(n \times b)}{N},$$

where: $\sum(n \times b)$ – sum of product of the number of leaves with the same percent of severity and value of severity, N – number of assessed leaves.

Climatic conditions. The experimental area belongs to the maritime agroclimatic region. The weather conditions differed considerably between years (Table 1).

Table 1. Meteorological conditions of the vegetation periods, 2002–2007

Month	Air temperature, °C					Rainfall, mm				
	ten-day period			per month	+/– of the long-term mean	ten-day period			per month	+/– of the long-term mean
	I	II	III			I	II	III		
					2002					
April	3.1	8.8	9.5	7.1	+1.5	0.4	3.8	9.9	14.1	−29.9
May	17.0	12.4	16.4	15.3	+4.1	0.3	11.6	8.4	20.3	−23.8
June	16.5	16.3	14.5	15.8	+1.0	1.0	41.2	21.3	63.5	−0.3
July	17.1	20.6	18.2	18.6	+1.8	32.7	56.8	42.9	132.4	+45.8
August	20.3	20.8	18.8	20.0	+3.6	0	0	0.3	0.3	−88.7
					2003					
April	0.0	6.1	8.5	4.9	−0.7	19.2	9.5	18.5	47.2	+3.1
May	9.5	10.9	14.3	11.6	+0.4	14.9	23.5	4.1	42.5	+1.6
June	15.5	13.3	14.9	14.6	−0.2	2.5	19.6	50.6	72.7	+8.8
July	17.0	19.7	21.4	19.4	+2.6	22.8	13.5	11.6	47.9	−38.0
August	18.7	17.1	14.4	16.7	+0.3	10.0	35.2	71.6	116.8	+27.3
					2004					
April	5.1	8.2	8.4	7.2	+1.6	6.4	5.7	3.7	15.8	−27.8
May	15.0	8.5	8.7	10.7	−0.5	4.6	16.2	16.0	36.8	−7.1
June	13.7	12.5	14.1	13.4	−1.3	3.5	41.7	23.7	68.9	+4.9
July	15.1	15.4	17.0	15.8	−1.0	31.7	12.9	7.9	52.5	−32.8
August	20.5	17.9	16.0	18.1	+1.7	4.2	30.3	29.9	64.4	−24.7
					2005					
April	5.0	8.2	5.5	6.2	+0.6	10.0	2.0	3.0	15.0	−28.1
May	8.6	8.9	15.8	11.1	−0.1	5.0	27.0	6.0	37.0	−6.8
June	12.0	15.5	15.6	14.4	−0.3	6.0	30.0	9.0	45.0	−18.7
July	18.6	19.8	17.4	18.6	+1.8	36.0	98.0	59.0	193.0	+105.8
August	16.2	15.6	16.6	16.1	−0.3	171.0	81.0	15.0	267.0	+174.9
					2006					
April	2.8	4.2	9.5	5.5	−0.1	18.7	8.3	0.0	27.0	−15.8
May	14.3	10.3	10.1	11.6	+0.4	0.6	12.3	31.3	44.2	+0.4
June	10.8	17.4	18.6	15.6	+0.9	4.9	1.0	16.3	22.2	−40.8
July	22.1	18.7	20.4	20.4	+3.5	0.0	1.7	2.6	4.3	−80.7
August	18.7	18.3	16.5	17.8	+1.3	9.5	27.8	36.1	73.4	−18.4
					2007					
April	2.9	6.8	8.3	6.0	+0.4	7.4	18.4	0.0	25.8	−17.0
May	7.0	11.1	18.4	12.2	+1.0	10.3	40.3	10.0	60.6	+16.5
June	18.8	16.9	15.6	17.1	+2.3	0.7	38.6	65.9	105.2	+41.5
July	15.2	17.0	16.5	16.2	−0.7	155.0	8.8	87.1	250.9	+162.4
August	18.7	19.2	16.4	18.1	+1.6	17.7	26.5	36.3	80.5	−11.1

In the spring of 2002, warm and dry weather prevailed. At the beginning of summer there was sufficient warmth and moisture for the development of perennial grasses, and in August with prevailing dry weather and declining moisture reserves, the conditions for grass growth were only satisfactory. In the spring and summer of 2003, except for July, hydrothermal conditions were favourable for the development of perennial grasses. The autumn conditions were also conducive to the emergence, establishment and growth of cereals. During the spring-summer period of 2004 agrometeorological conditions for the development of cereals and perennial grasses were satisfactory, since the amount of rainfall was by 20% lower than the long-term mean. The autumn was warm and wet, which might have intensified biochemical processes in the soil and leaching of some part of released nitrogen. In 2005, the spring and beginning of summer were drier (rainfall only 80%) compared with the long-term mean. Rainy second half of summer hindered cereal harvesting. In 2006, the spring was late and dry. Only in the third ten-day period of May, heavy rainfall occurred (61.9 mm). The high temperature in the second half of June, shortage of rainfall and high radiation afflux created conditions for the development of drought that lasted until the middle of August. During the summer months the amount of rainfall was 99.9 mm, i.e. only 42% of the mean long-term rate. In 2007, the spring was early. Warm and moderately wet weather prevailed. The mean air temperature of June was 17.1°C, by 2.4°C higher than the long-term mean, and that of July was close to long-term mean. The amount of rainfall that fell during the mentioned summer months was high, 1.7 and 3 times higher than the long-term mean. Conditions conducive to leaching of nitrogen compounds occurred in July in which 250.9 mm of rainfall fell.

The experimental data were processed by *ANOVA* and correlation-regression analysis methods (Tarakanovas, Raudonius, 2003).

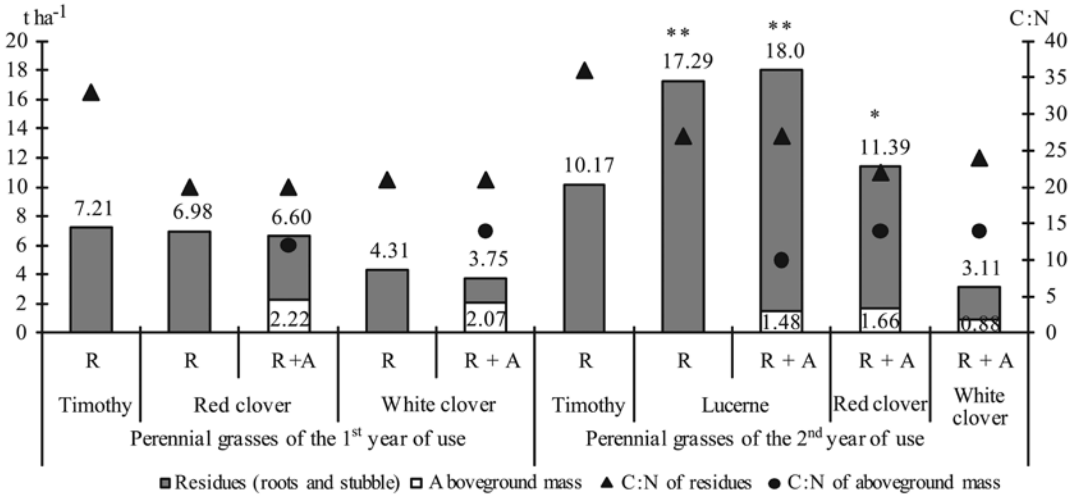
Results and discussion

Environmentally friendly agriculture should move towards a more closed nutrient cycle. Every member of an agrocenosis (rotation) is estimated as a preceding crop according to the cumulative organic and nutritive quantities in the soil and structured conditions for plants growing after them (Nemeikšienė et al., 2010 b). The effect of plants on the soil is related to the quantity of roots and aboveground phytomass left in the soil (Talgre et al., 2009), their chemical composition (Nemeikšienė et al., 2010 a) and decomposition rate (Tripolskaja, 2005).

Other researchers suggest that plant growth and development depend on site-specific variations of atmospheric physical characteristics. In Western Lithuania, the annual herbage dry matter yield strongly correlates (r = 0.77) with the sum of positive temperatures. In May, the dry matter yield of herbage is most markedly influenced by the warmth, on which duration of herbage re-growth depends (r = 0.88), while in June and July the greatest effect is exerted by rainfall (r = 0.83) (Daugeliene, Zekoniene, 2009).

Analysis of variance showed that differently-managed perennial grass species had a significant effect on the contents of residues and total phytomass, respectively: $F_{act.} = 11.31 > F_{tabl.0.1} = 5.35$ and $F_{act.} = 10.65 > F_{tabl.0.1} = 5.35$ $P < 0.01$.

The research findings showed that significantly highest phytomass dry matter content was left in the soil by differently-managed lucerne and red clover of the 2nd year of use (Fig.).



Notes. LSD_{05} total phytomass – 5.227; * – significant at $P < 0.05$, and ** – significant at $P < 0.01$. R – ploughed-in only residues, aboveground mass removed from field; R + A – ploughed-in total phytomass.

Figure. Phytomass of perennial grasses and C:N ratio (mean data 2003–2004 and 2004–2005)

Lucerne and red clover have the most abundant root system, compared with that of other species tested. Plant roots can be a relevant carbon sequestration source (Hogberg, Hogberg, 2002). Lucerne and red clover residues (roots and stubble) accounted for 92.4% and 87.2% of the total phytomass used for green manure. Differently-managed white clover left the lowest content of phytomass dry matter (on average 4.31 t ha^{-1}), whose residues accounted for 64.3–77.9% of the total phytomass used for green manure. The researchers suggest that the ratio of legume roots to above-ground part is highly dependent on legume species, management and plant age (Slepetys, 2009).

By fully utilising the entire growing season, perennial grasses withhold nutrients in the topsoil layer and accumulate a high biogenic element potential in the phytomass. Chemical analyses of the phytomass of the tested grasses revealed that the aboveground mass and residues (roots and stubble) differed in the composition of biogenic elements.

Incorporated nitrogen content in the soil was significantly dependent upon the residue quantity of perennial grass species and plant age (Table 2). With incorporation of lower residue content of perennial grasses of the 1st year of use, the soil received less nutrients than with residues of perennial grasses of the 2nd year of use. According to literature (Šarūnaitė et al., 2008), the herbage yield and amount of nitrogen accumulated in herbage and biologically fixed over the two years of sward's age depended on legume species and competitive plant (cover crop) species. The amounts of nitrogen accumulated by red clover and ryegrass swards and those of biologically fixed nitrogen were significantly lower than those accumulated and fixed by lucerne/ryegrass swards.

Table 2. The amount of nutrients incorporated into the soil with phytomass of perennial grasses (kg ha^{-1}), 2003–2005

Perennial grasses	$N_{tot.}$		P_2O_5		K_2O	
	residues	aboveground mass	residues	aboveground mass	residues	aboveground mass
Perennial grasses of the 1st year of use, 2003–2004						
Timothy (R)	52.30	4.05[1]	6.30	0.6[1]	22.30	5.6[1]
Red clover (R + A)	112.75	66.15*	11.55	7.45**	49.5	55.65*
Red clover (R)	137.00	–	14.80	–	58.75	–
White clover (R + A)	63.00	55.3*	4.05	7.75**	17.55	48.45*
White clover (R)	60.6	–	5.15	–	21.25	–
Perennial grasses of the 2nd year of use, 2004–2005						
Timothy (R)	88.45	–	14.4	–	56.35	–
Lucerne (R + A)	243.15**	51.50	25.65**	5.35*	123.35**	30.9
Lucerne (R)	262.6**	–	26.00**	–	133.55**	–
Red clover(R + A)	184.85*	43.35	20.40	4.35	100.15*	29.15
White clover (R + A)	45.8	23.55	5.65	3.60	25.1	13.85
LSD_{05}	105.093	48.501	14.288	3.779	60.568	34.155

Notes. * – significant at $P < 0.05$, and ** – significant at $P < 0.01$; [1] – aftermath of timothy for the statistical calculation. R – ploughed-in only residues, aboveground mass removed from field; R + A – ploughed-in total phytomass.

Subject to the species of plants, their biological and morphological properties, biomass and chemical composition, major nitrogen content was incorporated into the soil after ploughing phytomass of differently-managed lucerne and red clover of the 2nd year of use. Significantly lower nitrogen content was incorporated into the soil together with phytomass of white clover and timothy, on average 2.4–3.6 times less, compared to red clover and lucerne sward.

The largest amounts of phosphorus and potassium, like those of nitrogen, were contributed to the soil with lucerne aboveground mass and residues. With red clover phytomass the soil received 129.3 kg ha^{-1} K_2O and a relatively small quantity of P_2O_5 (24.75 kg ha^{-1}). Significantly lower phosphorus and potassium content was incorporated into the soil with the phytomass of white clover and timothy.

Phytomass quality is defined by the carbon to nitrogen ratio (C:N) (Fig.). The C:N ratio, which determines transformation processes of the incorporated organic matter in the soil differed between the aboveground and residue (roots and stubbles) mass and between grass and legume species and between plant age. It has been found that plant materials with a C:N ratio less than 20 may result in net N mineralization and those with a C:N ratio greater than 20 tend to cause net immobilization (Quemada, Carbrera, 1995).

The C:N ratio of the aboveground mass of perennial grasses was lowest and more favourable for a more rapid decomposition (10.0–14.0) than in residues (roots and stubble) (20.0–36.0). This was determined by plant development stage, because phytomass was ploughed-in at the beginning of flowering. In perennial grass residues, carbon to nitrogen ratio depended on grass species and their development stage. The C:N ratio of lucerne and both clover species was similar (22.0–27.0); however, much lower than that of timothy (36.0). The higher C:N for timothy was determined by a low nitrogen content in its phytomass. The C:N ratio of perennial grasses of the 1st year of use was established to be lower than that of perennial grasses of the 2nd year of use. The higher C:N ratio moderated decomposition of incorporaded organic matter.

Perennial grasses with different biological characteristics determined a diverse accumulation of total nitrogen, organic carbon and available P_2O_5 and K_2O in the soil (Table 3).

N and C generally are closely linked, but their accumulation dynamics may differ (Vertès et al., 2007). The correlation regression analysis showed that after ploughing-in perennial grasses, the relations of organic carbon to total nitrogen and available phosphorus to organic carbon were moderately strong and significant (r = 0.510* and 0.490*, respectively).

Before sowing spring barley, the content of organic carbon in the soil tended to increase compared to analogical data before the trial establishment. The content of total nitrogen in the soil was 0.06–0.11%; however, compared with its content before the trial the content of total nitrogen after lucerne (R + A) was higher by 11.0%, after differently-managed white clover by 20.0–37.5%.

Table 3. The effect of different perennial grasses for green manure on the variation of soil agrochemical properties, 2002–2006

Perennial grasses for green manure	Before trial establishment				Before spring barley sowing			
	$C_{org.}$	$N_{tot.}$	P_2O_5	K_2O	$C_{org.}$	$N_{tot.}$	P_2O_5	K_2O
	%		mg kg^{-1}		%		mg kg^{-1}	
Perennial grasses of the 1st year of use ploughed-in as green manure								
	2002–2003				2004–2005			
Timothy (R)	0.97	0.10	159	149	1.18	0.09	162	124
Red clover (R + A)	0.95	0.09	182	120	1.32	0.08	161	124
Red clover (R)	0.96	0.10	141	122	1.06	0.10	129	99
White clover (R + A)	0.94	0.11	156	161	1.12	0.09	161	134
White clover (R)	0.92	0.08	199	166	0.96	0.11	187	115
Perennial grasses of the 2nd year of use ploughed-in as green manure								
	2002–2003				2005–2006			
Timothy (R)	0.90	0.08	130	120	1.11	0.08	84	130
Lucerne (R + A)	1.00	0.09	134	150	1.14	0.10	115	103
Lucerne (R)	0.94	0.08	104	148	1.21	0.08	96	131
Red clover (R + A)	1.01	0.11	131	148	1.34	0.11	118	124
White clover (R + A)	1.05	0.10	119	140	1.28	0.12**	121	116
LSD_{05}	0.110	0.047	68.350	84.117	0.363	0.024	74,190	58.718

Notes. ** – significant at $P < 0.01$. R – ploughed-in only residues, aboveground mass removed from field; R + A – ploughed-in total phytomass.

The amount of available phosphorus increased (1.7–3.2%) with ploughing-in white clover aboveground mass. The amount of available potassium increased (3.3–8.3%) with ploughing-in red clover of the 1st year of use aboveground mass and timothy of the 2nd year of use.

According to the numerous studies in Estonia, in the case of barley growing after residues of red clover and lucerne, the estimated N input to the soil was 220–237 kg ha^{-1}, after white clover 247 kg ha^{-1} (Viil, Võsa, 2005; Talgre et al., 2009).

Spring barley was grown after winter triticale which accounted for part of the nutrients inserted into the soil with green manure (Skuodiene, Nekrosiene, 2012).

With mineralization of residues of perennial grasses, gradually released nitrogen exerted a significant effect on the yield forming elements of spring barley (Table 4). Perennial grasses of the 2nd year of use determined more favourable soil conditions for the development of spring barley. Lucerne and red clover of the 2nd year of use have the most abundant root system, compared with that of other species tested. Decomposition of the roots was slower than the above-ground biomass (Velička et al., 2006).

According to the average research data, spring barley grown after perennial grasses of the 2st year of use was denser than after perennial grasses of the 1st year of use: spring barley total and productive stem number was essentiality higher. The 1000 grain weight and spring barley grain yield was higher after perennial grasses of the 2st year of use too.

Table 4. The influence of perennial grasses on biometrical indices and spring barley grain yield ($x \pm$ SE), 2005–2007

Perennial grasses for green manure	Number of stems m^{-2}	Number of productive stems m^{-2}	1000 grain weight g	Grain yield t ha^{-1}
Perennial grasses of the 1st year of use ploughed-in as green manure, 2005–2006				
Timothy (R)	394.2 ± 14.11	300.5 ± 12.40	35.65 ± 0.46	1.44 ± 0.20
Red clover (R + A)	437.0 ± 22.33	325.8 ± 15.49	34.42 ± 0.76	1.51 ± 0.15
Red clover (R)	439.0 ± 19.24	316.5 ± 17.41	34.49 ± 0.88	1.49 ± 0.13
White clover (R + A)	400.8 ± 23.38	296.2 ± 25.20	34.77 ± 0.68	1.47 ± 0.19
White clover (R)	452.5 ± 26.06	339.0 ± 24.29	36.26 ± 0.38	1.35 ± 0.05
Perennial grasses of the 2nd year of use ploughed-in as green manure, 2006–2007				
Timothy (R)	491.2 ± 39.26*	323.5 ± 28.61	35.43 ± 0.48	1.55 ± 0.09
Lucerne (R + A)	557.0 ±43.29**	376.5 ± 31.80*	36.14 ± 0.19	1.80 ± 0.12**
Lucerne (R)	553.2 ±29.39**	369.0 ± 22.44*	36.78 ± 0.31	1.64 ± 0.13
Red clover (R + A)	537.0 ±36.85**	369.5 ± 26.69*	36.44 ± 0.29	1.58 ± 0.17
White clover (R + A)	511.0 ±35.22**	357.2 ± 31.22	36.42 ± 0.41	1.60 ± 0.17
LSD_{05}	77.610	64.746	1.476	0.267
Results of Fisher-test of productivity parameters of spring barley				
Replication variance	3.16**	2.32*	1.36	15.66**
Treatment variance	4.93**	1.65	2.80	1.72

Notes. * – significant at $P < 0.05$, and ** – significant at $P < 0.01$. R – ploughed-in only residues, aboveground mass removed from field; R + A – ploughed-in total phytomass.

The correlation of spring barley total stem number, productive stem number and grain yield with the content of organic carbon accumulated by perennial grasses was moderately strong and strong (r = 0.504*, 0.640** and 0.727**, respectively). The correlation of spring barley productive stem number, grain yield with the content of available phosphorus accumulated by perennial grasses was moderately strong and strong (r = 0.506* and 0.790**, respectively). Available potassium content in the soil influenced only barley grain yield (r = 0.548*). There was no relation between 1000 grain weight and agrochemical soil properties.

Spring barley productivity was significantly influenced by species of perennial grasses as well as methods of their aboveground mass application. Comparison of various perennial grasses used as green manure revealed that spring barley yield was highest in the background of lucerne (R + A). This practice of cereal cultivation resulted in the highest grain yield, 9.0–14.0% higher than that after perennial grasses of the 2nd year of use and 16.0–25.0% higher than that after perennial grasses of the 1st year of use. Andersen and Olsen (1993) have not found any second-year after-effect and Schröder et al. (1996) found only a slightly increasing after-effect of green manures on barley yield. Research, carried out in Estonia, showed a significant positive second-year after-effect on the barley yield with pure sowings of red clover and lucerne as green manure (Talgre et al., 2009).

One of the major factors affecting spring barley productivity is disease infestation. During the 2005–2007 period, spring barley leaves were affected by a total of 6 species of pathogenic fungi. However, only *Drechslera teres* (Sacc.) Shoem. causing net blotch, spot blotch (causal agent *Drechslera sorokiniana* (Sacc.) Subram.) and septoria speckled leaf blotch (causal agent *Septoria* spp.) occurred in spring barley crop most severely during the growing season. The 1.1–1.3 times higher disease incidence (from 90% to 100%) and 1.7–2.1 times higher diseases severity (from 10% to 70%) were recorded in 2006 compared to disease incidence and severity in 2005 and 2007. Although the weather conditions in 2006 were inimical for the spread of barley foliar diseases due to the general lack of moisture, a higher incidence of all foliar diseases was noted with higher rainfall at the end of May. The dry weather that set in later did not inhibit the spread of barley foliar diseases. The summer of 2007 was very favourable for rapid net blotch spreading and development, when high levels of infection were reported all across Lithuania. But infection scorings in the field conditions in Central Lithuania were relatively low. It was explained by different origin of barley varieties used in the experiment growing in a small area (Statkevičiūtė, Leistrumaitė, 2008). In different years, at spring barley booting stage (BBCH 37–39), diseases affected from 80% to 90% of the barley leaves tested and the disease severity was from 7.95% to 10.05%. At spring barley milk maturity stage (BBCH 73–75), in many cases we recorded 100% incidence of diseases and an especially high severity (about 50–60%). The experiment carried out at the same location in 2003 and 2004 showed that spring barley (cvs 'Barke' and 'Prestige') at milk maturity stage was affected by foliar diseases in average 10.05–20.43% (Brazienė et al., 2008). In this experiment, spring barley was fertilized with mineral fertilizers and grain yield was on average twice as high as in our experiment. However, research carried out in South Lithuania showed that with increased nitrogen fertilizer incorporation into the soil the severity of net blotch and spot blotch tended to increase, but the severity of leaf blotch tended to decrease (Brazienė, Dabkevičius, 2002). While in Estonia, research done under similar conditions gave opposite results: 1.2 times lower disease incidence was recorded on spring barley grown in the soil heavily fertilized with organic fertilizers, compared with the disease severity on spring barley without any fertilization (Lõiveke, Sepp, 2009). Crops receiving more nitrogen are denser, and therefore less rainfall reaches the base of the canopy. The interactions between crop and pathogen development are discussed with reference to the implications for predicting disease risk. The development of sustainable strategies for the management of diseases depends on an improved understanding of the biology of diseases and its interactions with the barley host. A move towards more intensive barley production and early and extended crop planting coupled with cultivar susceptibility are believed to have contributed to increased levels of diseases. Different cultural strategies to decrease the severity of diseases, such as crop rotation, use of differently-managed perennial grasses as green manure, different species of the perennial grasses are aimed at different stages in the development of epidemics. Averaged data of our experiment suggest that at spring barley booting stage foliar disease incidence was 1.1–1.2 times higher on the spring barley that had been grown after differently-managed perennial grasses of the 2nd year of use. In all agrocenoses, the highest disease incidence (from 93.55% to 98.60%) was recorded on spring barley grown after lucerne, compared with its incidence on spring barley grown after differently-managed other species of perennial grasses. Nearly 100% of spring barley in all treatments was affected by foliar diseases at milk maturity stage, therefore there were no differences established between spring barley grown under different nutrition conditions. Significant differences in disease incidence between the treatments stood out only at the end of barley vegetation – milk maturity stage when the disease severity reached 50% and more. A 1.1–1.2-time higher disease severity was recorded on spring barley grown after red and white clover of the 2nd year of use, particularly after lucerne. The lowest disease severity was recorded on spring barley grown after timothy. According to the analysis of variance, spring barley foliar disease severity significantly depended on the growing conditions: $F_{act.} > F_{tabl.}$ (Table 5).

When estimating disease infestation, it is important to relate it to plant population density. It is maintained that more conducive conditions for disease spread occur in a denser stand (Robinson, Jalli, 1999). Our research evidence suggests that a slightly higher disease incidence occurred in a spring barley stand with a higher population density. The relationship between disease severity at spring barley milk maturity stage and number of total spring barley stems and productive stems was very strong (Table 6). The same trend was established

Table 5. Analysis of variance of spring barley foliar disease severity

Variance	DF	Sum of squares	Mean squares $F_{act.}$	Mean squares $F_{tabl.0.5}$	Mean squares $F_{tabl.\ 0.1}$
Total	65	2546.22	–	–	–
Treatments	16	1144.25	19.22**	4.44	7.85
Replications	6	1511.01	8.45*	4.02	7.12
Years	1	30.21	2.55	3.85	5.89
Stages of spring barley maturity	2	102.44	4.01	5.16	8.15

* – significant at $P < 0.05$, and ** – significant at $P < 0.01$

Table 6. The effect of foliar disease severity (x) on spring barley productivity (y) parameters as influenced by green manure application

Data averaged over 2005–2007

Spring barley productivity parameters	Correlation coefficients	Regression equations
Disease severity at spring barley booting stage		
Number of stems m^{-2}	0.455*	y = 15.061 + 0.022x
Number of productive stems m^{-2}	0.502*	y = 19.245 + 0.602x
Disease severity at spring barley milk maturity stage		
Number of stems m^{-2}	0.905**	y = 45.086 + 0.055x
Number of productive stems m^{-2}	0.834**	y = 39.442 + 0.012x
1000 grain weight g	0.332	y = 8.450 − 0.521x
Grain yield t ha^{-1}	0.320	y = 6.95 − 0.025x

* – significant at $P < 0.05$, and ** – significant at $P < 0.01$

at the spring barley booting stage too. This indicates that disease incidence during the experimental period was influenced namely by the nutrition conditions of spring barley habitat which were formed by the perennial grasses' phytomass incorporated into the soil in the crop rotation. Decreasing crop density during the growing season can reduce severity of some disease epidemics in barley crops (Hoad, Wilson, 2006). Decreasing rate of nitrogen applications may have a similar effect, perhaps mediated through effects on micro-climate or on barley physiology, which may affect disease pathogenesis. Such input reductions may not decrease profitability, since lower crop density may not decrease yield, or decreased fertiliser costs with lower nitrogen inputs may compensate for decreased yield. Changes in canopy structure induced by changes in cultural practices constitute disease escape mechanisms. Hoad and Wilson (2006) also noted that these cultural changes could be associated with changes in plant growth habit and that a semi-prostrate habit during stem extension was associated with decreased severity of diseases on the upper leaves.

Disease severity had no significant influence on 1000 grain weight and grain yield of spring barley (Table 6). It was established that these spring barley productivity parameters did not vary visibly between the treatments (Table 4). There are several experiments showing that net blotch infection suppresses spring barley height and reduces yield due to 1000 grain weight reduction, but has no effect on spike number (Robinson, 2000). The data of the experiment, conducted at the Lithuanian Institute of Agriculture in 2007 did not show any significant changes in spike number either, but the number of spikelets was reduced in many cases (Statkevičiūtė, Leistrumaitė, 2008).

Conclusions

1. Higher contents (by 1.2–5.2 times) of nitrogen, phosphorus and potassium were contributed to the soil with lucerne and red clover phytomass of the 2nd year of use, compared with those contributed to the soil with the phytomass of perennial grasses of the 1st year of use. The phytomass of perennial grasses of the 2nd year of use, ploughed-in as green manure, determined more favourable soil properties, and this had a positive effect on the formation of productivity elements of spring barley grown in a crop rotation in the second year.

2. The residual effect of phytomass of differently-managed perennial grasses influenced the interactions between spring barley agrocenosis components. The correlation of spring barley total stem number, productive stem number and grain yield with the content of organic carbon in the soil was moderately strong and strong (*r* = 0.504*, 0.640** and 0.727**, respectively). The correlation of spring barley productive stem number and grain yield with the content of available phosphorus in the soil was moderately strong and strong (*r* = 0.506* and 0.790**, respectively). Available potassium content in the soil influenced only barley grain yield (*r* = 0.548*).

3. Spring barley yielded best after lucerne, when its aboveground mass had been ploughed-in as green manure. This practice of cereal cultivation resulted in the highest grain yield or 9.0–14.0% higher than that after red and white clover and timothy of the 2nd year of use and 16.0–25.0% higher than after perennial grasses of the 1st year of use.

4. Spring barley grown without chemical fertilizers and plant protection measures were infected by foliar diseases at a very high level. Foliar disease incidence and severity were by 1.1–1.2 times higher in the agrocenoses of spring barley after legumes of the 2nd year of use, compared with spring barley grown after perennial grasses of the 1st year of use. Spring barley stand was denser there too. The total and productive number of stems per crop stand had a significant effect on spring barley foliar disease severity ($P < 0.05$).

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Daugiamečių žolių kaip žaliosios trąšos įtaka dirvožemio agrocheminiams rodikliams ir vasariniams miežiams

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Santrauka

Lauko bandymai vykdyti Lietuvos žemdirbystės instituto Vėžaičių filiale. Dirvožemis – pajaurėjęs giliau glėjiškas išplautžemis (IDg 4-e), lengvas priemolis ant vidutinio sunkumo priemolio. Tikslas – ištirti skirtingai naudojamų daugiamečių žolių fitomasės kaip žaliosios trąšos įtaką gerinant dirvožemio savybes ir sėjomainoje auginamų vasarinių miežių produktyvumui bei fitopatologinei būklei antraisiais žaliosios trąšos poveikio metais. Nustatyta, kad daugiausia augalų fitomasės dirvožemyje liko po įvairiai naudojamų mėlynžiedžių liucernų (19,48 ir 17,29 t ha^{-1}) ir antrųjų naudojimo metų raudonųjų dobilų (13,06 t ha^{-1}). Su fitomase į dirvožemį azoto pateko atitinkamai 294,6, 262,6 bei 228,2 kg ha^{-1}, fosforo – 31,0, 26,5 bei 24,8 kg ha^{-1} ir kalio – 154,2, 133,6 bei 129,3 kg ha^{-1}. Daugiamečių žolių antžeminės masės C:N santykis buvo mažiausias ir palankesnis greitesniam skaidymuisi (10,0–14,0) nei liekanų (šaknų bei ražienų) (20,0–36,0). Mineralizuojantis antrųjų naudojimo metų daugiamečių žolių fitomasei, dirvožemyje sukaupti mitybos elementai turėjo teigiamos įtakos antraisiais metais po žaliosios trąšos įterpimo augintiems vasariniams miežiams. Vasarinių miežių bendro bei produktyvių stiebų skaičiaus ir grūdų derliaus ryšys su daugiamečių žolių suformuotu C kiekiu dirvožemyje buvo vidutinio stiprumo ir stiprus (atitinkamai r = 0,504*, 0,640** ir 0,727**). Vasarinių miežių produktyvių stiebų skaičiaus ir grūdų derliaus ryšys su daugiamečių žolių suformuotu fosforo kiekiu dirvožemyje buvo vidutinio stiprumo ir stiprus (atitinkamai r = 0,506* ir 0,790**). Kalio kiekis dirvožemyje turėjo įtakos tik miežių grūdų derliui (r = 0,548*).
Skirtingos vasarinių miežių mitybos sąlygos turėjo reikšmingos įtakos (P < 0,05) šių javų lapų ligų plitimui. Miežiuose, augusiuose dirvožemyje, į kurį įterptos antrųjų naudojimo metų pupinės žolės, fiksuotas 1,1–1,2 karto intensyvesnis lapų ligų išplitimas ir intensyvumas. Bendras bei produktyvių miežių stiebų skaičius reikšmingai didino šių augalų lapų ligų intensyvumą miežių bamblėjimo ir pieninės brandos tarpsniais (atitinkamai r = 0,455*, 0,502*, 0,905** ir 0,834**), tačiau lapų ligų intensyvumas neturėjo reikšmingos įtakos miežių grūdų derliui ir 1000-čio grūdų masei.

Reikšminiai žodžiai: daugiametės žolės, fitomasės įtaka, vasariniai miežiai, produktyvumas, ligos.