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Impact of perennial legumes and timothy as green manure on productivity of *Secale cereale* L. and *x Triticosecale* Wittm and on occurrence of cereal diseases

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Abstract. In 2002–2005 experiments were carried out at the Lithuanian Institute of Agriculture's Vėžaičiai Branch (West Lithuania) on a podzolized gleyic soil to study 1) the ecological significance of perennial legumes and timothy used as green manure for the biological properties of triticale and rye, and 2) on diseases affecting these cereals. Our experimental evidence suggests that residues of the perennial grasses tested and ploughed-in aftermath contributed different contents of nitrogen to the soil. The highest content of nitrogen (185.8 kg ha^{-1}) and other nutrients (P_2O_5, K_2O) was contributed to the soil with the addition of red clover residues and aftermath. However, when triticale and rye were grown after white clover as a preceding crop (1st crop for forage, aftermath ploughed in), the highest grain yield (on average 3.13 t ha^{-1} of triticale and 3.82 t ha^{-1} of rye) was obtained, which was by 0.34 and 0.28 t ha^{-1} higher compared to grain yield following similarly managed red clover. It was determined that some yield-forming indicators of cereal, such as plant height, ear length, number of grains per ear were higher for white clover rather than for red clover or timothy. The choice of preceding crop had no significant effect on differences in protein content in the winter cereal grain. However, different growing conditions of winter cereals, i.e. different preceding crops, had a significant effect on the occurrence of scald, brown rust and septoria.

Key words: green manure, *Secale cereale* L., × *Triticosecale* Wittm., yield, biological properties, diseases

INTRODUCTION

The productivity of winter cereals depends on soil properties, meteorological factors, fertilisation, and especially humus content in the soil. When soil is deficient in humus, the crop yield is highly dependent on climate conditions: in wet years heavy-textured soils tend to become lumpy, whereas in dry years light-textured soils lose moisture rapidly and plants are prone to wilting (Tripolskaja, 2005).

Although crop production farms are generally short of farmyard manure, it can be replaced by green manure. The incorporation of nitrogen-rich plant green material into the soil mobilises nitrogen and intensifies microbiological processes, which result in improved plant nitrogen content, soil structure, stability, etc (Abdallahi & Dayegamiye, 2000; Arlauskienė & Maikštėnienė, 2001; Janušienė & Žekonienė, 2004). The largest amount of organic matter is left in the soil with the residues of perennial grasses, less with annual grasses, winter cereals, maize, spring cereals, grain legumes and others. (Arlauskienė, 2000; Janušienė, 1992; Magyla et al., 1997; Maikštėnienė et al., 2004, Trepaschev, 1979). The use of green manure tends to reduce weed, disease and pest incidence, and fewer nutrients are leached from the plough layer into deeper soil layers (Tripolskaja, 2005).

The residues and ploughed-in green material of perennial grasses used as preceding crops have a positive effect on the formation of productive elements of cereal crops in both the first and second years (Arlauskienė, 2000). In the crop rotations with perennial grasses the soil received much more C, N and ashy elements P_2O_5 and K_2O with plant residues. Protein content in winter cereal grain significantly depended on nitrogen applied with plant residues and organic manure; nitrogen also influenced the grain quality of winter triticale (Royo et al., 1996; Chalk, 1998; Spakov, 1999; Alaru et al., 2003; Maikštėnienė et al., 2004).

In biological farming, which does not allow the use of chemical plant protection products, plant diseases become a grave problem. In the years of strong occurence of disease, yield losses of 30–50% occur (Woś et al., 1994). In many countries winter cereals are heavily damaged annually by diseases such as scald, root rot, leaf spots, and various rusts (Gontarenko et al., 1998). The incidence of fungal diseases in winter cereals is determined by the weather conditions, imbalanced mineral fertilisation, crop species and variety, soil preparation, sowing time, preceding crop, weed infestation, abundance of pests, and luxuriance of the crop stand. It was found that the occurrence of mildews and rusts is determined by the weather conditions, but has less effect on the incidence of scald. In some but not all cases, more abundant mineral fertilisation of winter cereals slows down the spread of Septoria. Some researchers' data suggest that more abundant fertilisation promotes the spread of Septoria (Woś et al., 1994; Bailey et al., 1996, Conway, 1996; Hutcheon et al., 1996; Lisova et al., 1996; Eyal, 1999). However, experimental results often vary considerably by year. It is maintained that preceding crops of winter cereals have a strong effect on the occurrence of root rot, however, there is little experimental evidence for this on the spread of foliar diseases (Lõiveke et al., 2003). While estimating the relationship between cereal disease incidence and various environmental factors, there is often no single opinion as to which factor plays a decisive role in the occurrence of diseases, therefore the overall effects of the whole complex of ecological factors are estimated.

The objective of the present study was to assess the impact of using perennial legumes and timothy as green manure on the productivity formation of cereal agrocenoses and on the occurrence of cereal disease.

MATERIALS AND METHODS

The experiments were conducted at the Lithuanian Institute of Agriculture's Vėžaičiai Branch in 2002–2005. Experimental design: ***A factor – preceding crops of winter cereals:*** 1. Red clover – cut twice (R); 2. Red clover – 1^{st} crop for forage, aftermath ploughed in (R+A); 3. White clover – cut twice (R); 4. White clover – 1st crop for forage, aftermath ploughed in (R+A); 5. Timothy – cut twice (R); ***B factor – cereals:*** 1. Triticale; 2. Rye.

Two analogous experiments were set up in 2002 and 2003; each experiment lasted for three years. The field experiments were conducted using a multi-factorial method. 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.

The triticale variety 'Tevo' and rye variety 'Rūkai' were grown according to ecological cultivation recommendations. The cereals were grown after variously managed preceding crops: red clover 'Vyliai', white clover 'Sūduviai' and timothy 'Gintaras II'. Cereals were sown at a seed rate of 200 kg ha^{-1} and the preceding crops were red clover – 4.5 kg ha^{-1}, white clover – 4.5 kg ha^{-1}, timothy – 10 kg ha^{-1}.

Plant green material was chopped and shallowly incorporated during the phytocenosis flourishing period, and was deeply ploughed in (25 cm) after two weeks. In 2003 cereals were sown on September 8; in 2004 on September 6. In order to determine the ecological value of differing preceding crops, no mineral fertilisers or plant protection products were used.

Soil samples were collected before establishment and after perennial grasses were ploughed in from a 0–20 cm depth. Available P_2O_5 and K_2O were determined by the A-L method, total nitrogen by Kjeldahl, organic carbon by a mineraliser 'Heraeus'. Protein content (g kg^{-1}) in the grain was calculated as nitrogen content (g kg^{-1}) x coefficient 6.25.

Plant residue mass was determined by the Katchinski monolith washing method. We considered the following as plant residues: stubble, un-decomposed plant parts present on the soil surface, and roots at the 25 cm depth. The mass of all plant residues and overground 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 green material of the preceding crops, their plant residues and cereal grain and straw was determined by colorimetry and potassium, by flame photometry methods. The share of nitrogen fixed from the atmosphere by legume bacteria in the plant mass was calculated by multiplying the nitrogen content by the Chopkins – Piters coefficient 0.63 (Trepačev, 1979).

Grain samples for analyses were taken from each plot after pre-cleaning. One thousand-grain weight was determined according to ISO 580–77. The data on 1000-grain weight and yield were adjusted to 15% moisture content.

Disease assessment. Foliar disease assessments on rye and winter triticale were carried out in 2004–2005 in the third ten-day period of June at late milk maturity stage (BBCH 77–80). In each area under assessment 10 locations were randomly chosen and three normally developed stems were taken per location.Three top green leaves were assessed per stem.

The following methods were used for the diagnostics of fungal diseases: visual, according to external symptoms and microscopy (EPPO Standarts…, 1997; Šurkus & Gaurilčikienė, 2002).

Climatic conditions. Weather conditions during separate years differed considerably, and this affected not only the development of perennial grasses but also the intensity of organic matter breakdown, the formation of the biological parameters of cereals and the occurrence of diseases. 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 20% lower than the long-term mean. Autumn was warm and wet, which might have intensified biochemical processes in the soil and the leaching of some released nitrogen. In 2005, the spring and early summer were drier - rainfall was only 80% compared with the long-term mean. Rain during the second half of spring hindered cereal harvesting.

The experimental data were processed by ANOVA and correlation-regression analysis methods (Tarakanovas, 1999). The symbols used in the paper: * and ** are significant at a 95 and 99% probability level; R = ploughed-in residues, R+A = ploughed-in residues and aftermath.

RESULTS AND DISCUSSION

Perennial grasses differing in phytomass and nitrogen content were chosen as preceding crops for triticale and rye. In the sowing year conditions were favourable for the growth of perennial grasses, however, legumes and grasses differed in phytomass and productivity coefficients. The overground phytomass of legumes was 2.5–2.9 times higher than underground, and timothy was 0.9 times lower (biological productivity coefficients amounted to 0.32–0.40 and 1.26, respectively). A similar trend was also identified in the years of grass use. The underground phytomass of legumes significantly correlated with the overground phytomass (white clover r = 0.63** and red clover r = 0.58*); the overground and underground phytomass increased simultaneously.

Averaged data indicate that the dry matter yield of red clover was the highest (5.96 t ha^{-1}). The average dry matter yield of white clover was by 1.22 t ha^{-1}, and that of timothy by 3.24 t ha^{-1} lower than that of red clover. Statistically significant yield differences were identified between individual plant species. Legumes accounted for 92.6–96.6% of the dry matter yield.

Legumes with ploughed-in aftermath left 70–71% of the total phytomass in the soil in the form of roots and plant residues: red clover 8.8, and white clover 5.8 t ha^{-1} dry matter. Different legumes contribute different nutrient content to the biological turnover. Nutrient content in the preceding crops is also dependent on the sward botanical composition (Maikštėnienė & Arlauskienė, 2001). Analyses of the chemical composition of green manure showed that the highest concentrations of nitrogen and potassium were found in white clover overground phytomass, and those of phosphorus in red clover overground phytomass (Table 1). The overground part of the plant was richer in nutrients than the underground part: nitrogen content by 1.4–1.6, phosphorus by 2.5–9.8 and potassium by 2.1–3.6 times. The lowest nutrient concentration was identified in the residues of timothy.

Table 1. Chemical composition of green manure and plant residues.

Perennial grasses	Green manure			Plant residues		
	Nutrients %					
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Red clover	2.41	2.54	2.32	1.75	0.26	1.12
White clover	2.80	0.76	2.95	1.69	0.19	0.82
Timothy	1.10	0.37	1.83	0.74	0.15	0.57

The largest amount of all nutrients was contributed to the soil after the ploughing in of red clover aftermath (Table 2). With the incorporation of lower dry matter contents of green manure, which was determined by the yield of plant species and weather conditions, the soil received fewer nutrients than with plant residues. After red clover, with overground phytomass and residues, the soil received 185.8 kg ha^{-1} nitrogen; nitrogen fixed by legume bacteria from the atmosphere accounted for the larger (117.0 kg ha^{-1}) part. Here, the content of nitrogen was 1.5 times higher than after identically managed white clover.

Table 2. Amount of nutrients incorporated into the soil with plant residues of preceding crops and with aftermath.

Preceding crops of winter cereals	DM of plant residues and green manure	Nutrients kg ha^{-1}			
		N		P_2O_5	K_2O
		Total	Fixed		
Red clover (R)	8.19	144.8	91.2	37.4	85.9
Red clover (R+A)	10.1	185.8	117.0	50.1	138.0
White clover (R)	5.58	68.9	43.4	15.6	38.5
White clover (R+A)	7.18	125.9	79.3	33.4	94.9
Timothy (R)	8.59	60.2	–	18.4	40.9

The largest amounts of phosphorus and potassium, like those of nitrogen, were contributed to the soil with red clover overground phytomass and residues. With the incorporation of red and white clover aftermath (2.22 and 2.07 t ha^{-1} dry matter), the soil received more nutrients than with ploughed-in root and plant residues of the above mentioned clovers: nitrogen by 1.3–1.8, phosphorus by 1.3–2.1 and potassium by 1.6–2.5 times more. Although the soil received fewer nutrients with lower mass, the ratio N: P_2O_5: K_2O remained similar, i.e. 1 kg : 0.2–0.3 kg : 0.6–0.7 kg. Perennial grasses with different biological characteristics determined a diverse accumulation of total nitrogen, humus and available P_2O_5 and K_2O in the soil (Table 3).

Table 3. The effect of different legumes on soil agrochemical properties.

Preceding crops of winter cereals	N %	Humus %	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}

Note: 1– before trial establishment, 2 – after ploughing in of perennial grasses

Experimental evidence indicates that the total nitrogen content was similar (0.11–0.12%) in the plough layer (0–20 cm depth) after all preceding crops, however, compared with its content before the trial, the total nitrogen content after red clover was 20–50% higher, after white clover 10–20% higher. The highest increase in humus content (0.25 percentage units) occurred with the ploughing in of red clover aftermath, slightly less (0.21 percentage units) with variously managed white clover. The largest amount of available phosphorus in the plough layer was identified after red clover, with its aftermath ploughed in, and that of available potassium, after identically managed white clover.

During mineralization of nitrogen-rich residues of the legumes, the gradually released nitrogen has a positive effect on the formation of biological parameters of the yield during all cereal growth stages, unlike mineral fertilisers, a large part of which is leached (McGuire et al., 1999). The productivity of cereals is determined by numerous conditions and characteristics: the growing period, overwinter survival, ear productivity, grain size, photosynthetic efficiency, disease resistance, and others (Chlebnikov et al., 1997; Plyčevaitienė, 2002).

Different preceding crops and diverse amounts of nutrients contributed to the soil determined the formation of biological parameters of yields of winter rye and triticale. Analysis of variance of the data suggests that the crop stand density and the number of productive stems were significantly affected only by the species of cereals (respectively: $F_{fact.} = 13.49 > F_{theor.0.1} = 7.06$ and $F_{fact.} = 32.82 > F_{theor.0.1} = 7.06$); plant height, ear length, number of grains per ear and 1000-grain weight were affected by both factors investigated, i.e. by preceding crops of winter cereals (respectively: $F_{fact.} = 9.67 > F_{theor.0.1} = 3.63$, $F_{fact.} = 3.86 > F_{theor.0.1} = 3.63$, $F_{fact.} = 2.87 > F_{theor.0.5} = 2.52$ and $F_{fact.} = 3.10 > F_{theor.0.5} = 2.52$) and cereal species (respectively: $F_{fact.} = 1129 > F_{theor.0.1} = 7.06$, $F_{fact.} = 197.17 > F_{theor.0.1} = 7.06$, $F_{fact.} = 29.65 > F_{theor.0.1} = 7.06$ and $F_{fact.} = 252.71 > F_{theor.0.1} = 7.06$).

Crop stand density data show that triticale had a significantly higher number of plants, 11.0%, more than rye (Table 4). Preceding crops did not have any effect on the crop stand density. Similar data were obtained while analysing the biological value of legumes in agrocenoses on heavy loam soils (Arlauskienė & Maikštėnienė, 2001). Insignificant differences in the number of plants per area unit might have occurred due to different seed placement depth, different seed vigour and other factors. The most important factor for high yield is the number of productive stems per area unit, which indicates the biological stability of the variety, its persistence or resistance to variable environmental conditions (Chlebnikov et al., 1997; Plyčevaitienė, 2002).

The intensity of the productive tillering of all crops was also dependent on the weather conditions. In 2004, when there was a shortage of moisture during the growing season, i.e. the rainfall constituted only 72% of the long-term rate, the mean tillering coefficient of triticale was 1.17, and of rye 1.08. During the 2005 growing season the amount of rainfall was 169% of the long-term rate; the mean tillering coefficient of triticale was lower (1.08), and higher for rye (1.13).

The number of productive stems in triticale crops was on average 322.6 per m^2 or 21.8% more than that of rye. The highest number of productive stems formed in the cultivation sites occurred with ploughed-in red clover aftermath.

Table 4. The effect of preceding crops on the yield forming indicators.

Cereals (factor B)	Preceding crops of cereals (factor A)					Means for B factor
	Red clover		White clover		Timothy	
	R	R+A	R	R+A	**R**	
Number of plants m^{-2}						
Triticale	174.8	183.5	185.0	175.2	176.5	179.0
Rye	146.0	147.5	153.0	146.0	159.0	150.3

Means for A factor	160.4	165.5	169.0	160.6	167.8	
LSD_{05A} = 15.62	LSD_{05B} = 7.81	$LSD_{05A \times B}$ = 23.43	$S_x\%$ = 7.505			
Productive stems m^{-2}						
Triticale	325.2	334.2	323.0	310.2	320.0	322.6
Rye	236.5	250.5	250.0	267.8	262.8	253.5
Means for A factor	280.9	292.4	286.5	289.0	291.4	
LSD_{05A} = 24.09	LSD_{05B} = 12.04	$LSD_{05A \times B}$ = 36.13	$S_x\%$ = 6.617			
Plant height cm						
Triticale	95.6	94.0	96.5	97.6	88.6	94.5
Rye	135.0	131.7	138.5	136.2	126.4	133.6
Means for A factor	115.3	112.9	117.5	116.9	107.5	
LSD_{05A} = 2.32	LSD_{05B} = 1.16	$LSD_{05A \times B}$ = 3.48	$S_x\%$ = 1.614			
Ear length cm						
Triticale	6.48	6.82	6.62	6.89	5.75	6.5
Rye	8.56	8.78	9.18	8.92	8.40	8.8
Means for A factor	7.5	7.8	7.9	7.9	7.1	
LSD_{05A} = 0.32	LSD_{05B} = 0.16	$LSD_{05A \times B}$ = 0.48	$S_x\%$ = 3.32			
Number of grain per ear						
Triticale	33.9	35.4	35.2	36.5	30.1	34.2
Rye	38.6	40.2	42.2	41.6	38.0	40.2
Means for A factor	36.2	37.8	38.8	39.1	34.1	
LSD_{05A} = 2.17	LSD_{05B} = 1.09	$LSD_{05A \times B}$ = 3.26	$S_x\%$ = 4.626			
1000 grain weight g						
Triticale	39.2	37.7	37.3	37.6	37.1	37.8
Rye	42.8	42.5	42.1	42.6	41.6	42.4
Means for A factor	41.0	40.1	39.7	40.1	39.5	
LSD_{05A} = 0.58	LSD_{05B} = 0.29	$LSD_{05A \times B}$ = 0.87	$S_x\%$ = 1.13			

Diverse nitrogen contents in clover residues and aftermath determined the different plant height of cereals. The greatest plant height of both cereal species was recorded in the treatments fertilised with white clover. When white clover treatments were compared, no significant differences were revealed, but different management of red clover did have some significant effect. Cereals having ploughed-in red clover residues grew taller, those after growth of timothy were the shortest.

Table 5. The effect of preceding crops on cereal grain yield and grain protein content (mean±standard error of mean).

Cereals (factor B)	Preceding crops of cereals (factor A)					Means for B factor
	Red clover		White clover		Timothy	
	R	R+A	R	R+A	R	
Grain yield (t ha^{-1})						
Triticale	2.78±0.11	2.79±0.21	2.94±0.14	3.13±0.22	2.07±0.21	2.74±0.10
Rye	3.23±0.15	3.54±0.28	3.41±0.25	3.82±0.27	2.35±0.28	3.27±0.13

Means for A factor	3.00±0.11	3.16±0.19	3.18±0.15	3.85±0.19	2.21±0.17	
	LSD_{05A}= 0.26	LSD_{05B} = 0.13	$LSD_{05A\times B}$ = 0.39	S_x% = 6.810		
Grain protein content (g kg^{-1})						
Triticale	92.00±12.00	89.60±13.40	95.80±5.20	87.20±4.70	90.00±8.10	90.92±3.26
Rye	80.65±3.15	83.15±1.25	78.45±4.05	85.30±2.20	85.30±7.80	82.57±1.70
Means for A factor	86.33±6.03	86.38±5.80	87.13±5.69	86.25±2.19	87.65±4.79	
	LSD_{05A}= 8.35	LSD_{05B} = 4.18	$LSD_{05A\times B}$ = 12.53	S_x%= 6.730		

Similar data were obtained while analysing ear length. The ears of cereals grown after timothy were significantly shorter (8–10%), compared with clover as the preceding crops. Various clover green manures had no significant effect on ear length; appreciably longer ears were recorded only after white clover.

Averaged data show that winter rye matured 17.5% more grain (or 6 grains more) per ear compared with winter triticale. The higher number of grains per ear for the varieties of both cereals was obtained in the treatments fertilised with white clover residues and aftermath. The 1000-grain weight varies due to weather conditions during the grain formation and ripening stages, and is affected by fertilisation and the number of plants per area unit (Plyčevaitienė, 2002).

The 1000-grain weight of winter rye was significantly higher (4.6 g) than that of triticale, and was affected less by the preceding crops than were the number of grains per ear. The lowest 1000-grain weight was recorded after timothy and white clover of which only residues were ploughed in. However, having incorporated a larger amount of green manure, i.e. both red and white clover residues and aftermath, the soil received more nutrients. This leads to the conclusion that incorporating a higher content of biological nitrogen had a significant effect on the 1000-grain weight of cereals.

The data of ANOVA analysis show that both factors tested had a significant effect on grain yield: cereal species $F_{fact.}$= 9.46 > $F_{theor.0.1}$= 3.63 and preceding crops $F_{fact.}$ = 4.89 > $F_{theor.0.5}$ = 3.99 (Table 5).

Cereal species had the greatest effect on both 1000-grain weight and grain yield; the effect of the preceding crop was less significant. Average data shows that rye grain yield, irrespective of different preceding crops, was by 0.53 t ha^{-1} higher than that of triticale. Comparison of the preceding crops indicates that the highest cereal grain yield was obtained when white clover aftermath was ploughed in: triticale increased by 0.19 t ha^{-1} and that of rye by 0.41 t ha^{-1}, whereas ploughing in red clover aftermath only mildly affected the rye grain yield.

Enriching the soil with various nutrients did not have any significant effect on protein content in cereal grain (Table 5). In all cases the nitrogen content in triticale grain was 2–12% higher than that of rye. The nitrogen content was positively influenced by nitrogen–rich plant residues only in rye. Comparison of the preceding crops shows that the highest increase (18%) in grain protein was obtained having ploughed in the aftermath of white clover, however the highest content of nitrogen was contributed to the soil with red clover. It can be explained as follows: a small increase in humus content can be identified after the ploughing-in of legumes that have a long root system, such as red clover. But most often, after the ploughing-in of green manure and enriching the soil with nitrogen-rich, readily mineralising substances, the activity of micro-organisms increases and they break down to the final stages of decomposition but not towards humus formation. The progression or destruction processes can be changed by balancing the carbon to nitrogen ratio in the soil. The different effects were determined after the ploughing-in of white clover (Tripolskaja, 2005). This had a positive effect on the formation of biological parameters and for increasing the protein content of cereals grown after white clover.

Disease Management

Both the quality and quantity parameters of biological characteristics of cereals are markedly affected by their resistance to disease. The intensive spread of diseases reduces both cereal productivity and grain quality. On ecological farms, the use of fungicides is not a solution to the problem. It is thought that the occurrence of diseases can be successfully controlled by soil and crop management practices and crop rotations as well as by using high–quality preceding crops. During the experimental period the leaves of rye and winter triticale were affected by 10 species of fungal disease causal agents: *Rhynchosporium secalis* (Oudem.) J. J. Davis, *Septoria secalis* Prill. & Delacr., *S. tritici* Roberge ex Desmaz., *Puccinia recondita* Roberge ex Desmaz., *P. striiformis* West., *P. glumarum* Eriks. and Hen., *P. graminis* Pers. f. sp. *secalis* Eriks. & E. Henn., *Erysiphe graminis* DC. f. sp. Em. Marchal, *Stagonospora nodorum* (Berk.) E. Castell. & Germano), *Drechleria tritici–repentis* (Died.) Shoem. The spread of the following foliar diseases was more intensive: in rye – scald, brown rust and powdery mildew (only in 2005); in winter triticale – scald, brown rust and leaf spots (septoria, glume blotch). The differing preceding crops of cereals had a significant effect only on the occurrence of scald, brown rust and septoria (Table 6, 7). Experimental findings suggest that in 2004 scald affected from 29.2 to 47.5% of rye leaves (Table 6).

Significant differences were determined between treatments, i.e. the incidence of scald in rye grown after variously-managed preceding crops differed. The highest disease pressure was identified in rye grown after white clover whose residues and aftermath were ploughed in: the rye grown under such conditions were 1.7–1.9 times more scald-affected than rye grown after the other preceding crops. The severity of scald was similar in the entire agrocenose – on average 10%. The number of productive stems of rye did not have any effect on scald severity and incidence (r = 0.171 and 0.215). In 2005 scald was extremely severe and affected from 50.8 to 69.2% of rye leaves. Rye that grew after white clover whose aftermath was ploughed in was 1.4 times more affected by this disease causal agent; rye that grew after white clover with only residues ploughed in was affected 1.3 times more than the rye preceded by timothy (Table 6).

Table 6. The effect of preceding crops on foliar fungal diseases of rye.

Disease	Experi-mental year	Disease incidence and severity	Preceding crops of winter cereals					LSD_{05}
			Red clover		White clover		Timothy	
			R	R+A	R	R+A	R	
Scald	2004	incidence	38.30	39.20	35.00	47.50	29.20	0.26
(causal agent		severity	9.75	8.22	7.00	7.00	8.22	0.25

Rhynchosporium secalis (Oudem) J. J. Davis)	2005	incidence	59.20	52.50	65.80	69.20	50.80	0.84
		severity	10.55	8.75	18.32	16.52	14.62	0.45
Brown rust (causal agent	2004	incidence	5.80	5.80	10.80	16.60	9.50	0.55
		severity	1.62	1.51	1.83	1.63	1.58	0.14
Puccinia recondita	2005	incidence	12.50	10.80	9.20	10.00	10.80	0.28
Roberge ex Desmaz.)		severity	0.52	0.85	0.66	0.85	0.62	0.18

Table 7. The effect of preceding crops on triticale foliar diseases.

Disease	Experi-mental year	Disease incidence and severity	Preceding crops of winter cereals					LSD_{05}
			Red clover		White clover		Timot-hy R	
			R	R+A	R	R+A		
Scald (causal agent	2004	incidence	40.00	36.70	52.50	43.80	31.30	1.21
		severity	9.82	9.46	8.41	8.09	8.27	0.23
Rhynchosporium secalis (Oudem)	2005	incidence	21.30	17.50	20.00	21.30	18.80	0.74
J. J. Davis)		severity	6.22	5.31	6.55	4.95	4.85	0.30
Brown rust (causal agent	2004	incidence	16.90	16.30	23.80	21.30	16.30	0.95
		severity	0.24	0.32	0.30	0.35	0.39	0.09
Puccinia recondita	2005	incidence	10.00	11.30	10.00	8.80	13.80	0.45
Roberge ex Desmaz.)		severity	0.57	0.26	0.59	0.09	0.55	0.10
Septoria (causal agent: *Septoria*	2004	incidence	16.30	16.30	22.00	21.30	11.20	0.52
		severity	0.35	0.42	0.51	0.40	0.45	0.05
tritici Roberge in Desmaz.)	2005	incidence	17.50	18.80	25.00	23.80	22.50	0.87
		severity	2.95	2.56	2.22	3.20	2.59	0.07

The incidence of scald was also higher in rye grown after white clover by 1.1 and 1.2 times, respectively. The lowest incidence was recorded in rye grown after variously-managed red clover. The incidence and severity of scald depended also on the density of the rye stand. A medium-strong positive correlation was identified between scald incidence and severity and the number of productive rye stems: $y = 21.976 + 0.132x$, $r = 0.638$ and $y = 0.097 + 0.062x$, $r = 0.598$ ($P < 0.05$).

In 2004 and 2005 the incidence of brown rust in rye agrocenose was similar; however, the disease severity varied (Table 7). In 2004 the higher amount of rainfall in June promoted a more intensive occurrence of brown rust in rye, whereas warmer and drier weather during the same period in 2005 resulted in 2.2–3.0 times lower severity of the disease. The greatest number of brown rust-affected rye (10.8–16.6%), was identified in the treatments where rye was grown after variously-managed white clover; the rye preceded by red clover and timothy were the least affected. Conversely, in 2005, the rye grown after red clover and timothy was 1.1–1.4 times more affected by brown rust, compared with the rye grown after white clover. This suggests that rye growing in differing conditions, i.e. after different preceding crops, does not have any consistent effect on brown rust incidence and severity. However, a medium-strong correlation was identified between rye stand density and brown rust incidence in 2005: $y = 16.047 – 0.019x$, $r = –0.606$ ($P < 0.05$).

In the experimental years the incidence of scald was rather high not only on rye but also on winter triticale. In 2004 after various preceding crops, from 31.3 to 52.5% of winter triticale plants were scald-affected; in 2005, from 18.8 to 21.3% (Table 7).

Significant differences in the incidence of scald were determined among all treatments, however the highest incidence and severity were identified in winter triticale grown after legumes, compared with the triticale preceded by spiked plants. Winter triticale stand density had a great effect on the incidence of scald. A correlation was identified between scald incidence and the total number of winter triticale stems ($y = 38.085 – 0.049$, $r = –0.565$; $P < 0.05$) and between scald incidence and the number of triticale productive stems ($y = 37.179 – 0.056x$, $r = –0.778$; $P < 0.05$). Differing triticale stand densities did not affect the severity of scald ($r = –0.267$ and $–0.166$, respectively).

During the experimental period in all agrocenoses, winter triticale was affected by brown rust causal agent *Puccinia recondita* Roberge ex Desmaz., however the disease severity was very low and in most cases did not reach 1%. In some cases only traces of the disease were identified. The relationship between the incidence of brown rust and ecological conditions of the cereal cultivation site was identified: in 2004 a 5.0–7.5% higher disease incidence was recorded in winter triticale which was preceded by variously-managed white clover. However in 2005 an opposite trend of brown rust incidence was observed; the disease incidence was 1.4–1.6 times higher in the cultivation sites where timothy residues were ploughed in for the preceding crop of the cereal, compared with winter triticale grown after white clover.

A moderately strong infection of septoria was identified in winter triticale (Table 7). The incidence of septoria, and in many cases its severity, was significantly affected by varying winter triticale growing conditions;,in 2004, especially, the infection level on winter triticale grown after differently-managed white clover was twice as high as in triticale preceded by timothy. Slightly fewer septoria-affected winter triticale leaves were identified in the stands with a lower plant density: $r = –0.395$.

CONCLUSIONS

The perennial legumes white and red clover accumulate biological nitrogen in their roots and plant residues, which is an important factor for the maintenance of soil potential fertility and productivity of the agroecosystem. The highest content of nitrogen (185.8 kg ha^{-1}) was contributed to the soil with red clover residues and aftermath.

White clover residues and aftermath ploughed in as green manure determined more favourable soil properties, and had a positive effect on the formation of productivity elements of cereals grown after white clover, and, even without mineral and organic fertilisation made it possible to produce on average 3.13 t ha^{-1} of triticale and 3.82 t ha^{-1} of rye grain or by 0.34 and 0.28 t ha^{-1} more, compared with their identical cultivation after red clover.

The highest protein increase (18%) in rye grain was obtained in treatment with ploughed-in white clover aftermath, compared with the other preceding crops, but the differences were not significant.

In rye and winter triticale preceded by white clover we identified a more intensive occurrence of diseases, such as scald (causal agent *Rhynchosporium secalis* (Oudem.) J. J. Davis), and in winter triticale, septoria, compared with the other preceding crops. The incidence of scald was significantly affected by the number of productive stems of cereals: in rye $r = 0.638$, in winter triticale $r = -0.778$ ($P < 0.05$).

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