ORIGINAL ARTICLE

EFFECT OF LONG-TERM GREEN FALLOW ON INORGANIC NITROGEN CONTENT IN THE SOIL

VPLYV DLHODOBÉHO ZELENÉHO ÚHORU NA OBSAH ANORGANICKÉHO DUSÍKA V PODE

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SÚHRN

Vzhľadom na riešenie ekologického poľnohospodárstva, spôsobov hospodárenia v chránených a vodohospodárskych oblastiach, zvyšovania vegetačného krytu, znižovania strát dusíka, ako aj znižovania nadprodukcie poľnohospodárskych plodín, objavujú sa snahy vyčleniť časť ornej pôdy s poľnohospodárskeho využívania a uskutočňovať jej krátkodobé úhorovanie. Cieľom našej práce bolo sledovať vplyv spôsobu využívania viacročného zeleného úhoru (6-ročný úhor bez agrotechnických zásahov s výnimkou kosby) na zmeny v dynamike anorganických foriem dusíka v pôde a jej pH. Pokus mal tri nehnojené varianty: 1. zelený nekosený úhor, 2. kosený zelený úhor, hmota zostala na parcele, 3. kosený zelený úhor, hmota sa z parcely odstraňovala. Vo všetkých variantoch v pôde prevládal amónny dusík, ktorého podiel na N_{an} bol v priemere 70 %, čo vyplývalo zo slabej nitrifikácie v daných podmienkach. Štatisticky najvýznamnejší vplyv na zmeny anorganického dusíka mal ročník a to najmä množstvo zrážok, ktoré výrazne podmieňuje aktivitu nitrifikačných procesov. V rámci variantov bola preukaznosť iba medzi druhým a tretím variantom u dusičnanového dusíka. Štatisticky vysoko preukazné rozdiely však boli medzi odbermi a to medzi jarným a jesenným odberom. Nízke hodnoty dusičnanového dusíka boli podmienené aj mierne kyslou až kyslou pôdnou reakciou. Tieto hodnoty však ukazujú na nízku možnú migráciu dusičnanového dusíka do podzemných vôd.

KĽÚČOVÉ SLOVÁ: zelený úhor, dusičnanový dusík, amoniakálny dusík, pH, nitrifikácia

ABSTRACT

The impact of fallow management on the dynamics of inorganic nitrogen and pH was evaluated in the field experiment established on Ortic Luvisol during 1996 – 2000. The green fallow was maintained on the field for 6 years without tillage except of mowing. The trial included the following variants of management: 1. uncut green fallow, 2. cut green fallow, biomass remained on the field, 3. cut green fallow, biomass was removed from the field. The soil samples were collected from a 0 to 0,3 m of depth to do analyses of nitrogen and pH. During the growing season (spring, summer and autumn aspects) the contents of ammonia nitrogen, nitrate nitrogen and pH were measured. In each treatment the ammonium nitrogen predominated and with its ratio to total nitrogen ranged around 70 %. In studied variants the significance in nitrate nitrogen content was found only between 2^{nd} and 3^{rd} variant. However, statistically highly significant differences were found between spring and autumn sampling. A year had the most significant effect on changes of inorganic nitrogen, especially amount of rainfall that influenced significantly the activity of nitrification process. The mean values of nitrate nitrogen were influenced by acid soil pH reaction.

KEY WORDS: green fallow, nitrate nitrogen, ammonium nitrogen, pH, nitrification

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DETAILED ABSTRACT

Uvedená problematika sa riešila v rokoch 1996 - 2000 v podmienkach stacionárneho poľného pokusu na experimentálnej báze SPU Nitra - Dolná Malanta na hnedozemných zosprašovaných proluviálnych sedimentoch. Pokus bol realizovaný na úhorovanej pôde, na ktorej neboli od roku 1994 uskutočnené žiadne agrotechnické zásahy (s výnimkou kosby). V priebehu sukcesie rastlinného spoločenstva sa vyvinul porast, v ktorom dominantné zastúpenie vo všetkých variantoch mali *Cirsium arvense, Erigeron canadensis a Triplerospermum inodorum*.

V pokuse boli použité nasledovné varianty:

1. variant - nekosený,
2. variant - kosený, zelená hmota zostáva na parcele,
3. variant - kosený, zelená hmota je z parcely odstránená.

Všetky varianty pokusu boli bez hnojenia v štvornásobnom opakovaní. Zemina na stanovenie N-NO_3^- (kolorimetricky kyselinou fenoldisulfónovou), N-NH_4^+ (kolorimetricky Nesslerovým činidlom) a pH (v roztoku 1 M KCl) sa odoberala z hĺbky 0 - 0.3 m.

Počas piatich rokov sledovania (1996 - 2000) obsahov N-NO_3^- , N-NH_4^+ a pH sa v rámci zvolených spôsobov obhospodarovania zeleného úhoru zistila určitá tendencia zmien anorganického dusíka v pôde.

Priemerná hodnota N-NH_4^+ v priebehu pokusného obdobia bola 5,30 mg.kg^{-1} ± 2,2862 (tab. III.). Variabilita nameraných hodnôt amoniakálneho dusíka je pomerne vysoká (43,12 %). Z týchto výsledkov vyplýva, že pri zvolenej hladine významnosti α = 0,01 na hodnoty N-NH_4^+ mal štatisticky významný vplyv odber a ročník. V priemere najvyššia hodnota amónneho dusíka bola v druhom odbere (6,32 mg.kg^{-1}) a v piatom roku roku (8,06 mg.kg^{-1}). Štatisticky významnejší bol vplyv odberov.

Dusičnanový dusík je v lúčnych pôdach zastúpený v nepatrných množstvách. V uvedenom pokuse sa pohybovali priemerné hodnoty v rozmedzí 0,49 – 5,79 mg.kg^{-1} s variačným koeficientom 40,19 %. Priemerná hodnota za celé pokusné obdobie bola 1,87 mg.kg^{-1} ± 0,7506 (tab. III.). Zo sledovaných faktorov mali na hladine významnosti α = 0,01 štatisticky významný vplyv varianty, odber a ročník.

Pôdna reakcia je dôležitou vlastnosťou pôdy a ukazovateľom pôdnej úrodnosti nakoľko priamo, resp. nepriamo určuje ekologické podmienky pre rastliny a pôdne mikroorganizmy. Jej hodnota sa v sledovaných variantoch pohybovala od kyslej po mierne kyslú. Priemerná hodnota za celé vegetačné obdobie bola 5,44 ± 0,148 s nízkym variačným koeficientom 2,72 %.

Nízke obsahy rozpustných foriem dusíka pod zeleným úhorom umožňujú realizovať dočasné „úhorovanie„„ t.j. vyčlenenie orných pôd z poľnohospodárskeho využívania z rôznych dôvodov (znečistenie, erózia a pod.).

INTRODUCTION

The development of agro-ecosystems and special industrial systems brings both positive results and negative effects including changes of physical and chemical soil properties, decrease of organic matter content, soil exhaustion and other serious problems.

Considering the above-mentioned and other widespread problems (ecological farming, farming in protected areas and regions of fresh water resources, improvement of soil surface by cover crops, creation of bio-corridors, looses of nitrogen by flooding, volatilisation and emission of gas nitrogen compounds, etc.), a big effort of the last period was exerted especially in the agriculturally developed countries in order to realise temporal detachment of arable land from agricultural exploitation and to provide a short-term fallowing on it.Nitrogen from grass covers plays a special role because of its large influence on production ability and qualitative harvest parameters, complicated chemical conversion in the soil which stimulate uptake of other mineral nutrients. Changes of content, forms and dynamics of nitrogen in the soil depend not only on applied quantity of nitrogen, but also on soil quality, and hence microbiological processes including nitrogen mineralization and immobilization [10, 6, 7, 5].

The content of soil inorganic nitrogen forms under permanent grass cover is qualitatively and quantitatively different from the content in arable land. This difference is caused by different chemical, physical and also biological conditions in the soil, that may show intensity of mineralization, nitrification and immobilization [17, 5].

In the paper we evaluate the effect of green fallow conservation on content of inorganic nitrogen and pH in the soil.

Table 1: Weather conditions in the field trial during tested years
Tabuľka 1: Poveternostné podmienky viacročného poľného pokusu

Month	Sum of month precipitations (mm)					
	Average 1951-1980	1996	1997	1998	1999	2000
I .	31,00	50,30	18,20	15,00	9,50	17,00
II .	32,00	20,00	20,50	0,00	30,30	14,00
III .	33,00	12,00	8,90	9,00	20,50	80,00
IV .	43,00	91,50	30,10	47,00	59,60	27,00
V.	55,00	157,90	43,50	33,00	30,00	28,00
VI .	70,00	49,90	61,30	29,00	131,50	6,00
VII .	64,00	65,60	117,20	61,00	90,60	61,00
VIII .	58,00	53,60	13,40	31,00	47,10	22,00
IX .	37,00	71,70	27,90	150,00	7,10	52,00
X .	41,00	33,30	31,50	78,00	32,70	28,00
XI .	54,00	37,60	108,10	28,00	49,70	89,00
XII .	43,00	25,90	14,30	18,00	40,90	45,00
Year	561,00	669,30	495,00	499,00	549,50	469,00
	Average month temperatures (^{o}C)					
Month	Average 1951 -1980	1996	1997	1998	1999	2000
I .	-1,70	-2,30	-2,60	2,00	-0,60	-3,20
II .	0,50	-2,60	1,70	4,50	-0,20	1,90
III .	4,70	2,10	4,50	3,90	6,50	4,70
IV .	10,10	11,10	7,60	12,00	12,10	13,00
V.	14,80	16,30	15,90	15,20	15,60	17,20
VI .	18,30	19,30	18,60	19,60	18,50	19,90
VII .	19,70	19,10	19,00	21,00	20,60	19,00
VIII .	19,20	19,40	20,80	20,90	19,00	22,10
IX .	15,40	12,20	15,30	15,10	18,10	15,40
X .	10,10	11,00	7,30	10,70	9,70	13,20
XI .	4,90	7,10	5,20	2,00	1,90	8,00
XII .	0,50	-2,40	2,50	-2,30	-0,10	2,20
Year	9,70	9,20	9,65	10,40	10,10	11,10

MATERIAL AND METHODS

In 1996 - 2000 in the field stationary experiment of the SPU Nitra - Horná Malanta the aim of this work was provided on Orthic-Luvisol. The experiment was done on the fallow soil where no tillage has been provided since 1994 except of mowing. During succession of vegetable population community the cover was represented by dominant species *Cirsium arvense, Erigeron Canadensis and Triplerospermum inodorum.*

The following variants were used in the experiment:

1. variant – uncut,
2. variant – cut, green mass remained on the field,
3. variant – cut, green mass was removed from the field.

All variants were in 4 repetitions. The weather conditions during the experiment are shown in Table 1.

1996	1997	1998	1999	2000
23.7	23.4	20.4	15.4	4.4
16.10	29.7	8.7	6.7	10.7
	15.10	14.10	19.10	9.10

The results are evaluated in tables and statistically by STATGRAPHICS program

The soil was sampled to analyse of $N\text{-}NO_3$ (using colour method by acid phenol 2,4 dihydrosulphide), $N\text{-}NH_4^+$ (colour method by Nessler agent) in 1 % K_2SO_4 liquor and pH (in 1 M KCl solution) from a depth of 0 – 0,3 m in the following terms (Table 2):

Table 2: Content of inorganic nitrogen ($mg.kg^{-1}$) and pH changes of the soil during investigating period
Tabuľka 2: Obsah anorganických foriem dusíka ($mg.kg^{-1}$) v pôde a pH počas sledovaného obdobia

Year	I 1996	I 1997	I 1998	I 1999	I 2000	II 1996	II 1997	II 1998	II 1999	II 2000	III 1996	III 1997	III 1998	III 1999	III 2000
	-	4,26	4,36	6,56	5,89	-	3,98	4,05	5,99	6,35	-	3,58	3,65	7,67	5,95
$N\text{-}NH_4^+$	7,03	4,34	2,89	7,33	11,82	6,20	3,05	3,13	6,87	11,87	5,38	3,20	3,36	6,52	11,61
	4,75	3,85	5,05	3,82	6,45	3,24	3,46	4,88	4,09	6,22	3,56	3,50	4,14	3,99	6,37
	-	1,33	1,45	1,60	2,09	1,27	1,27	1,20	5,79	2,06	-	1,20	1,80	1,62	1,66
$N\text{-}NO_3^-$	1,78	1,61	1,53	2,41	1,47	1,47	1,47	1,26	2,70	2,14	1,61	1,27	1,82	2,25	0,49
	1,34	2,34	1,17	5,52	4,94	2,16	2,16	2,34	2,96	2,03	1,46	1,97	1,34	2,15	1,10
	-	5,60	5,50	5,70	5,48	-	5,45	5,40	5,40	5,78	-	5,38	5,40	5,35	5,65
pH	5,60	5,40	5,32	5,50	5,58	5,45	5,30	5,45	5,45	5,58	5,40	5,35	5,38	5,30	5,30
	5,52	5,35	5,87	5,30	5,48	5,45	5,25	5,32	5,25	5,45	5,55	5,32	5,43	5,20	5,25

RESULTS AND DISCUSSION

In 1996-2000 the $N\text{-}NO_3^-$, $N\text{-}NH_4^+$ contents and pH were monitored when a slight tendency of changes of inorganic nitrogen in soil was found using selected methods of the green fallow conservation.

During the experimental period the ammonium nitrogen content was predominated. Its contribution to total N_{an} was 74 % compared to arable lands, where ratio between $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ was more comparable. During the experimental period a fluctuation in free $N\text{-}NH_4^+$ content was found from 2,89 to 11,87 $mg.kg^{-1}$, what is probably related to weak nitrification, as stated also by some authors [2, 6, 12, 17, 4, 1] caused by a less abundant nitrifying bacteria that are limited in concentration because of a low soil pH and probably decreased concentration of oxygen.

Table 3: Basic statistical characteristics of measured data ($N-NO_3^-$, $N-NH_4^+$ a pH)
Tabuľka 3: Základné štatistické charakteristiky ($N-NO_3^-$, $N-NH_4^+$ a pH)

Statistical characteristics	$N-NH_4^+$	$N-NO_3^-$	pH
number of observations	168	168	168
average value	5,3022	1,8677	5,4367
standard deviation	2,2862	0,7506	0,1480
standard error	0,1764	0,0579	0,0114
variance	5,2267	0,5643	0,0219
coefficient of variance (%)	43,1179	40,1883	2,7228
chisquare	108,841	55,9937	40,5519
significance level	0,0	$7,871 . 10^{-9}$	$1,354 . 10^{-5}$

An average year concentration of $N-NH_4^+$ was 5,30 mg. kg^{-1} ± 2,2862 (Table 3). The variability of measured values of ammonia nitrogen is relatively high (v = 43,12 %). We have found from the results of normal file testing (value x^2 and P value) that no figure ($N-NH^{4+}$, $N-NO_3^-$ and pH) had normal allocation, therefore the non-parametrical Kruskal-Wallis test was used for the next statistic elaboration of measured values (Table 4).

Table 4: Kruskal – Wallis one-way analysis of dana
Tabuľka 4: Analýza variancie podľa Kruskal-Wallisa

Source of variability		Sample size	Test statistic	Significance level
$N-NH_4^+$	Treatment	168	4,2644	0,11857
	Sampling	168	10,5558	$5,10 \cdot 10^{-3}$ ++
	Year	168	90,2094	0,0 ++
	Replication	168	0,0563	0,9965
$N-NO_3^-$	Treatment	168	12,4551	$1,974 \cdot 10^{-3}$ ++
	Sampling	168	10,6082	$4,971 \cdot 10^{-3}$ ++
	Year	168	48,1632	$8,726 \cdot 10^{-10}$ ++
	Replication	168	$1,8722 \cdot 10^{-3}$	0,9999
pH	Treatment	168	25,2306	$3,32 \cdot 10^{-6}$ ++
	Sampling	168	16,5824	$2,51 \cdot 10^{-4}$ ++
	Year	168	28,1256	$1,17 \cdot 10^{-5}$ ++
	Replication	168	0,3689	0,9466

As it is seen from the results received at the statistically important α = 0,01 level of significance, both the year and sampling influenced the $N-NH_4^+$ content to the largest extent. In average, the highest ammonia nitrogen level was found in the second sampling (6,32 mg.kg $^{-1}$) and in the fifth experimental year (8,06 mg.kg^{-1}). Extrapolation done according to Dunn (Table 5) show highly significant variations between 2nd and 3rd sampling. Statistically significant values were also found among tested years except of the differences between the second and third year. Sum of precipitation (mm) in tested years was practically similar, reaching 495 mm in 1997 and 499 mm in 1998 (Table 1).

The data refer to the considerable influence of weather conditions on microbial soil activity during a year and also to the intensity of both mineralization and follow-up nitrification processes affecting the analysed inorganic nitrogen forms content. The soil humidity also plays a very important role in this processes.

A low soil water content allows a good aeration and gas exchange in the soil - atmosphere system (including oxygen income into the soil). Water celluloid of soil particles becomes thinner during the soil drying, leading to a longer and more complicated way of water molecules diffusion in the soil. [15] found, that water deficit directly inhibits soil microbial activity, because it decreases the intracellular tension of microbes and reduces hydration, and hence the activity of special enzymes.

Table 5: Analysis of contrasts of measured data according to Dunn
Tabuľka 5: Testovanie rozdielov podľa Dunna

Source of variability	Sample size	Range of averages	Contrasts α = 0,05	Contrasts α = 0,01
	24	84,3958		A
	36	43,7500	A	A B
$N – NH_4^+$ - year	36	49,8333		C
	36	111,8330	A	B C
	36	132,6530		A B C
	48	91,7500	A	
$N- NH_4^+$ - sampling	60	94,9667		A
	60	68,2333	A	A
	24	75,4792		A
	36	67,1389		B
$N-NO_3^-$ - year	36	59,8472		C
	36	131,4030		A B C D
	36	85,6250		D
	56	87,8036		
$N-NO_3^-$ - treatments	56	98,8125		A
	56	66,8839		A
	48	71,4167		A
$N-NO_3^-$- sampling	60	79,0917	A	
	60	100,3750	A	A
	24	114,2710		A
	36	63,4444	A	A B
pH - year	36	83,9722		
	36	65,3750	A	A C
	36	105,3610		B C
	56	108,7860		A B
pH - treatments	56	81,6786		A
	56	63,0357		B
	48	107,3330		A
pH – sampling	60	81,0833	A	
	60	69,6500	A	A

Weak soil nitrification under grass cover also has a practical effect. The nitrogen applied as $N-NH_4^+$ nitrifies slowly which causes lower $N-NO_3^-$ losses [1, 8, 9, 16].

Nitrate nitrogen in meadow grounds was represented in negligible amount. In our experiment the average values of $N-NO_3^-$ changed from 0,49 to 5,79 mg. kg^{-1} (index of variance v = 40,19 %). The average year value was 1,87 mg. kg^{-1} ± 0,7506 (Table 3). All the investigated factors, such as variant, sampling and year were statistically influenced at the level of importance α = 0,01 (Table 4). The statistically important differences were found especially between the second and third variant, and between the first and third sampling of a tested year. In spite of the low seasonal dynamics of nitrate nitrogen in the grass stand soils, important statistical differences (α = 0,01) were found between the fourth (1999) and the rest of tested years.

The very often reason of a weak nitrification activity in the grass stand soils is supposed to be acid soil reaction, disability of nitrifying bacteria to compete with a rich heterotrophic microflora and grass roots for the source of nitrogen [18, 16].

The pH is an important soil property and indicator of soil fertility because it directly and indirectly modifies ecological conditions for plants and soil bacteria development. The average pH value during the vegetation period was 5,44 ± 0,148 with low variation coefficient 2,72 % (Table 3). All investigated factors (variant, sampling, year) had a statistically important influence on pH values at the level of importance $\alpha = 0{,}01$ (Table 4). According to tested differences of estimation, the considerable differences were found between the first and third variant (Table 5) and between the first and third sampling, that may indicate the role of green fallow on the changes of soil pH solution.

$z(\alpha, n_1, n_2)$
$z(0{,}05;\ 48;\ 60) = 22{,}51$; $z(0{,}01;\ 48;\ 60) = 27{,}60$; $z(0{,}05;\ 60;\ 60) = 21{,}22$; $z(0{,}01;\ 60;\ 60) = 26{,}02$; $z(0{,}05;\ 24;\ 36) = 30{,}13$; $z(0{,}01;\ 24;\ 36) = 37{,}53$; $z(0{,}05;\ 36;\ 36) = 30{,}13$; $z(0{,}01;\ 36;\ 36) = 37{,}53$; $z(0{,}05;\ 56;\ 56) = 21{,}97$; $z(0{,}01;\ 56;\ 56) = 26{,}93$,

where:

z –quantil of normal distribution
α - level of significance
n_1 –sample size
n_2 –size of independence incident sample

Impact of soil pH on preferable ion uptake was evaluated by Fecenko who stress that lower pH enables a better uptake of NO_3^- nitrogen compared to N-NH_4^+ form.

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