EFFECT OF NITROGEN FERTILIZATION AND APPLICATION OF SOIL PROPERTIES IMPROVING MICROBIAL PREPARATIONS ON THE CONTENT OF MINERAL NITROGEN IN SOIL AFTER SPRING WHEAT HARVESTING

WPŁYW NAWOŻENIA AZOTEM ORAZ APLIKACJI MIKROBIOLOGICZNYCH PREPARATÓW POPRAWIAJĄCYCH WŁAŚCIWOŚCI GLEBY NA ZAWARTOŚĆ AZOTU MINERALNEGO W GLEBIE PO ZBIORZE PSZENICY JAREJ

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ABSTRACT

The effect of nitrogen dose and application of soil properties improving microbial preparations on the content of mineral nitrogen in soil after spring wheat harvesting were evaluated in a three-year field experiment. The investigations were conducted under conditions of Luvic Chernozem. Diverse nitrogen fertilization (0, 40, 80, 120 and 180 $kg \cdot ha^{-1}$) was applied and microbial preparations: Proplantan AM, Effective Microorganisms EM and UGmax Soil Fertilizer. The content on N_{min} in the soil after wheat harvesting, particularly in the upper layers of the soil profile was growing with increasing nitrogen fertilization level. The amount of nitrate nitrogen in the soil after harvest plants was below the average content of N-NO3 for this category of agronomic soil in Poland. Bigger quantity of mineral nitrogen in soil after plant harvesting than before their sowing was registered only on the obejcts receiving 160 $kg\ N \cdot ha^{-1}$ in the years characterized by a similar to multiannual average amount and distribution of rainfall during the period from April to June. Microbial preparations Proplantan AM and Effective Microorganisms EM caused a significant decrease in nitrate and ammonium nitrogen in the 0-30 and 30-60 cm soil layers.

Keywords: soil nitrogen, microbial preparations, nitrogen fertilization, spring wheat

STRESZCZENIE

W trzyletnim doświadczeniu polowym oceniano wpływ wielkości dawki azotu oraz aplikacji mikrobiologicznych preparatów poprawiających właściwości gleby na zawartość azotu mineralnego w glebie po zbiorze pszenicy jarej. Badania realizowano w warunkach glebowych czarnoziemu zdegradowanego. W uprawie pszenicy stosowano zróżnicowane nawożenie azotem (0, 40, 80, 120 i 180 $kg \cdot ha^{-1}$) oraz mikrobiologiczne preparaty: Proplantan AM, Efektywne Mikroorganizmy EM i

Użyźniacz Glebowy UGmax. Zawartość N_{min} w glebie po zbiorze pszenicy, szczególnie w górnych warstwach profilu glebowego zwiększała się wraz ze wzrostem poziomu nawożenia azotem. Ilość azotu azotanowego w glebie po zbiorze roślin kształtowała się poniżej przeciętnej zawartości N-NO_3 dla tej kategorii agronomicznej gleb w Polsce. Większą ilość azotu mineralnego w glebie po zbiorze roślin niż przed ich siewem stwierdzono tylko w obiektach nawożonych dawką 160 kg N·ha^{-1} w latach charakteryzujących się podobną do średniej wieloletniej ilością i rozkładem opadów w okresie od kwietnia do czerwca. Preparaty mikrobiologiczne Proplantan AM i Efektywne Mikroorganizmy EM powodowały istotne zmniejszenie zawartości azotu azotanowego i amonowego w warstwach gleby 0-30 i 30-60 cm.

Słowa kluczowe: azot mineralny w glebie, preparaty mikrobiologiczne, nawożenie azotem, pszenica jara

STRESZCZENIE SZCZEGÓŁOWE

Celem badań było określenie wpływu preparatów mikrobiologicznych oraz dawki azotu na kształtowanie się zawartości azotu mineralnego w glebie po zbiorze pszenicy jarej. Czynnikami doświadczenia były poziomy nawożenia azotem: 0, 40, 80, 120 i 160 kg·ha^{-1} oraz mikrobiologiczne preparaty poprawiające właściwości gleby: Proplantan AM, Efektywne Mikroorganizmy EM oraz Użyźniacz Glebowy UGmax . Preparaty aplikowano doglebowo przed wiosenną uprawą roli i pogłównie w fazie pierwszego kolanka (BBCH-31). Azot na obiektach nawożonych dawkami 40 i 80 kg·ha^{-1} stosowano w całości przedsiewnie, natomiast w dawkach większych, 80 kg N·ha^{-1} przedsiewnie, a pozostałą część pogłównie w fazie strzelania w źdźbło i kłoszenia (BBCH-32 i 51). Próbki gleby do oznaczeń zawartości azotanowej i amonowej formy azotu mineralnego pobierano przed siewem i po zbiorze pszenicy jarej z warstw 0-30 cm, 30-60 cm i 60-90 cm. Zawartość azotu mineralnego w glebie po zbiorze pszenicy jarej zwiększała się wraz z poziomem zastosowanego nawożenia. Zależność ta była najbardziej widoczna w górnej i środkowej części profilu glebowego, szczególnie w przypadku N-NO_3. Większą ilość azotu mineralnego w glebie po zbiorze roślin niż przed ich siewem stwierdzono tylko w obiektach nawożonych dawką 160 kg N·ha^{-1} w latach charakteryzujących się podobną do średniej wieloletniej ilością i rozkładem opadów w okresie od kwietnia do czerwca. Ilość azotanowej formy azotu mineralnego w glebie ciężkiej po zbiorze pszenicy jarej we wszystkich obiektach nawozowych kształtowała się poniżej przeciętnej zawartości N-NO_3 dla tej kategorii agronomicznej gleb w Polsce. Oceniane w badaniach preparaty mikrobiologiczne Proplantan AM i Efektywne Mikroorganizmy EM powodowały częściową immobilizację azotu czego efektem była mniejsza niż w obiekcie kontrolnym zawartość azotu mineralnego w glebie po zbiorze pszenicy jarej.

INTRODUCTION

Application of nitrogen fertilizers significantly contributed to a growth of agricultural production in the world. However, irrespective of the obtained benefits, excessive use of nitrogen always involves a risk of environmental pollution. In soil nitrogen occurs mainly in organic compounds and only 1–5% constitutes a form of ammonium and nitrate ions. In agrosystems dynamic changes of mineral nitrogen content soil occur

in result of this component uptake by crops, weeds and soil microorganisms, losses through leaching and evaporation, but also in result of nitrogen inflow as a consequence of nitrogen compounds emission from the atmosphere and fertilization (Deng, et al., 2000; Fotyma, et al., 2002). Nitrogen originating from mineral fertilizers enters the cycle of nitrogen transformations in soil and the degree of its utilization depends among others on the dose and form of fertilizer, fertilization technique, soil conditions, the weather course and the crop species and cultivar. Plants use up on average 50% of the supplied nitrogen dose. The other part of nitrogen becomes immobilized or lost. Previous research demonstrated that between 15 and 50% of nitrogen is leached to deeper soil layers and underground waters where it is accumulated as nitrates, nitrites and organic compounds, such as amines or nitrosamines, which are counted to dangerous poisons (Doran, et al., 1996; Mazur and Mazur, 2006; Newbould, 1989). Moreover, in the soil environment nitrogen significantly influences the number and qualitative selection of soil microorganisms (Barabasz, et al., 2002; Byrnes, 1990). It leads to a disturbance of microbiological balance and in consequence to soil degradation and decline in crop yield. One of the ways to recover soil biological activity may be application of microbial preparations improving soil properties. The effective microorganism technology has been increasingly more widely used in agricultural practice. However, the effect of microbial preparations on soil properties and plant yielding under diversified site and climatic conditions is not unanimous. The supporters prove an advantageous effect of microbial preparations on plant and soil healthiness, whereas the opponents point to a small reliability of the results due to a short period of investigations and their local range (Boligłowa and Gleń, 2008; Piskier, 2006; Shah, et al., 2001; Vliet, et al., 2006).
The aim of the investigations was determining the effect of microbial preparations improving soil properties and nitrogen dose on the mineral nitrogen content in soil after spring wheat harvesting.

MATERIAL AND METHODS

The investigations were conducted in 2006-2008 at the Experimental Station in Prusy (50°07'N and 20°05'E, 271 m a.s.l.) near Krakow. The field experiment was localised on Luvic chernozem developed from loess. Characteristics of the soil conditions was presented in Table 1. The factor of the experiment, set up in to split–block design in 4 replications, were levels of nitrogen fertilization: 0, 40, 80, 120 and 160 kg·ha^{-1} and microbial preparations improving soil properties: Proplantan AM (3 l·ha^{-1}), Effective Microorganisms EM (3 l·ha^{-1}), and UGmax Soil Fertilizer (0.9 l·ha^{-1}). The preparations were applied to the soil prior to spring tillage and as top dressing in the phase of first node (BBCH 31). Further in the paper the preparations will be described respectively as AM, EM and UGmax. Proplantan AM (ROGÓW OST-WEST and Heribert Heinrichs) contains disaccharide, and polysaccharide, lactic acid, carotene, riboflavin, thiamine, amylase, sea salt and minerals. Effective Microorganisms EM preparation (Greenland Technology EM, Poland) contains milk bacteria (*Lactobacillus casei*, *Streptococcus lactis*), photosynthetic bacteria (*Rhodopseudomonas palustrus*, *Rhodobacter space*), yeast (*Saccharomyces albus*, *Candida utilis*), actinomycetes (*Streptomyces albus*, *S. griseus*) and moulds (*Aspergillus oryzae*, *Mucom hiemalis*). UGmax soil fertilizer (P.P.U.U BOGDAN, Poland) contains yeast, lactic acid bacteria, photosynthetic bacteria, bacteria of *Azotobacter*, *Pseudomonas*, actinomycetes, macroelements (g·l^{-1}): K – 3.5, N – 1.2, S – 1.0, P – 0.5, Na – 0.2, Mg – 0.1 and microelements (mg·l^{-1}): Zn – 20.0, Mn – 0.3. On the objects fertilized with 40 and 80 kg of nitrogen the whole dose was applied pre-sowing, whereas in case of bigger doses, 80 kg N·ha^{-1} was used pre-sowing and the rest as top dressing at shooting and earing stage (BBCH 32 and 51). Nitrogen was used in the form of ammonium nitrate. Phosphorus (superphosphate) and potassium (potassium chloride) fertilization was applied at the rate of 50 kg P_2O_5·ha^{-1} and 120 kg K_2O·ha^{-1}. Potatoes were the forecrop for spring wheat, Bombona cv. Sowing was performed in the first decade of April and harvesting fell for the first and second decades of August. Sowing density was 450 germinating kernels per 1 m^2 and row spacing 12.5 cm. Harvesting plot area was 10 m^2. Weeds were controlled by means of Lintur 70 WG, whereas diseases were combated by means of Tilt Plus 400 EC and Amistar 250 SC fungicides.

Soil samples for nitrate and ammonium forms of mineral nitrogen were collected before sowing and after harvesting of spring wheat from the 0-30, 30-60 and 60-90 cm soil layers. The soil collected from four points on a plot was mixed into one joint sample and stored refrigerated until analysis. The analysis was based on the spectrophotometric measurement of the concentration of nitrate ions (NO_3) and ammonium (NH_4) in soil extract 1% solution of potassium sulphate. For NO_3 was measured intensity of yellow color formed by the reaction of an acid phenyldisulphonic. For the determination of NH_4 measured intensity of the resulting blue color of the reaction of sodium phenolate and sodium chlorate. The results of analyses were elaborated statistically by means of ANOVA analysis and significance of differences was verified by means of Tukey test on the significance level α =0.05.

Precipitation-thermal conditions during the period of field investigations were less favourable for the growth and development of spring wheat than multiannual average for this region (Table 2). Rainfall total from April to August in all years of research was definitely lower, while an average temperature higher than in the analysed period for the years 1997-2007. A marked rainfall deficit was registered in July 2006 and in May and June, 2008.

RESULTS AND DISCUSSION

The contents of nitrate and ammonium forms of mineral nitrogen in soil after spring wheat harvesting depended significantly on the level of nitrogen fertilization, application of microbial preparations and the weather conditions during the period of plant vegetation (Table 3 and 4). The dominant form was nitrate nitrogen - best available to plant and its share in the total amount of mineral nitrogen was on average 65%. The content of N-NO_3 in the 0-90 cm soil layer remained on the level of 42 kg·ha^{-1}, regardless of the experimental factors, whereas respectively N-NH_4 was on the level of 22 kg·ha^{-1}. The relations between the share of individual nitrogen forms described above are in compliance with the reports of other authors (Fotyma, 2000; Fotyma, et al., 2002; Sztuder, 2007; Sztuder and Strączyński, 2008). Czępińska-Kamińska, et al., (1999), Łabętowicz and Rutkowska, (1996), and Skowrońska, (2004) present a different opinion, thinking that under conditions of moderate climate soils N-NH_4 is the dominating form of mineral nitrogen.

Moreover, considerable differences were assessed in N_{min} distribution in the analyzed layers of the soil profile. The highest quantities of mineral nitrogen were determined in the 0.30 cm, on average 21.8 kg N-NO_3 and 10.8 kg N-NH_4·ha^{-1}, while the lowest in the 60-90 cm layer, respectively 6.5 kg N-NO_3 and 4.9 kg N-NH_4·ha^{-1}. Mineral nitrogen concentrations diminishing in soil with depth were also registered by

Rutkowska, et al., (2002) and Trawczyński, (2004). According to Fotyma, et al., (2002) a half of the total quantity of mineral nitrogen present in the whole soil profile occurs in the 0-30 cm arable layer, moreover N_{min} concentrations in this soil layer are the most changeable. On the other hand, Skowrońska, (2004) demonstrated the occurrence of mineral nitrogen accumulation zone below the arable layer. In the presented investigations, the share of mineral nitrogen occurring to the depth of 30 cm constituted 51%, in the 30-60 cm 31% and in the 60-90cm layer 18% of N_{min} present in the whole soil profile. N-NO_3 concentrations in the soil profile revealed a distribution similar to the distribution of the total N_{min} content. 52% of N-NO_3 was in the upper layer, 32% in the middle layer and 16% in the lower layer of the soil profile. Obtained research results are compatible with the reports of Fotyma, et al., (2002), who demonstrated that over half of N-NO_3 remains in the 0-30 cm layer, 28% at the depth of 30-60 cm and 20% in the 60-90 cm layer.

Mineral nitrogen concentration in soil after plant harvesting, particularly in the upper layers of the soil profile was increasing with growing level of nitrogen fertilization. The content of nitrate nitrogen form at the depth to 30 cm fluctuated from 12.6 kg N-$NO_3 \cdot ha^{-1}$ on the non-fertilized object to 29.7 kg N-$NO_3 \cdot ha^{-1}$ on the object fertilized with 160 kg N·ha^{-1}. In the 30-60 cm layer the amount of this form ranged from 8.8 to 18.6 kg N-$NO_{3,}$ whereas in the 60-90 cm layer, respectively from 5.5 to 7.2 kg N-$NO_3 \cdot ha^{-1}$. On the other hand the content of ammonium form of mineral nitrogen in the 0-30 cm soil layer fluctuated from 7.2 to 14.9 kg N-$NH_4 \cdot ha^{-1}$, at the depth of 30-60 cm from 4.8 to 8.3 kg N-$NH_4 \cdot ha^{-1}$ and in the 60-90 cm layer from 4.1 to 5.8 kg N-$NH_4 \cdot ha^{-1}$. Nitrogen fertilization applied in spring wheat cultivation in the form of ammonium nitrate affected an increase in N-NO_3 content to a greater degree than N-NH_4. The quantity of nitrates on non-fertilized object after plant harvesting was twice lower than on the objects fertilized with a dose of 160 kg N·ha^{-1}. Abad, et al., (2004) revealed a similar dependence in cultivation of durum wheat fertilized in the range of 0-200 kg N·ha^{-1} and Richards, et al., (1996) in winter barley cultivation. Despite its good availability to plants, NO_3 accumulates in soil due to nitrification process which is most intensive during vegetation period. Nitrogen, unused by crops may become a source of environment burdening with nitrates. As reported by Fotyma, (2000) average content of N-NO_3 in heavy soil after plant harvesting is 75 kg·ha^{-1}. In the Author's own research, exceeded values were never noted on any fertilizer treatments after spring wheat harvesting, i.e. in the second decade of August. However, the content of mineral nitrogen in soil after plant harvesting may increase under the influence of organic matter mineralization. Dying biomass of the microorganisms which contributed to immobilization of mineral nitrogen may play a crucial role. In the Author's own research a significant decline in nitrate and ammonium nitrogen was registered in the 0-30 and 30-60 cm soil layers after application of AM and EM microbial preparations. The effect of mineral nitrogen immobilization was particularly pronounced on non-fertilized objects and on the objects receiving 80, 120 and 160 kg N·ha^{-1}. The fact contradicts the opinion of Jingguo and Bakken, (1997a; 1997b) that nitrogen is not biologically immobilized by soil microorganisms but also the results obtained by Jakubas, et al., (2010) pointing to a marked increase in N_{min} content in soil incubated with preparations containing effective microorganisms.

The quantity of mineral nitrogen in soil after spring wheat harvesting depended significantly also on the weather conditions during vegetation period and N_{min} concentrations in spring (Table 5). Average content of mineral nitrogen in soil prior to wheat sowing fluctuated from 72.8 to 98.5 kg·ha^{-1}, whereas after harvesting from 60.9

to 70.9 kg·ha^{-1}. A bigger amount of mineral nitrogen in soil after plant harvesting than before their sowing was registered only on the objects fertilized with 160 kg N·ha^{-1} in 2006 and 2007. Small amount of mineral nitrogen in soil after spring wheat harvesting in 2008 might have resulted from insufficient rainfall amount in April, May and June, respectively 70, 43 and 33% of the average multiannual precipitation total. It is particularly important, since, as reported by Bloem, et al., (1994), nitrogen mineralization occurs most intensively during the period from April to June. The significance of the weather conditions effect on the amount of nitrogen inflow from mineralization was also demonstrated by Kolberg, et al., (1999), Sieling, et al., (1999) and López-Bellido, (2001).

Linear regression analysis confirmed the occurrence of significant dependencies between the nitrogen dose and contents of $N–NO_3$ and $N–NH_4$ in soil after spring wheat harvesting (Figure 1). These dependencies were most pronounced in the upper layer of the soil profile and the weakest in the lower soil layer. The value of determination coefficient (R^2) proves that the differences in concentrations of mineral nitrogen in the 0-90 cm soil layer may be explained by nitrogen dose in 87% for $N-NO_3$ and in 79% for $N-NH_4$. Moreover, nitrogen fertilization of spring wheat caused a higher accumulation of $N-NO_3$ than $N-NH_4$ in the soil profile.

CONCLUSIONS

Mineral nitrogen concentrations in soil after spring wheat harvesting were increasing with fertilization level. The dependence was the most apparent in the upper and middle part of the soil profile, particularly for $N-NO_3$. A higher quantity of mineral nitrogen was registered in soil after plant harvesting than before their sowing only on the objects fertilized with 160 kg N·ha^{-1} in the years characterized by similar to average multiannual amount and distribution of rainfall from April to June. The amount of nitrate form of nitrogen in soil after harvest of spring wheat in all fertilizer objects was below average content of $N-NO_3$ in soil of this agronomic category in Poland. Microbial preparations Proplantan AM and Effective Microorganisms EM caused a partial immobilization of mineral nitrogen in soil.

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Table 1. Characteristics of the soil (0-30 cm layer)

Tabela 1. Charakterystyka warunków glebowych (warstwa 0-30 cm)

Properties Właściwości	Value Wartość
pH_{KCl}	6.1
total C ($g \cdot kg^{-1}$) C ogółem	1.02
total N ($g \cdot kg^{-1}$) N ogółem	1.14
C:N ratio stosunek C:N	0.89
P_2O_5 ($mg \cdot kg^{-1}$)	150.2
K_2O ($mg \cdot kg^{-1}$)	168.5
MgO ($mg \cdot kg^{-1}$)	112.1
sand ($g \cdot kg^{-1}$) piasek	120
silt ($g \cdot kg^{-1}$) pył	540
clay ($g \cdot kg^{-1}$) ił	340

Table 2. Characteristic of climatic conditions

Tabela 2. Charakterystyka warunków klimatycznych

Year Rok	Month Miesiąc					Mean/Sum Średnia/Suma
	IV	V	VI	VII	VIII	
temperature (^{o}C) temperatura						
2006	9.2	13.2	17.4	21.6	17.7	15.8
2007	10.4	15.8	18.1	19.6	19.4	16.7
2008	8.6	14.1	18.5	19.1	18.2	15.7
Long–term period 1997–2007 Wielolecie	8.1	13.7	16.5	18.2	17.9	14.9
rainfalls (mm) opady						
2006	36	60	62	28	93	279
2007	15	57	59	72	125	328
2008	35	28	26	142	45	276
Long–term period 1997–2007 Wielolecie	50	65	80	75	79	349

Table 3. Content of N-NO_3 in the soil after harvest of wheat (kg·ha^{-1})

Tabela 3. Zawartość N-NO_3 w glebie po zbiorze pszenicy (kg·ha^{-1})

Dose of N (kg·ha^{-1}) Dawka N	Microbial preparation Preparat mikrobiologiczny				Year Rok			Mean Średnia
	control	AM	EM	UGmax	2006	2007	2008	
soil layer 0-30 cm warstwa gleby 0-30 cm								
0	14.5	11.9	10.8	13.4	11.6	12.0	14.3	12.6
40	17.6	20.1	19.6	20.2	17.4	20.7	20.0	19.4
80	23.5	21.1	19.9	21.2	19.2	23.5	21.5	21.4
120	27.3	24.7	24.5	26.3	23.7	28.6	24.8	25.7
160	32.7	26.7	28.9	30.7	28.0	31.5	29.7	29.7
Mean Średnia	23.1	20.9	20.7	22.4	20.0	23.3	22.1	
$LSD_{0.05}$ $NIR_{0.05}$	1.05				1.95			1.58
soil layer 30-60 cm warstwa gleby 30-60 cm								
0	10.3	7.0	8.0	9.8	8.5	7.7	10.2	8.8
40	11.9	9.7	9.4	10.7	9.6	9.2	12.3	10.4
80	16.4	13.2	12.7	14.5	12.3	14.9	15.3	14.2
120	16.1	13.2	14.7	16.7	14.3	13.9	17.3	15.2
160	19.0	16.0	19.5	19.9	15.2	20.9	19.6	18.6
Mean Średnia	14.8	11.8	12.9	14.3	12.0	13.3	15.0	
$LSD_{0.05}$ $NIR_{0.05}$	1.41				1.18			1.49
soil layer 60-90 cm warstwa gleby 60-90 cm								
0	5.4	5.5	5.6	5.5	3.5	6.1	6.8	5.5
40	6.3	6.4	6.8	6.3	6.3	6.4	6.5	6.4
80	6.3	6.4	6.4	6.3	6.0	6.4	6.5	6.3
120	6.7	7.0	7.3	6.8	6.7	7.1	6.9	6.9
160	7.4	7.2	6.8	7.4	7.1	7.1	7.3	7.2
Mean Średnia	6.4	6.5	6.6	6.5	6.0	6.6	6.8	
$LSD_{0.05}$ $NIR_{0.05}$	n.s. r.n.				0.85			0.54
soil layer 0-90 cm warstwa gleby 0-90 cm								
0	30.2	24.4	24.4	28.7	23.7	25.8	31.2	26.9
40	35.7	36.1	35.8	37.1	33.3	36.3	38.9	36.2
80	46.1	40.6	39.0	42.0	37.5	44.8	43.4	41.9
120	50.1	44.8	46.5	49.8	44.8	49.6	49.0	47.8
160	59.1	49.9	55.2	57.9	50.4	59.5	56.7	55.5
Mean Średnia	44.2	39.2	40.2	43.1	37.9	43.2	43.8	
$LSD_{0.05}$ $NIR_{0.05}$	2.28				1.31			2.16

n.s. – non significant difference
r.n. – różnica nieistotna

Table 4. Content of N-NH_4 in the soil after harvest of wheat (kg·ha^{-1})

Tabela 4. Zawartość N-NH_4 w glebie po zbiorze pszenicy (kg·ha^{-1})

Dose of N (kg·ha^{-1}) Dawka N	Microbial preparation Preparat mikrobiologiczny				Year Rok			Mean Średnia
	control	AM	EM	UGmax	2006	2007	2008	
soil layer 0-30 cm warstwa gleby 0-30 cm								
0	7.8	6.8	7.2	7.0	7.0	6.5	8.2	7.2
40	8.9	9.1	8.0	9.3	8.7	9.2	8.6	8.8
80	11.0	9.6	8.8	10.1	9.0	11.3	9.3	9.8
120	14.2	12.1	12.7	13.5	12.7	13.7	12.9	13.1
160	15.9	14.1	13.5	16.2	15.2	13.5	16.0	14.9
Mean Średnia	11.6	10.3	10.0	11.2	10.5	10.8	11.0	
$LSD_{0.05}$ $NIR_{0.05}$	0.81				n.s. r.n.			1.05
soil layer 30-60 cm warstwa gleby 30-60 cm								
0	5.8	3.7	4.8	4.9	4.4	4.2	5.8	4.8
40	5.8	5.7	5.2	5.5	5.9	4.8	5.9	5.6
80	7.6	6.6	7.0	7.2	6.7	8.0	6.7	7.1
120	8.1	7.6	6.3	8.2	7.3	7.9	7.4	7.5
160	9.8	6.6	7.6	9.4	7.6	9.8	7.6	8.3
Mean Średnia	7.4	6.0	6.2	7.0	6.4	6.9	6.7	
$LSD_{0.05}$ $NIR_{0.05}$	0.78				n.s. r.n.			1.16
soil layer 60-90 cm warstwa gleby 60-90 cm								
0	4.5	4.4	3.9	3.8	3.5	4.8	4.1	4.1
40	4.6	5.1	5.0	4.6	3.4	7.0	4.0	4.8
80	5.0	5.1	5.0	4.9	3.7	7.5	3.7	5.0
120	5.1	5.1	5.0	5.0	3.4	7.6	4.0	5.0
160	5.8	5.8	5.7	5.7	3.9	9.0	4.6	5.8
Mean Średnia	5.0	5.1	4.9	4.8	3.6	7.2	4.1	
$LSD_{0.05}$ $NIR_{0.05}$	n.s. r.n.				0.83			0.38
soil layer 0-90 cm warstwa gleby 0-90 cm								
0	18.7	14.7	15.9	15.9	15.2	15.5	18.2	16.3
40	19.4	20.0	18.1	19.8	18.3	21.3	18.4	19.3
80	23.5	21.1	20.8	22.0	19.4	26.5	19.6	21.8
120	27.3	24.1	24.0	26.8	23.7	29.0	24.0	25.5
160	31.5	25.6	26.8	31.3	26.5	32.4	27.4	28.8
Mean Średnia	24.1	21.1	21.1	23.1	20.6	25.0	21.5	
$LSD_{0.05}$ $NIR_{0.05}$	1.37				2.95			1.74

n.s. – non significant difference
r.n. – różnica nieistotna

Table 5. Content of mineral nitrogen ($N\text{-}NO_3 + N\text{-}NH_4$) in the soil layer of 0-90 cm

Tabela 5. Zawartość azotu mineralnego (N-NO3 + N-H4) w warstwie gleby 0-90 cm

Factor Czynnik	Before sowing Przed siewem	After harvest Po zbiorze Dose of N ($kg \cdot ha^{-1}$) Dawka N					Mean Średnia	$LSD_{0.05}$ $NIR_{0.05}$
		0	40	80	120	160		
Microbial preparation								
control	84.0	48.9	55.1	69.7	77.4	90.6	71.0	
AM	85.6	39.1	56.2	61.7	68.9	75.5	64.5	3.29
EM	86.5	40.3	53.9	59.8	70.5	81.9	65.5	
UGmax	83.6	44.6	56.9	63.9	76.6	89.2	69.1	
Year								
2006	72.8	38.8	51.7	56.9	68.5	76.9	60.9	
2007	83.4	41.4	57.6	71.4	78.6	91.9	70.7	4.49
2008	98.5	49.5	57.3	63.0	73.0	84.1	70.9	
Mean Średnia	84.9	43.2	55.5	63.8	73.3	84.3		
$LSD_{0.05}$ $NIR_{0.05}$				3.42				

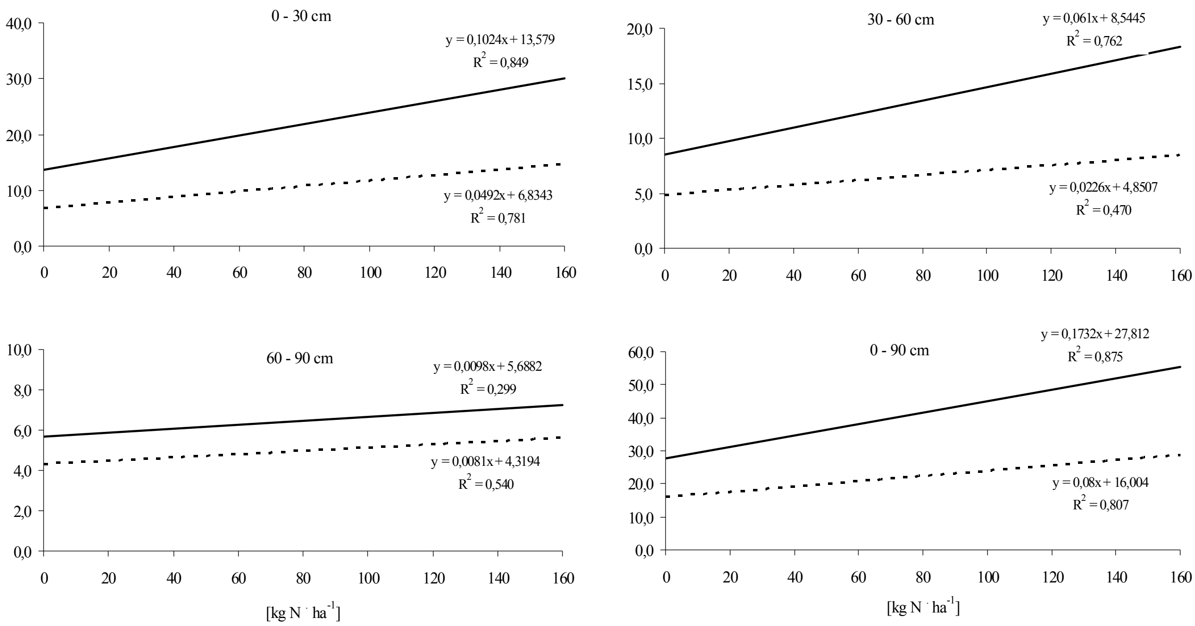

Figure 1. The relationship between the level of nitrogen fertilization and mineral nitrogen content in soil (—— N-NO_3, - - - N-NH_4) after harvest of spring wheat

Wykres 1. Zależność pomiędzy poziomem nawożenia azotem a zawartością azotu mineralnego w glebie (—— N-NO_3, - - - N-NH_4) po zbiorze pszenicy jarej