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IMPACT OF VARIED ORGANIC MANURING ON NITROGEN CONTENT AND UPTAKE BY CROP PLANTS

ODDZIAŁYWANIE ZRÓŻNICOWANEGO NAWOŻENIA ORGANICZNEGO NA ZAWARTOŚĆ I POBRANIE AZOTU PRZEZ ROŚLINY

Abstract: An experiment was conducted in the years 2001–2005 to determine the direct and secondary effect of barley straw (treatment with and without straw) and summer intercrop biomass (control without organic manuring, farmyard manure, summer intercrop: red clover, Westerwold ryegrass, red clover + Westerwold ryegrass) on total nitrogen content and uptake by sugar beet and spring wheat. Additionally, the farmyard manure effect was compared with the effect of summer intercrop biomass on nitrogen content and uptake by the crop plants. A field experiment was set up as a split-block design with three replicates. It was found that an application of barley straw, farmyard manure and summer intercrop biomass significantly increased total nitrogen content in sugar beet roots and leaves as well as spring wheat grain and straw. It also increased total nitrogen uptake by the crop plants. When farmyard manure had been replaced with the biomass of either red clover or red clover + Westerwold ryegrass, there were observed no significant differences in the total nitrogen content in sugar beet roots as well as spring wheat grain and straw. The highest total nitrogen content was found in the leaves of sugar beet plants harvested from the red clover-amended treatment. The quantity of nitrogen taken up by sugar beet grown in the treatment amended with red clover + Westerwold ryegrass as well as red clover was greater compared with the farmyard manure-amended treatment. The secondary effect of red clover + Westerwold ryegrass biomass on total nitrogen uptake by spring wheat did not differ significantly from farmyard manure effect whereas the effects of red clover and Westerwold ryegrass were significantly smaller.

Keywords: sugar beet, spring wheat, straw, farmyard manure, summer intercrop, total nitrogen content and uptake

Of the cultural operations, fertilisation and manuring are the factors that most strongly affect plant chemical composition and quality [1–5]. As production of farmyard manure, being the most valuable manure in sugar beet cultivation, is on the decline, numerous attempts are made to search for alternative forms of organic manures. In recent years intercrop green manures and straw have acquired more and more importance on crop production-oriented farms as a source of organic matter in the soil

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[6–8]. As a result, many try to answer the question of how does farming without farmyard manure application influence crop plant yields and quality.

The objective of the study was to evaluate the direct and secondary effect of barley straw and summer intercrop biomass on total nitrogen content and uptake by sugar beet and spring triticale. Moreover, the effect of farmyard manure application was compared to intercrop biomass incorporation on changes in total nitrogen content and uptake by the crop plants.

Materials and methods

Field studies were conducted in the years 2001–2005 at the Experimental Farm in Zawady on neutral soil (pH in KCl 6.71–6.93) classified as Mollic Gleysol characterized by average available phosphorus, potassium and magnesium (49.3–55.1 mg P · kg^{-1}, 112.4–120.2 mg K · kg^{-1} and 55.7–57.3 mg Mg · kg^{-1}) contents. The total nitrogen content in the soil prior to the experiment set-up was 0.93–1.05 g · kg^{-1}, the soil hydrolytic acidity was 14.2–15.1 mmol(+) · kg^{-1}, the sum of exchangeable bases was 92.3–106.5 mmol(+) · kg^{-1}, total exchangeable capacity was 107.4–120.7 mmol(+) · kg^{-1} and saturation with base cations was 85.9–88.2 %. The soil belongs to the cereal-fodder strong complex, quality class IIIb. A split-plot design with three replicates was used in this study and it comprised two factors: I. Barley straw application (treatment with and without straw); II. Summer intercrop biomass application (control – without organic matter, cattle farmyard manure, intercrop: red clover, Westerwold ryegrass, red clover + Westerwold ryegrass). The overall plot area was 37.8 m^2 but the harvested area was 21.6 m^2.

Summer intercrops were sown into spring barley cultivated for grain whose straw was incorporated in selected plots. When averaged across all the three years, straw dry matter yield amounted to 4.05 Mg · ha^{-1}. A supplementary nitrogen rate of 7 kg per 1 Mg straw was applied in the barley straw-manured plots, excluding plots under red clover. In the third decade of October, prior to intercrop cutting, their cut dry matter was determined in addition to the dry matter of post-harvest residues sampled from the 30-cm soil layer. Dry matter yield of summer intercrops (cut matter + post-harvest residues) averaged 6.76, 10.49 and 9.11 Mg · ha^{-1} for, respectively, red clover, Westerwold ryegrass and red clover + Westerwold ryegrass mixture. Cattle farmyard manure was applied at a rate of 30 Mg · ha^{-1} and ploughed under in the third decade of October, similarly to barley straw and summer intercrop biomass.

Sugar beet cv Korab was cultivated in the first year (2002–2004) and spring wheat cv Helia was grown in the second year (2003–2005) following an application of barley straw, farmyard manure and intercrop biomass. Mineral fertilizer rates per 1 ha in the cultivation of sugar beet were: 110.0 kg N, 32.7 kg P and 116.2 kg K. Phosphorus and potassium fertilizers and two-thirds of the nitrogen fertilizer were applied in the spring prior to soil tillage performed using a cultivation unit. The remaining amount of nitrogen fertilizer was spread following thinning of sugar beet plants. Spot seeding of sugar beet was conducted in the third decade of April. The in-row spacing was 12 cm and between-row spacing was 45 cm. Weed control was achieved by means of Betanal

Elite 274 EC (phenmedipham, desmedipham, ethofumesate) and Fusilade Forte 150 EC (fluazifop-P-butyl) whereas pests were combated using Decis 2.5 EC (deltamethrine). Sugar beet was harvested in the second decade of October. The crop that followed sugar beet was spring wheat. In the spring phosphorus, potassium and nitrogen fertilizers were applied pre-plant at the respective amounts of 24.0 kg P $\cdot$ ha^{-1}, 70.6 kg K $\cdot$ ha^{-1} and 50.0 kg N $\cdot$ ha^{-1} (the first rate). The second rate of nitrogen (30.0 kg N $\cdot$ ha^{-1}) was applied at the boot stage of spring wheat. Wheat grain was treated with Raxil Gel 206 (tiuram, tebuconazole) and sown in the first decade of April at the density of 500 grains per 1 m^2. The following preparations were applied to protect wheat plants during their growth: the herbicide Chwastox Trio 540 SL (mecoprop, MCPA, dicamba), the fungicide Amistar 250 SC (azoxystrobin) and the insecticide Fastac 100 EC (alpha-cypermethrin). Spring wheat was harvested at the full maturity stage in the first or second decade of August. During harvest there were determined sugar beet root and leaf yields as well as spring wheat grain and straw yields. Additionally, average samples of sugar beet roots and leaves as well as spring wheat grain and straw were taken and used to perform laboratory analyses. The plant material was fragmented and dried. Dry matter content in sugar beet roots and leaves as well as spring wheat grain and straw were determined by the oven-drying gravimetric method. Ground plant samples were wet-mineralized using sulphuric acid and with a catalyst. Total nitrogen content in sugar beet roots and leaves as well as spring wheat grain and straw were determined by the Kjeldahl method [9].

Table 1

Average air temperature and total rainfall according to the Zawady Meteorological Station

Month	Temperature [°C]						Rainfall [mm]					
	2001	2002	2003	2004	2005	1951–1990	2001	2002	2003	2004	2005	1951–1990
I	–1.0	–0.4	–3.7	–5.6	0.4	–3.1	19.9	8.7	7.7	11.5	13.2	24.5
II	–1.9	3.2	–5.6	–1.0	–4.0	–3.2	9.4	37.5	4.7	21.0	13.2	23.3
III	1.5	4.0	1.4	2.7	–0.7	1.0	3.6	15.8	7.0	19.6	11.7	27.0
IV	8.7	9.0	7.1	8.0	8.7	7.2	69.8	12.9	13.6	35.9	12.3	29.4
V	15.5	17.0	15.6	11.6	13.0	13.2	28.0	51.3	37.2	97.0	64.7	54.3
VI	17.1	17.2	18.4	15.4	15.9	16.2	36.0	61.1	26.6	52.8	44.1	69.3
VII	23.8	21.0	20.0	17.5	20.2	17.6	55.4	99.6	26.1	49.0	86.5	70.6
VIII	20.6	20.2	18.5	18.9	17.5	16.9	24.0	66.5	4.7	66.7	45.4	59.8
IX	12.1	12.9	13.5	13.0	15.0	12.7	108.0	18.7	24.3	19.5	15.8	48.2
X	10.6	6.9	5.4	9.4	8.5	8.0	28.0	48.9	38.0	29.5	0.0	32.0
XI	2.3	3.8	4.7	3.2	2.7	2.6	28.0	16.1	14.7	20.4	13.8	39.2
XII	–6.6	–7.7	0.5	1.3	–0.9	0.4	13.4	0.7	17.0	7.6	32.9	37.3
Average/Sum	8.6	8.9	8.0	7.9	8.0	7.5	423.5	437.8	221.6	430.5	353.6	514.9

Total nitrogen uptake was calculated on the basis of nitrogen content of the dry matter and yield of both crop plants. The experimental data were subjected to analysis of variance and treatment means were compared by Tukey's test at the significance level of 0.05.

Air temperature and precipitation amount and distribution over the study period varied (Table 1), which influenced the growth conditions of intercrops, sugar beet and spring wheat. Compared with long-term mean temperature (7.5 ^{o}C) and precipitation sum (514.9 mm), the average air temperature in the study years was higher (by 1.1 ^{o}C in 2001, 1.4 ^{o}C in 2002, 0.5 ^{o}C in 2003 and 2005 and by 0.4 ^{o}C in 2004) whereas the total rainfall was smaller (by 91.4, 77.1, 293.3, 84.4, and 161.3 mm in 2001, 2002, 2003, 2004 and in 2005, respectively). The rainfall was higher than the long-term mean in April and September of 2001, February, July, August and October of 2002, October of 2003, April, May and August of 2004 and May and July of 2005.

Results and discussion

The studies conducted under the conditions of the Siedlecka Upland showed that there was a significant influence of barley straw and intercrop biomass application on total nitrogen content in the roots and leaves of sugar beet (Table 2).

Table 2

Total nitrogen content [g · kg^{-1} d.m.] in sugar beet roots and leaves, average for 2002–2004

Application of summer intercrop biomass	Roots			Leaves		
	Application of barley straw*					
	a	b	average	a	b	average
Control	7.27	8.09	7.68	25.13	26.67	25.90
Farmyard manure	8.80	8.72	8.76	27.70	28.84	28.27
Red clover	8.88	9.17	9.03	30.40	31.66	31.03
Westerwold ryegrass	8.23	8.44	8.34	27.06	28.01	27.54
Red clover + Westerwold ryegrass	8.61	8.92	8.77	28.22	29.64	28.93
Average	8.36	8.67	—	27.70	28.96	—
$LSD_{0.05}$ for:						
straw incorporation			0.04			0.19
application of summer intercrop biomass			0.29			0.92
interaction: straw incorporation × application of summer intercrop biomass			0.41			1.37

* a – treatment with straw; b – treatment without straw.

An application of barley straw prior to sugar beet cultivation increased total nitrogen content by an average of 0.31 and 1.26 g · kg^{-1} d.m. in roots and leaves, respectively, as compared with the control. Sugar beet roots and leaves harvested from farmyard manure-amended treatments and summer intercrop biomass-manured treatments were characterized by a significantly higher total nitrogen content compared with the control (respectively, by 1.08 and 0.66–1.35 g · kg^{-1} d.m. for roots, and by 2.37 and 1.64–5.13

g · kg^{-1} d.m. for leaves). Also experimental results of studies by other authors demonstrated an increase in total nitrogen content in leaves and roots of sugar beet as a result of an application of farmyard manure [3, 6] and stubble intercrops [2]. Natural and organic manures are a source of macro- and microelements which are gradually released and made available to the following plants during the process of organic matter mineralization [4, 6, 10]. Nitrogen availability for plants depends on the C/N ratio of the mineralized organic matter. A narrow C/N ratio is associated with intense mineralization of nitrogen utilized by plants [11]. In this experiment an influence of Westerwold ryegrass biomass on total nitrogen content in sugar beet roots was significantly smaller compared with farmyard manure in the treatments without straw. The highest total nitrogen content was determined in roots harvested from plots manured with both barley straw combined with red clover and a mixture of red clover and Westerwold ryegrass. When farmyard manure was replaced with red clover biomass in treatments with and without barley straw, there was observed a significant increase in total nitrogen content in sugar beet leaves. The differentiated influence of farmyard manure and intercrop green manures, either with or without straw, on total nitrogen content in sugar beet roots and leaves, which was also reported by Wesolowski et al [7] and Słowinski et al [12], results from the speed of the organic matter mineralization. Sugar beet leaves, being an assimilative and photosynthesis organ, were characterized by a higher total nitrogen content than roots [10, 12].

The amount of total nitrogen taken up was calculated as an outcome of dry matter yield and nitrogen content in the yield [10, 13]. There was found a significant influence of an application of barley straw and intercrop biomass on total nitrogen uptake by sugar beet roots and leaves (Table 3).

Table 3

Total nitrogen uptake [kg · ha^{-1}] by sugar beet roots and leaves, average for 2002–2004

Application of summer intercrop biomass	Roots			Leaves			In total (roots + leaves)		
	Application of barley straw*								
	a	b	average	a	b	average	a	b	average
Control	101.2	119.2	110.2	118.6	144.8	131.7	219.8	264.0	241.9
Farmyard manure	135.1	138.7	136.9	160.9	173.4	167.2	296.0	312.1	304.1
Red clover	133.1	148.8	141.0	168.5	210.2	189.3	301.6	359.0	330.3
Westerwold ryegrass	119.9	123.9	121.9	135.8	146.9	141.4	255.7	270.8	263.3
Red clover + Westerwold ryegrass	141.5	151.8	146.7	166.4	195.4	180.9	307.9	347.2	327.6
Average	126.2	136.5	—	150.0	174.1	—	276.2	310.6	—
$LSD_{0.05}$ for:									
straw incorporation			1.4			1.8			3.7
application of summer intercrop biomass			6.8			8.9			16.8
interaction: straw incorporation × application of summer intercrop biomass			8.9			11.6			22.1

* a – treatment with straw; b – treatment without straw.

Total nitrogen uptake by sugar beet roots and leaves in the barley straw-amended treatment was significantly higher (respectively by 10.3 and 24.1 kg · ha^{-1}, on average) compared with the treatment without straw. Farmyard manure and biomass of summer intercrops significantly increased total nitrogen uptake by roots (by 26.7 and 11.7–36.5 kg · ha^{-1}, respectively) and leaves (by 35.5 and 9.7–57.6 kg · ha^{-1}, respectively) of sugar beet, compared with the control. The greatest total nitrogen amount was taken up by sugar beet roots and leaves in the treatment manured with the red clover + Westerwold ryegrass biomass as well as red clover. An impact of intercrop biomass on nitrogen uptake by sugar beet roots and leaves was modified by barley straw manuring. The overall uptake of total nitrogen by sugar beet (roots + leaves) ranged between 219.8 kg · ha^{-1} in the control without straw to 359.0 kg · ha^{-1} in the barley straw + red clover-amended treatment. The amount of nitrogen taken up by sugar beet roots and leaves detected in this experiment was within the limits mentioned by Wisniewski [10].

Total nitrogen content in spring wheat grain and straw fluctuated significantly under an influence of barley straw and intercrop biomass in the second year following their application (Table 4).

Table 4

Total nitrogen content in spring wheat grain and straw, average for 2003–2005 [g · kg^{-1} d.m.]

Application of summer intercrop biomass	Grain			Straw		
	Application of barley straw*					
	a	b	average	a	b	average
Control	23.89	24.33	24.11	7.00	7.23	7.12
Farmyard manure	25.10	25.96	25.53	7.90	8.18	8.04
Red clover	24.81	25.73	25.27	7.63	8.00	7.82
Westerwold ryegrass	24.42	25.08	24.75	7.37	7.79	7.58
Red clover + Westerwold ryegrass	25.71	26.23	25.97	7.87	8.26	8.07
Average	24.79	25.47	—	7.55	7.89	—
$LSD_{0.05}$ for:						
straw incorporation			0.13			0.06
application of summer intercrop biomass			0.58			0.27
interaction: straw incorporation × application of summer intercrop biomass			0.72			0.40

* a – treatment with straw; b – treatment without straw.

Barley straw ploughed under prior to the previous crop cultivation significantly increased total nitrogen content in grain (on average by 0.68 g · kg^{-1} d.m.) and straw (on average by 0.34 g · kg^{-1} d.m.) of spring wheat, compared with the control. Total nitrogen content in spring wheat grain and straw harvested from farmyard manure--amended treatment was significantly higher (by 1.42 and 0.92 g · kg^{-1} d.m., respectively) compared with the control grain and straw. Manuring with summer intercrop biomass increased total nitrogen content in spring wheat grain and straw (by 0.64–1.86 and 0.46–0.95 g · kg^{-1} d.m., respectively) in the second year following biomass application, as compared with the control. A beneficial secondary effect of farmyard manure on nitrogen content in cereal grain was found by Mazur and Koc [1] as well as Wiater and Debicki [4]. Stopes et al [13] reported that wheat grain from rotations including green manures is characterized by an increased nitrogen content. It is due to improved nitrogen release as a result of mineralization of fertilizers applied. An interaction of the experimental factors indicated that total nitrogen content was significantly reduced in spring wheat grain in the treatment where barley straw had been applied in combination with Westerwold ryegrass, and in spring wheat straw in the treatment without barley straw incorporation, compared with farmyard manure. In the remaining treatments, the secondary effect of summer intercrop biomass on total nitrogen content in spring wheat grain and straw was similar to the effect produced by an application of farmyard manure.

Total nitrogen uptake by spring wheat grain and straw was modified by an application of barley straw and summer intercrop biomass (Table 5).

Table 5

Total nitrogen uptake by spring wheat grain and straw, average for 2003–2005 [kg · ha^{-1}]

Application of summer intercrop biomass	Grain			Straw			In total (grain + straw)		
	Application of barley straw*								
	a	b	average	a	b	average	a	b	average
Control	84.6	93.3	88.9	27.3	28.2	27.8	111.9	121.5	116.7
Farmyard manure	112.8	120.2	116.5	32.8	36.5	34.6	145.6	156.7	151.1
Red clover	99.9	115.8	107.9	31.0	34.9	32.9	130.9	150.6	140.8
Westerwold ryegrass	97.2	109.9	103.6	29.4	32.8	31.1	126.6	142.7	134.7
Red clover + Westerwold ryegrass	115.2	122.6	118.9	33.8	36.4	35.1	149.0	159.0	154.0
Average	101.9	112.4	—	30.9	33.7	—	132.8	146.1	—
$LSD_{0.05}$ for:									
straw incorporation			1.1			0.4			1.7
application of summer intercrop biomass			5.9			1.9			7.6
interaction: straw incorporation × application of summer intercrop biomass			7.2			2.5			8.9

* a – treatment with straw; b – treatment without straw.

Barley straw preceding the previous crop significantly increased total nitrogen uptake by the cereal grain (on average by 10.5 kg · ha^{-1}) and straw (on average by 2.8 kg · ha^{-1}) compared with the control without straw. Farmyard manure and summer intercrop biomass significantly increased total nitrogen uptake by spring wheat grain (by 27.6 and 14.7–30.0 kg · ha^{-1}, respectively) and straw (6.8 and 3.3–7.3 kg · ha^{-1}, respectively) compared with the control. The overall uptake of total nitrogen by spring triticale harvested from treatments where the red clover + Westerwold ryegrass mixture had been used as a manure was at the level similar to that recorded for farmyard manure-amended treatment. In contrast, farmyard manure replaced by the biomass of red clover and Westerwold ryegrass significantly reduced the overall uptake of total nitrogen by spring wheat. The secondary effect of summer intercrop biomass on total nitrogen uptake by spring wheat grain and yield fluctuated depending on barley straw application. Amounts of nitrogen taken up by spring wheat ranged between 111.9 and 159.0 kg · ha^{-1} according to the treatment and supported the results reported by Goos et al [5].

Conclusions

1. Manuring with barley straw, farmyard manure and summer intercrop biomass increased total nitrogen content in sugar beet roots and leaves as well as spring wheat grain and straw. It also increased total nitrogen uptake by both the crop plants.
2. The effect of farmyard manure was similar to the impact of red clover and a red clover + Westerwold ryegrass on total nitrogen content in sugar beet roots and spring wheat grain and yield.
3. The quantity of nitrogen taken up by sugar beet in the treatment amended with red clover + Westerwold ryegrass as well as red clover was greater compared with the farmyard manure-amended treatment. The secondary effect of a red clover + Westerwold ryegrass mixture on total nitrogen uptake by spring wheat was similar to farmyard manure whereas the effect of red clover and Westerwold ryegrass was significantly smaller than farmyard manure.

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ODDZIAŁYWANIE ZRÓŻNICOWANEGO NAWOŻENIA ORGANICZNEGO NA ZAWARTOŚĆ I POBRANIE AZOTU PRZEZ ROŚLINY

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Abstrakt: W doświadczeniu przeprowadzonym w latach 2001–2005 określono bezpośrednie i następcze oddziaływanie słomy jęczmiennej (obiekt bez słomy, obiekt ze słomą) oraz biomasy wsiewki międzyplonowej (obiekt kontrolny bez nawożenia organicznego, obornik, wsiewka międzyplonowa: koniczyna czerwona, życica westrwoldzka, koniczyna czerwona + życica westerwoldzka) na zawartość i pobranie azotu ogółem przez burak cukrowy i pszenicę jarą. Porównano również wpływ obornika z działaniem biomasy wsiewek międzyplonowych na zawartość i pobranie azotu ogółem z plonem roślin. Eksperyment polowy założono w układzie split-blok, w trzech powtórzeniach. Stwierdzono, że nawożenie słomą jęczmienną, obornikiem i biomasą wsiewek międzyplonowych powoduje istotny wzrost zawartości azotu ogółem w korzeniach i liściach buraka cukrowego oraz w ziarnie i słomie pszenicy jarej. Zwiększa również pobranie azotu ogółem z plonem roślin. Zastąpienie obornika biomasą koniczyny czerwonej i mieszanki koniczyny czerwonej z życicą westerwoldzką nie różnicuje istotnie zawartości azotu ogółem w korzeniach buraka cukrowego oraz w ziarnie i słomie pszenicy jarej. Największą zawartością azotu ogółem cechowały się liście buraka cukrowego z obiektu nawożonego biomasą koniczyny czerwonej. Ilość azotu pobranego z plonem buraka cukrowego na obiekcie nawożonym biomasą mieszanki koniczyny czerwonej z życicą westerwoldzką oraz koniczyny czerwonej kształtowała się na wyższym poziomie niż z plonem w wariancie z obornikiem. Następcze działanie biomasy mieszanki koniczyny czerwonej z życicą westerwoldzką na pobranie azotu ogółem przez pszenicę jarą nie różniło się istotnie od wpływu obornika, a biomasy koniczyny czerwonej i życicy westerwoldzikiej było istotnie mniejsze.

Słowa kluczowe: burak cukrowy, pszenica jara, słoma, obornik, wsiewka międzyplonowa, zawartość i pobranie azotu ogółem