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THE VALUE OF GREEN MANURES IN SUSTAINABLE MANAGEMENT IN SPRING BARLEY AGROCENOSES

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ABSTRACT

Field experiments were conducted at the Vezaiciai Branch of the Lithuanian Research Centre for Agriculture and Forestry during the period 2002-2007. Different green manure crops were compared for amounts of N, P, K and C organic left into soil; their effects on spring barley productivity and incidence of foliar diseases were estimated. The highest amounts of plant residues were left in the soil by variously-managed Lucerne and red clover of the 2nd year of use. With Lucerne (ploughed-in residues and aftermath growth, and only residues ploughed-in) and red clover, the soil received 303.6, 271.2 and 236.2 kg ha^{-1} of nitrogen, 32.3, 27.3 and 25.9 kg ha^{-1} of phosphorus, and 166.6, 144.6 and 139.8 kg ha^{-1} of potassium respectively. Timothy and legumes of the 2nd year of use residues and ploughed down green manures positively affected productivity of spring barley. Variously-managed timothy and legumes had a significant effect on the spread of foliar diseases in spring barley, by improving the N supply and increasing stand density.

Key words: green manure, spring barley, yield forming elements, foliar diseases.

INTRODUCTION

Organic farming is a priority trend of economic development in Lithuania. By the end of 2012, the agricultural area occupied by organic farming in Lithuania was 162600 hectares. But not all territories are usable for such farming. Nearly 40% of the soils are insufficiently fertile (Tripolskaja and Šidlauskas, 2010); moreover, those in the Western part of the country are characterised by an acid reaction (Repsiene and Skuodiene, 2010). To sustain fertility of such soils, organic fertilization is imperative. Currently, in Lithuania‘s small farms, animal manure and mineral fertilisers are used considerably less than in large-scale agricultural production, resulting in a negative soil humus balance. Thus, both soil fertility and crop productivity depend largely on the use of organic fertlilisers in both organic and conventional cultivation; consequently, green manure crops have an increasingly important role in farming (Talgre et al., 2009b). 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). Cultivation of legumes results in an increase mobility of phosphorous compounds in the soil, enriches soil with organic matter too (Tripolskaja, 2005; Talgre et al., 2009a). The largest amount of organic matter is left in soil with residues of perennial grases, less with other crops (Maiksteniene and Arlauskiene, 2004).

Spring barley is one of the main food crops in Europe, but it is often subjected to various harmful diseases in its growth and development process. Resistance against diseases is one of the key factors for plants used in organic farming systems (Bankina and Gaile, 2009). Many authors indicated that the incidence of fungal diseases of barley is determined by the weather conditions, imbalanced mineral fertilisation (barley growing on potassium deficient soil is more susceptible to powdery mildew), crop species and variety, soil preparation,

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preceding crops and other factors (Bailey et al., 1996; Dreiseitl, 2007; Jayasena et al., 2008).

The present study is a comprehensive rotation trial involving the range of rotations commonly practiced in the Lithuania western region, to estimate the beneficial effect of the green manure on C, N, P and K amounts in the soil. Few studies have considered the effect of variable residues on soil organic matter status. Although legumes in rotation generally increase soil organic matter, this depends on the legume in question. For instance, in Australia, Whitebread et al. (2000) found that lucerne increased soil organic matter (Whitebread et al., 2000). There is a high potential to improve yields in organic cereal systems through improved management of green manures. This requires a more detailed knowledge of the short and long term N cycling of green manure residues for specific crop rotations and soils (Doltra and Olesen, 2013).

Not only are these cereal-legume rotation economically viable, they can also improve soil structure and sequester atmospheric C as well, thus helping to mitigate the adverse effects of greenhouse gasses. Any modest increase in soil C from cropping would have a major impact on global C sequestration.

The aim of the present study was to explore the effects of variously-managed legumes and timothy phytomass used as green manure on spring barley nutrition conditions, yield forming indicators and incidence of foliar diseases.

MATERIAL AND METHODS

Site description

The field experiments were conducted in Western Lithuania at the Vezaiciai Branch of the Lithuanian Research Centre for Agriculture and Forestry (central coordinates: 55°43'24N, 21°27'24E) in 2002-2007. Two analogous experiments were set up in 2002 and 2003. The field experiments were done following multi-factorial method. The total plot size amounted to 96.0 m^2 (6.0 x 16.0m), harvested area of legumes and timothy to 22.4 m^2 (1.4 x 16.0 m), and harvested area of cereals to 36.8 m^2 (2.3 x 16.0 m). The experimental treatments were replicated four times and were arranged randomly. The soil of the experimental site was albi-edohypogleyic luvisol, light loam on medium heavy loam, pH_{KCl} 6.0-6.1. Some other soil agrochemical characteristics are presented in Table 3.

Experimental design

The experiments were conducted in the following crop rotation sequence: spring barley (*Hordeum vulgare* L.) variety ‘Ula’ undersown with perennial crops; perennial crops (pure); winter triticale (*Triticosecale* Wittm.) variety ‘Tevo’; spring barley.

Perennial crops: red clover (*Trifolium pratense* L.) ‘Vyliai’, white clover (*Trifolium repens* L.) ‘Suduviai’, Lucerne (*Medicago sativa* L) ‘Birute’ and timothy (*Phleum pratense* L.) ‘Gintaras II’ were chosen as green manure for winter triticale. Spring barley was grown after winter triticale.

Legumes and timothy were treated differently by development:

- Legumes and timothy of the 1st year of use, ploughed as a green manure.
- Legumes and timothy of the 2nd year of use, ploughed as a green manure.

Management regimes of legumes and timothy were different too:

- Cut twice (1st and 2nd crop for forage), ploughed-in residues (R).
- 1st crop for forage, ploughed-in residues and aftermath (R+A).

What we mean by aftermath is the second crop of herbage that grew after timothy and legumes first cut.

For a control treatment timothy grass was chosen, which is best adapted to Lithuania's natural conditions.

The phytomass was chopped and shallowly incorporated during beginning of flowering of legumes and beginning of ear emergence of timothy. After two weeks the phytomass was deeply ploughed in 25 cm. Before sowing, the field was cultivated and harrowed at the same time. The winter triticale was sown at a rate of 200 kg ha^{-1}. The spring barley was grown after winter triticale (sown at 200 kg ha^{-1}). Cereals were grown considering ecological cultivation recommendations. Seeking to determine the ecological value of different preceding crops, no mineral fertilisers and plant protection products were used.

Plant and soil analyses

Plant residues mass was determined by the Katchinski monolith washing method. We considered the following as plant residues: stubble, undecomposed plant parts present on the soil surface and roots situated up to the 25 cm depth. The mass of all plant residues and overground mass were re-calculated to 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 green manure of legumes and timothy and in the plant residues was determined by colorimetry and potassium by flame photometry methods, total nitrogen by Kjeldahl.

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

Soil agrochemical characteristics in the 0-20 cm soil layer were determined using the following methods: pH_{KCl} – by electrometric method, available P_2O_5 and K_2O – by spectrometrical method from the Egner-Riem-Domingo (A-L) extract, total nitrogen by Kjeldahl, organic carbon by a elementar Analysen systeme (GmbH version V4.6.2*)*, type Liqui TOC II. The analyses regarding chemical qualities of plant and soil were carried out at the Agrochemical Laboratory of the Lithuanian Research Centre for Agriculture and Forestry.

Diseases assessment

Foliar disease assessments on spring barley were carried out in 2005-2007 at stem elongation stage (BBCH 37-39) and at milk maturity stage (BBCH 73-75). Growth stage (BBCH) was recorded at disease severity assessment (Meier, 1997). For averaging, 50 sample plants were collected from ten locations on every plot, on every variant by diagonals, 4 average samples. The following methods were used for the diagnostics of foliar fungal diseases: visual, according to external symptoms and microscopy. To assess foliar diseases EPPO guidelines were used (EPPO Standarts, 2004). Disease incidence, i.e. per cent of disease-affected leaves was calculated. Disease severity was calculated having added per cent of affected leaf area of each leaf and having divided the sum by the number of assessed leaves.

Climatic conditions

Western regions of Lithuania are strongly affected by the maritime climate (in winter it is warmer, in summer it is cooler than in eastern regions).

The soil is more podzolized and acid than in the other regions, it receives the highest rate of precipitation, which has amounted to on average 862 mm annually during the last 10 years. Weather data were acquired from the local automatic weather station located in immediate proximity (400-500 m) of trials.

Table 1. Weather conditions for 2002-2007, according to the Vezaiciai weather station

Year	2002	2003	2004	2005	2006	2007
Annual mean air temperature (°C)	7.8	7.0	7.0	7.0	7.5	7.9
Difference from long-term mean (°C)	+1.1	+0.3	+0.3	+0.3	+0.8	+1.1
Vegetation period mean air temperature (°C)	13.5	12.2	12.4	12.7	13.6	12.9
Difference from long-term mean (°C)	+1.4	+0.1	+0.3	+0.6	+1.4	+0.7
Annual precipitation totals (mm)	865.0	767.8	904.1	990.5	675.6	1244.3
Annual precipitation totals as percentage of the long-term mean (%)	102.5	91.2	107.2	117.2	80.2	146.5
Vegetation period precipitation totals (mm)	433.0	536.9	549.7	608.7	370.4	700.6
Difference from long-term mean (mm)	-82.2	+21.4	+33.7	+91.0	-143.9	+518.2

Weather conditions during years differed considerably, and this affected not only the development of legumes and timothy but also organic matter breakdown intensity and formation of cereal yield biological parameters, and disease occurrence (Table 1).

RESULTS

Amount of nutrients in the residues of crops and soil agrochemical properties

In our research legumes and timothy differing in phytomass and chemical composition were chosen as preceding crops for cereals. Significantly highest phytomass dry matter content was left in the soil by variously-managed Lucerne (17.29 and 19.48 t ha^{-1}) and red clover of the 2^{nd} year of use (13.06 t ha^{-1}) (Table 2).

Lucerne and red clover residues (roots and stubble without aftermath) accounted for 92.4 and 87.2% of the total phytomass used for green manure. Variously-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.

Table 2. Amount of nutrients in the residues of crops for green manure.
Average data of 2003-2005

Crops for green manure	Phytomass and amount of nutrients			
	Dry matter t ha^{-1}	N	P	K
		kg ha^{-1}		
Timothy and legumes of the 1^{st} year of use had been ploughed as a green manure				
Timothy (R) – control treatment	7.21	60.2	7.7	34.1
Red clover (R+A)	8.83	185.8*	20.5	115.0
Red clover (R)	6.98	144.8	16.1	67.4
White clover (R+A)	5.82	125.9	13.3	79.1
White clover (R)	4.31	68.9	6.6	32.1
Timothy and legumes of the 2^{nd} year of use had been ploughed as a green manure				
Timothy (R)	10.17	95.0	15.6	63.8
Lucerne (R+A)	19.48**	303.6**	32.3**	166.6**
Lucerne (R)	17.29**	271.2**	27.3*	144.6**
Red clover (R+A)	13.06*	236.2**	25.9*	139.8*
White clover (R+A)	3.99	77.0	10.7	46.4

In phytomass of legumes and timothy nitrogen reached 54.5-63.4% from total (N, P and K) amount, phosphorus – 6.1-8.9% and potassium – 29.5-36.6%.

Lucerne produced significantly highest phytomass yield and left the highest nutrient contents in the soil. After ploughing in of lucerne aftermath, the soil received 303.6 kg ha^{-1} of nitrogen, 32.3 kg ha^{-1} of phosphorus and 166.6 kg ha^{-1} of potassium.

Of the plants grown as green manure, lucerne proved to be the most valuable one since it contains of all nutrients 1.2-2.5 times more than after variously-managed red clover and 2.1-5.2 times more than after variously-managed white clover and 2.1-5.0 times more than after variously-managed timothy.

Legumes and timothy 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).

According to research data, of the 2^{nd} year of use of legumes and timothy as a green manure the content of organic carbon in the soil had a tendency to increase.

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 by 11.0% higher, and after variously-managed white clover by 20.0-37.5% higher.

The biggest amount (by 1.7-3.2%) of available phosphorus was found in the soil with ploughing in white clover aftermath, in comparison with amount of this element in the soil with ploughing in other crops for green manure. Whereas the amount of available potassium was the bigest by 3.3-8.3% in the soil with ploughing in red clover of the 1st year of use aftermath and timothy of the 2nd year of use.

Table 3. The effect of different crops for green manure on the variation of soil agrochemical properties. Average data of 2002-2006

Crops for green manure	Before trial establishment				Before sowing of spring barley			
	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 crops of the 1st year of use had been ploughed as a green manure								
Timothy (R) – *control treatment*	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 crops of the 2nd year of use had been ploughed as a green manure								
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	0.06	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

Spring barley productivity

With mineralization of residues of legumes and timothy, gradually released nitrogen exerted a significant effect on the yield forming elements of spring barley (Table 4). The effect of legumes and timothy as pre-crops depends on the development age of grasses and sward management method.

Table 4. The influence of green manure on spring barley grain yield and biometrical indices. Average data of 2005-2007 (x±SE)

Crops for green manure	Number of stems (units m^{-2})	Number of productive stems (units m^{-2})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Timothy and legumes of the 1st year of use had been ploughed as a green manure				
Timothy (R) – control treatment	394.2±14.11	300.5±12.40	1.44±0.20	1.49±0.13
Red clover (R+A)	437.0±22.33	325.8±15.49	1.51±0.15	1.41±0.13
Red clover (R)	439.0±19.24	316.5±17.41	1.49±0.13	1.64±0.11
White clover (R+A)	400.8±23.38	296.2±25.20	1.47±0.19	1.55±0.13
White clover (R)	452.5±26.06	339.0±24.29	1.35±0.05	1.73±0.09
Timothy and legumes of the 2nd year of use had been ploughed as a green manure				
Timothy (R)	491.2±39.26*	323.5±28.61	1.55±0.09	1.84±0.11*
Lucerne (R+A)	557.0±43.29**	376.5±31.80*	1.80±0.12**	2.10±0.15**
Lucerne (R)	553.2±29.39**	369.0±22.44*	1.64±0.13	1.88±0.11*
Red clover (R+A)	537.0±36.85**	369.5±26.69*	1.58±0.17	2.06±0.14**
White clover (R+A)	511.0±35.22**	357.2±31.22	1.60±0.17	1.89±0.16*

Significant impact on spring barley stems number and straw yield, was exerted by the ploughed in legumes and timothy of the 2nd year of use, especially by legumes. Data analysis employing ANOVA showed that lucerne and red clover of the 2nd year of use as pre-crops did not have any significant effect only on spring barley productive stems number. Spring barley yielded best after lucerne, when its aftermath 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 the one after other legumes and timothy of the 2nd year of use and 16.0-25.0% higher than after legumes and timothy of the 1st year of use.

Diseases incidence

Averaged data suggest that at spring barley stem elongation stage foliar diseases incidence was 1.1-1.2 times higher on the cereal crops that had been grown after variously-managed different legumes and timothy of the 2nd year of use. In all agrocenoses, the highest diseases incidence (from 93.55 to 98.60%) was recorded on spring barley grown after lucerne, compared with its incidence on spring barley grown after variously-managed other species of legumes and timothy (Table 5). Because plant protection products were not used, spring barley foliar diseases spread very intensively.

Table 5. The spring barley foliar diseases incidence and severity (%) depending on green manure application. Average data of 2005–2007 (x±SE)

Crops for green manure	Stages of spring barley maturity			
	Stem elongation (BBCH 37-39)		Milk maturity (BBCH 73-75)	
	Disease incidence	Disease severity	Disease incidence	Disease severity
Timothy and legumes of the 1st year of use had been ploughed as a green manure				
Timothy (R) – control treatment	89.35±4.55	7.95±1.25	100±0.0	56.25±5.55
Red clover (R+A)	84.55±7.36	9.98±1.12	100±0.01**	60.80±9.25**
Red clover (R)	82.95±5.55	9.53±0.65*	99±0.01*	59.25±10.60**
White clover (R+A)	86.85±3.65	8.60±0.95**	100±0.0*	60.50±9.65
White clover (R)	83.50±5.89	9.50±0.85**	99±0.01*	57.50±7.50**
Timothy and legumes of the 2nd year of use had been ploughed as a green manure				
Timothy (R)	91.85±8.90	8.50±0.88**	100±0.0**	57.50±3.95*
Lucerne (R+A)	98.60±9.55*	9.25±1.25	100±0.01**	69.80±4.95**
Lucerne (R)	93.55±11.25*	8.60±0.95*	100±0.0**	66.30±9.88*
Red clover (R+A)	88.65±5.65	10.05±1.10*	100±0.0**	66.75±9.55*
White clover (R+A)	92.55±4.85**	9.25±0.35*	100±0.0**	62.50±7.30

When estimating disease infestation, it is important to relate it to plant population density. It is accepted that more conducive conditions for disease spread occur in a denser stand (Robinson and Jalli, 1999). Our research evidence suggests that a slightly higher diseases incidence occurred in a spring barley stand with a higher population density. Relationship beetwen diseases incidence in spring barley stem elongation stage and number of all spring barley stems and productive stems was average and strong (r=0.704** and 0.593*, respectively). Relationship between diseases severity in spring barley at milk maturity stage and number of all spring barley stems and productive stems was very strong (r=0.905** and 0.834**, respectively). This indicates that foliar diseases incidence during the experimental period was influenced by the spring barley stand density. Although in a dense stand higher yields of barley are obtained, a positive correlation was found between the severity of foliar diseases in barley milk maturity stage, and barley grain yield (r=0.415*). Although in this case the spread of diseases did not have a strong negative impact on barley grain yield, on the basis of many years of practice it could be argued that such an intense spread of the diseases can reduced overall spring barley grain yield by about 20%.

DISCUSSION

Research on the use of various herbaceous species for green manure in contemporary agriculture has gained new relevance. Cheap and high quality green manure is an important element in crop alternation in specialised cereal crop rotations. The application of green manure improves phytosanitary state of soils as well as agrochemical and physical soil properties (Romanovskaja and Tripolskaja, 2003). Chen et al. (2011) analysed the effect of meat bone meal as an organic fertiliser on spring barley and oat yield and quality. They concluded that this organic fertiliser is efficient for cereals.

Seeking to balance nutrient transport in the ecosystem, the soil was supplied with overground phytomass of legumes and timothy for green manure. Incorporation of these nutrients is significant in compensating for the amount of nutrients removed with the yield. In the European Union directive 2006/0086 (COD) it is noted that the sustainable use of soils is important to produce as much plant phytomass and accumulate there organic carbon (C), to avoid its decrease in the soil (UUNFCCC..., 1997). A study done in Mediterranean region of Spain demonstated the sustainability potential of the organic farming, in absence of external inputs, adopting rotations based in cereals and legumes in alternate years, and incorporating all the residues into the soil (De Torres et al., 2013).

The effect of plants on the soil is also related to quantity of abandoned roots and aboveground phytomass (Talgre et al., 2009b), their chemical composition (Nemeiksiene et al., 2010), decomposition intensity (Tripolskaja, 2005), and climate conditions (Granstedt, 2000; Magyla et al., 2004).

Based on the calculated nutrient balance, the soil would not be depleted if the soils annually receive on average 120 kg of nitrogen, 40 kg of P_2O_5, and 120 kg of K_2O per hectare (Vaisvila et al., 1997). It was found that in sandy loam luvisol (East Lithuania) with incorporation of red clover aftermath yield the soil received on average 94.9 kg ha^{-1} of nitrogen, 8.64 kg ha^{-1} of phosphorus and 88.3 kg ha^{-1} of potassium (Romanovskaja and Tripolskaja, 2003). Under North Lithuania's conditions, where sod calcareous heavy loam soils prevail, the greatest amounts of nutrients were left in the soil after bastard lucerne (*Medicago varia* Martyn) and red clover, while the lowest contents were left after vetch and oats mixture. Clover left in the soil 56.0 kg ha^{-1} of phosphorus and 228.4 kg ha^{-1} of potassium. This was determined by plant residue mass and its chemical composition (Arlauskiene and Maiksteniene, 2001).

Our experimental findings suggest that under West Lithuania's conditions, in ecologically sensitive areas, the soil received on average 185.8-236.2 kg ha^{-1} of nitrogen, 20.5-25.9 kg ha^{-1} of phosphorus and 115.0-139.8 kg ha^{-1} of potassium with variously-management red clover aftermath yield (Table 2) Such amount of biological nitrogen is valuable from the ecological viewpoint, since it can meet N needs of cereals grown after clover (Maiksteniene and Arlauskiene, 2004).

According to 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} (Talgre et al., 2009a, Viil and Võsa, 2005).

During the experimental period the conditions for green manure mineralization were favourable since the air temperature in August was high 16.7, 18.1 and 16.2°C, in 2003 and 2004, respectively (Table 1). The amount of rainfall that fell in August 2003 and 2005 was much higher (130 and 230%) than the long-term mean and only in 2004 the amount of rainfall was lower (72% from the long-term average).

N and C generally are closely linked, but their accumulation dynamics may differ (Vertès et al., 2007). Correlation regression analysis showed that, after ploughing legumes and timothy, relations of organic carbon with total nitrogen and available phosphorus with organic carbon were moderately strong and significant (r=0.510* and r=0.490*, respectively) (Table 3). The C and N pools in the soil play an important role in nutrient cycling, plant productivity and the quality of the environment (Talgre et al., 2009b).

While calculating the NPK balance in the crop rotation, we estimate how much of these chemical elements is introduced into the soil with green manure, how much of nitrogen, phosphorus, potassium is accumulated by plants and how much is removed with triticale and barley grain and straw yield. Positive balance of all elements was obtained, when for green manure we used red clover and lucerne of the first and second year of use. Negative NPK balance was obtained having used common timothy of the first year and white clover of the second year of use as green manure.

In Western Lithuania soils are characterised by an acid reaction and are nutrient poor. Consequently, without measures to improve soil, spring barley grows and develops poorly; consequently the yields are very low (0.5-1.0 t ha^{-1}). Nutrients, released during mineralization of phytomass of perennial crops 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 stems number, productive stems number and grain yield with the content of organic carbon formed by legumes and timothy was moderately strong and strong (r=0.504*, 0.640** and 0.727**, respectively). The correlation of spring barley productive stems number, grain and straw yield with the content of available phosphorus left by legumes and timothy was also moderately strong and strong (r=0.506*, 0.790** and 0.546*, respectively). Available potassium content in the soil influenced only barley grain yield: r=0.548*.

Legumes and timothy of the 2^{nd} year of use determined more favourable soil conditions for the development of spring barley. Using this practice of cereal cultivation (without mineral fertilizers and farmyard manure), the studied biometrical indices were improved by 12.4-25.0%, compared to legumes and timothy after the 1^{st} year of use (Table 4). Similar regularities of green manure effect were identified while comparing Lucerne, red clover and vetch-oats mixture on heavy-textured soils (Arlauskiene and Maiksteniene, 2002). Andersen and Olsen (1993) did not find 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 leguminous crops and in undersowings of red clover and Lucerne as green manure (Talgre et al., 2009b). The efficiency of green manure in sandy loam soil increased when using this management means together with mineral fertilisation (Romanovskaja and Tripolskaja, 2003).

While the accumulation of C and N from rotation is attributed to the amount of residues from any particular rotation returned to the soil, the persistance of C and N in the soil can also be influenced by the nature of the legume root system, or its biochemical recalcitrance. However, the magnitude of the effect depended on cereal and crops species for green manure, soil and rotation type, and the application of N in manure (Doltra and Olesen, 2013).

Based on the positive relationship between total soil organic matter and the more biologically reactive biomass, labile carbon, and N fractions, the impact of perennial crops residues under western Lithuania conditions is likely to be more pronounced than suggested by gross soil organic matter values.

The occurrence of foliar diseases was significantly influenced by the ecological conditions of the habitat of spring barley. In most cases, statistically significant differences of diseases incidence and severity were established for barley grown after variously-managed different crop species, ploughed in as green manure in the crop rotation (Table 5). As observed by Finckh et al. (2000), cultivation of different plant species in the intercrops is considered to be one of the main plant protection practices reducing disease damage. However, higher diseases incidence and severity were determined on spring barley grown after lucerne or white and red clover, where the greatest amounts of these plant residues were left in the soil. Research carried out in south Lithuania showedthat with increased nitrogen fertiliser incorporation into the soil the severity of diseases tended to increase (Braziene and Dabkevicius, 2002). While in Estonia, research done under similar conditions gave opposite results: 1.2 times lower diseases incidence was recorded on spring barley grown in the soil heavily fertilised with organic fertilisers in the autumn, compared with the disease severity on spring barley without any fertilisation (Lõiveke and Sepp, 2009). However, it is true to say, that in our study spring barley foliar disease differences were likely related to stand density rather than directly due to the species of pre-crop.

CONCLUSIONS

It can be concluded that in order to balance nutrient content in the soil, legumes are recommended to be grown as green manure on organic farms. Some previous studies reported that the best pre-crop for green manure is red clover of the first year of use or lucerne of the third-fourth year of use. In contrast, in our study the greatest effect was achieved when ploughing down red clover or lucerne in the second year of use. Mineralization of their residues in the soil is effective in temperate climate conditions. Aiming at a higher yield increase of spring barley cultivated after winter cereals, it is recommended to plough down legumes, especially lucerne in the second year of use for pre-crops of cereals. This valuable manure can be successfully used in any country producing spring barley. Yet, it is noteworthy that spring barley growing in a nutrient-richer soil may be more prone to foliar diseases. In the case of severe disease occurrence, respective plant protection measures should be applied.

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