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INFLUENCE OF UNDERSOWN CROPS ON MINERAL NITROGEN CONTENT DETERMINED IN THE SOIL PROFILE IN AUTUMN AND IN SPRING IN CONVENTIONAL AND ORGANIC FARMING SYSTEMS

WPŁYW WSIEWEK MIĘDZYPLONOWYCH NA ZAWARTOŚĆ AZOTU MINERALNEGO OZNACZONEGO W GLEBIE JESIENIĄ I WIOSNĄ W KONWENCJONALNYM I EKOLOGICZNYM SYSTEMIE PRODUKCJI

Abstract: The aim of researches was to determine the influence of undersown crops plowed down in the autumn and left till spring in the form of mulch on mineral nitrogen content in the soil profile determined in autumn and in spring in conventional and organic farming systems.

The field experiments were conducted at the Zawady Experimental Farm owned by the University of Natural Sciences and Humanities in Siedlce. The following treatments were examined: factor 1 – Undersown crop: control object (no undersown crop cultivation), an undersown crop – biomass ploughed down in autumn (white melilot, white melilot + westerwold ryegrass, westerwold ryegrass), an undersown crop with its biomass used as a spring-incorporated mulch (white melilot, white melilot + westerwold ryegrass, westerwold ryegrass). factor 2 – farming system: conventional and organic. Ammonium and nitrate nitrogen contents were determined in two soil layers (0–30 and 31–60 cm) twice, *ie* in autumn and spring. The results showed that the highest soil concentrations of ammonium and nitrate ions were determined on control object, and in spring following white melilot incorporation.

The autumn and spring-determined soil contents of mineral nitrogen were significantly higher in the conventional in comparison with organic farming system. Mulching of the soil surface with undersown crops significantly reduced the mineral nitrogen content in soil in spring compared with the autumn-incorporated undersown crops.

Keywords: mineral nitrogen, soil, undersown crop, mulch, farming system

An assessment of mineral nitrogen content in soil has been assumed to be an indicator of environmental risk due to an excess concentration of nitrogen in the soil.

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Catch crops are thus used as "accumulators" of the nutrients unused by the plants proceeding in the rotation. Leaching of nutrients into ground waters from plant-covered or mulched soils is much lower compared with "black" fallow [1–5]. Suggestions are also made to leave catch crops on the soil surface as mulch over the winter months [3, 6, 7]. There is still a paucity of experimental data on the topic, however. As a result, a need arises to continue studies to determine the effect of undersown crops autumn-incorporated or left as mulch till spring on mineral nitrogen contents determined in the soil profile in autumn and spring in the conventional and organic farming system.

Material and methods

Field studies were conducted in the years 2005–2008 at the Experimental Farm in Zawady owned by the University of Natural Sciences and Humanities in Siedlce. The experimental soil was Stagnic luvisol. The pH in KCl of the topsoil ranged between 6.4 and 6.5 and the soil contained 0.689–0.691 g · kg^{-1} N_{tot}, including 4.45–4.47 mg · kg^{-1} $N\text{-}NH_4$ and 7.25–7.27 mg · kg^{-1} $N\text{-}NO_3$, and the following available forms: P, K and Mg at the respective amounts of: 50.6–50.7, 112.9–113.0, and 53.9–54.1 mg · kg^{-1} [8]. The experiment was established as a split-blocks design with three replications. The following treatments were examined: factor 1 – Undersown crop: control object (no undersown crop cultivation), an undersown crop – biomass ploughed down in autumn (white melilot 26 kg · ha^{-1}, white melilot + westerwold ryegrass 13 + 10 kg · ha^{-1}, westerwold ryegrass 20 kg · ha^{-1}), an undersown crop with its biomass used as a spring-incorporated mulch (white melilot 26 kg · ha^{-1}, white melilot + westerwold ryegrass 13 + 10 kg · ha^{-1}, westerwold ryegrass 20 kg · ha^{-1}). factor 2 – farming system: conventional and organic.

Spring triticale grown for grain was undersown with the aforementioned crops. Prior to the experiment set-up, mineral fertilizers were applied in the conventional farming system at the following rates: 60 kg N, 39.6 kg P and 99.6 kg K per l ha. In the organic system, instead of mineral fertilization, farmyard manure was applied at the rate of 30 Mg (ton) · ha^{-1} taking into consideration the fertilizer needs of potato which was to follow the undersown crops. Both spring triticale and undersown crops were planted in early April. Spring triticale was harvested in early August.

After the harvest of spring triticale nitrogen fertilization was applied into the plots under westerwold ryegrass at the rate of 60 kgN · ha^{-1}, and the mixture of white melilot and westerwold ryegrass at the rate of 30 kgN · ha^{-1} .The control was tilled (to maintain "black" soil) from the harvest of spring triticale to late autumn. Soil samples were collected from two soil layers (0–30 and 31–60 cm) twice, that is in autumn (late October) and the next spring (early April). The ammonium and nitrate nitrogen contents were determined by colorimetric method [8]. All the characteristics studied were subjected to split-block variance analysis. When sources of variation were declared significant by analysis of variance, Tukey's test was used to separate means.

Results and discussion

Autumn-determined mineral nitrogen content in the soil profile was significantly affected by the experimental factors and their interaction (Table 1 and 2).

Table 1

Soil $N\text{-}NH_4^+$ content determined in autumn, $mg \cdot kg^{-1}$ d.m. soil (means for 2005–2007)

Undersown crop	Farming system				Means	
	Conventional		Organic			
	Soil layer [cm]					
	0–30	31–60	0–30	31–60	0–30	31–60
Control object	4.86	2.43	3.93	1.85	4.40	2.14
White melilot	2.21	1.45	2.01	1.23	2.11	1.34
White melilot + westerwold ryegrass	1.78	1.31	1.53	1.12	1.66	1.22
Westerwold ryegrass	1.32	1.15	1.03	0.99	1.18	1.07
White melilot – mulch	2.19	1.44	1.99	1.21	2.09	1.33
White melilot + westerwold ryegrass – mulch	1.79	1.32	1.54	1.11	1.67	1.22
Westerwold ryegrass – mulch	1.34	1.16	1.05	0.98	1.20	1.07
Means	2.21	1.47	1.87	1.21	2.04	1.34
$LSD_{0.05}$						
Undersown crop					0.21	0.12
Farming system					0.19	0.16
Interaction					0.25	0.22

Table 2

Soil $N\text{-}NO_3^-$ content determined in autumn, $mg \cdot kg^{-1}$ d.m. soil (means for 2005–2007)

Undersown crop	Farming system				Means	
	Conventional		Organic			
	Soil layer [cm]					
	0–30	31–60	0–30	31–60	0–30	31–60
Control object	7.26	4.83	6.29	3.92	6.78	4.38
White melilot	4.89	2.41	4.21	2.00	4.55	2.21
White melilot + westerwold ryegrass	4.21	2.15	3.61	1.63	3.91	1.89
Westerwold ryegrass	3.50	1.85	2.99	1.24	3.25	1.55
White melilot – mulch	4.88	2.39	4.18	1.97	4.53	2.18
White melilot + westerwold ryegrass – mulch	4.20	2.14	2.62	1.62	3.41	1.88
Westerwold ryegrass – mulch	3.51	1.87	3.03	1.26	3.27	1.57
Means	4.64	2.52	3.85	1.95	4.24	2.24
$LSD_{0.05}$						
Undersown crop					0.28	0.22
Farming system					0.54	0.43
Interaction					0.61	0.47

The highest soil mineral nitrogen content was recorded in the control with no undersown crops. This is in agreement with the results reported by Fotyma [9] as well as Nowakowski and Kruger [4] who demonstrated that in autumn, when vegetation has ceased due to diminished nitrogen uptake and organic nitrogen mineralization, mineral nitrogen content in soil may increase. In this study inclusion of undersown crops into the cropping system, particularly westerwold ryegrass which is a non-leguminous plant, significantly reduced the soil mineral nitrogen content. The content was also significantly lower in the plots under the mixture of white melilot and westerwold ryegrass, compared with the control, though higher than under westerwold ryegrass. There was a clear reduction in soil mineral nitrogen content determined in late autumn following cultivation of undersown crops although is was definitely lower than the values reported elsewhere [10–12]. The possible explanation is that the soil nitrogen reservoir following cereals is large under intensive farming conditions, hence a greater influence of the catch crop. In the present study a higher soil nitrogen concentration was determined in the conventional versus organic farming system. Studies by Halberg et al [13], Werff et al [14] and Jonczyk [15] showed that the conventional farming system is characterized by excessive nitrogen which is used less efficiently. In this study there was found an interaction indicating that the highest soil mineral nitrogen content was in the control treatment where no undersown crop had been cultivated in the conventional farming system, and the lowest in the organic treatment under westerwold ryegrass. Similar findings were reported by Halberg et al [13] as well as by Duer [6].

An analysis of mineral nitrogen content in two soil layers in the study discussed here revealed that there was a clearly higher nitrogen concentration in the topsoil compared with the subsoil. It agrees with the results reported by Kus and Jonczyk [2]. Similarly to Sainju et al [16] and Trawczynski [17], the present work demonstrated a higher nitrate versus ammonium nitrogen content in the two soil layers. In autumn, the concentration of both the ions was the highest in both the soil layers of the control. Cultivation of undersown crops was followed by a significant reduction in $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ contents compared with their concentrations recorded in the two soil layers in the control with no undersown crops. The lowest ammonium and nitrate N contents were determined in the topsoil and subsoil following westerwold ryegrass, which agrees with the results reported by Breland [18] and Plaza et al [19].

The statistical analysis revealed a significant influence of the experimental factors together with their interaction on mineral nitrogen content in the soil profile in the spring (Table 3 and 4). Cultivation of undersown crops leads to significant increase of mineral nitrogen content in the topsoil, particularly following the incorporation of white melilot. This beneficial influence, that is stimulation of the process of organic nitrogen mineralization, is called the "priming effect" [16, 20, 21]. A significantly lower content of mineral nitrogen in soil, although higher than after westerwold ryegrass, was recorded following white melilot left as mulch till spring. The lowest mineral nitrogen concentration in the soil was determined in the treatment under westerwold ryegrass left on the soil surface over autumn and winter and incorporated in spring. According to Kus and Jonczyk [2], Nowakowski and Kruger [4] as well as Sanju and Sangh [21], the biomass of catch crop left on the soil surface decomposes more slowly than when ploughed in. In the present study it was demonstrated that, with adoption of this solution, there is potentially less risk of nitrogen loss from the soil over autumn and winter.

Table 3

Soil $N\text{-}NH_4^+$ content determined in spring, $mg \cdot kg^{-1}$ d.m. soil (means for 2006–2008)

Undersown crop	Farming system				Means	
	Conventional		Organic			
	Soil layer [cm]					
	0–30	31–60	0–30	31–60	0–30	31–60
Control object	5.44	3.95	4.30	2.71	4.87	3.33
White melilot	7.24	2.88	6.68	2.40	6.96	2.64
White melilot + westerwold ryegrass	6.57	2.54	6.23	2.24	6.40	2.39
Westerwold ryegrass	5.87	2.18	5.74	2.05	5.81	2.12
White melilot – mulch	6.56	2.35	6.15	2.01	6.36	2.18
White melilot + westerwold ryegrass – mulch	6.15	2.24	5.82	1.71	5.99	1.98
Westerwold ryegrass – mulch	5.71	2.09	5.45	1.37	5.58	1.73
Means	6.22	2.60	5.77	2.07	6.00	2.34
$LSD_{0.05}$						
Undersown crop					0.22	0.19
Farming system					0.20	0.17
Interaction					0.29	0.24

Table 4

Soil $N\text{-}NO_3^-$ content determined in spring, $mg \cdot kg^{-1}$ d.m. soil (means for 2006–2008)

Undersown crop	Farming system				Means	
	Conventional		Organic			
	Soil layer [cm]					
	0–30	31–60	0–30	31–60	0–30	31–60
Control object	8.90	6.89	7.79	5.82	8.35	6.36
White melilot	19.41	5.87	17.33	3.72	18.37	4.80
White melilot + westerwold ryegrass	16.69	4.90	14.88	3.36	15.79	4.13
Westerwold ryegrass	13.94	3.88	12.38	2.97	13.16	3.43
White melilot – mulch	15.24	4.21	14.89	3.11	15.07	3.66
White melilot + westerwold ryegrass – mulch	13.83	3.62	12.59	2.64	13.21	3.13
Westerwold ryegrass – mulch	12.38	2.97	10.25	2.13	11.32	2.55
Means	14.34	4.62	12.87	3.39	13.61	4.01
$LSD_{0.05}$						
Undersown crop					1.31	0.22
Farming system					1.12	0.17
Interaction					1.73	0.32

The lowest mineral nitrogen content in the topsoil was measured in the control. Also, the farming system significantly influenced the mineral nitrogen concentration in the soil. The highest ammonium and nitrate nitrogen contents were recorded in the conventional farming system, the finding previously reported by Halberg et al [13] and Jonczyk [15]. There was found an interaction between the experimental factors in the trial discussed, which revealed the highest mineral nitrogen content in the topsoil after autumn-incorporated white melilot in the conventional farming system, and the lowest in the control in the organic farming system.

Analysis of mineral nitrogen content in soil showed a higher concentration of nitrate versus ammonium ions both in autumn and spring. This is in agreement with the results of studies reported by Moler and Stinner [20] and Sainju et al [16]. The subsoil mineral nitrogen content in the present study was the highest in the control, and the lowest after westerwold ryegrass left on the soil surface as mulch until spring. It should be stressed that reduction of nitrogen losses in the soil by means of including undersown crops in both the conventional and organic farming systems has recently become an issue of special importance.

Conclusion

1. In the autumn the highest concentration of mineral forms was determined on control object, and in spring after white melilot ploughing.
2. The soil mineral nitrogen contents determined in autumn and spring were significantly higher in the conventional versus organic farming system.
3. Undersown crops left till spring in the form of mulch caused the decrease of mineral nitrogen content in spring in soil in comparison with undersown crops plowed down in autumn.
4. The topsoil was characterized by a higher ammonium and nitrate nitrogen contents compared with the subsoil.

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Abstrakt: Celem przeprowadzonych badań było określenie wpływu wsiewek międzyplonowych przyoranych jesienią i pozostawionych do wiosny w formie mulczu na zawartość mineralnych form azotu oznaczonego w profilu glebowym jesienią i wiosną w konwencjonalnym i ekologicznym systemie produkcji. Badania polowe przeprowadzono w RSD w Zawadach należącej do Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach. W doświadczeniu badano dwa czynniki. I. Wsiewka międzyplonowa: obiekt kontrolny (bez uprawy wsiewki międzyplonowej), wsiewka międzyplonowa – biomasa przyorana jesienią (nostrzyk biały, nostrzyk biały + życica westerwoldzka, życica westerwoldzka), wsieka międzyplonowa – biomasa pozostawiona do wiosny w formie mulczu (nostrzyk biały, nostrzyk biały + życica westerwoldzka, życica westerwoldzka). II. System produkcji: konwencjonalny, ekologiczny. Zawartość jonów amonowych i azotanowych oznaczono dwukrotnie, tj. jesienią i wiosną, w dwóch warstwach gleby (0–30 i 31–60 cm). Otrzymane wyniki badań pozwalają stwierdzić, że jesienią najwyższą zawartość mineralnych form azotu odnotowano na obiekcie kontrolnym, a wiosną po przyoraniu nostrzyku białego. W konwencjonalnym systemie produkcji zawartość azotu mineralnego oznaczonego w glebie zarówno jesienią, jak i wiosną była istotnie wyższa niż w ekologicznym systemie produkcji. Wsiewki międzyplonowe pozostawione do wiosny w formie mulczu spowodowały zmniejszenie zawartości azotu mineralnego w glebie wiosną w porównaniu do wsiewek międzyplonowych przyoranych jesienią.

Słowa kluczowe: azot mineralny, gleba, wsiewka międzyplonowa, mulcz, system produkcji