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IMPACT OF NITROGEN (^{15}N) APPLICATION TIME ON ITS UPTAKE AND DISTRIBUTION IN SPRING BARLEY PLANT PARTS

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ABSTRACT

The aim of the pot experiment was to determine the impact of timing of nitrogen application in the form of ammonium nitrate enriched with the ^{15}N isotope, on the uptake of ^{15}N by spring barley plant and its distribution in grain, awns, leaves, straw, and roots. 1.21 g of N per pot containing 10 kg of the soil was applied at two doses: 2/3 before the sowing, and 1/3 at the tillering phase or at the stalk-shooting phase. The distribution of the applied nitrogen, assumed as 100%, was the highest in grain (61.5%), and the lowest in roots (4%). The mean nitrogen utilisation coefficient value (%) measured with the difference method was 86.9 %, and that for the isotope dilution method – 61.0%. Postponing the time of nitrogen application from the tillering to the stalk-shooting phase differentiated the nitrogen utilisation coefficient value, which was higher for the difference method than for the isotope dilution method and it amounted to +32.3% at the tillering phase and +19.4% at the stalk-shooting phase.

Key words: the ^{15}N isotope, application timing, uptake and distribution of N in a plant, spring barley

INTRODUCTION

The share of cereal crops in the agricultural production is considerable, accounting for 65-75% of the total crop production. Proper fertilisation regime, especially with nitrogen, results in achieving maximum crop yields of the highest technological quality. In barley fertilisation, several systems and time periods of nitrogen application are suggested [7]. The most commonly recommended method involves applying of nitrogen at two or three times:

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before sowing, and then at tillering phase and/or stalk-shooting phase. Earlier fertilisation with nitrogen increases the growth and development of vegetative parts in a plant, whereas a later time period of application affects protein accumulation in grain.

High prices of mineral nitrogen fertilisers and uptake of the applied nitrogen in crops as effectively as possible to reduce the environment pollution bring about the importance of estimating nitrogen utilisation coefficient value in an undertaken research on method and timing of nitrogen fertilisation. The value may be calculated with the difference method or the isotopic dilution method, the latter involving ^{15}N or^{13} N nitrogen isotopes [5]. According to Hauck [2], the nitrogen utilisation coefficient value calculated with the difference method is higher by 6-7% than that arrived at the isotopic dilution method. Westerman and Kurtz [11] corroborated Hauck's findings, establishing even a higher difference, 17-34%.

The difference in nitrogen utilisation coefficient values has large practical and theoretical consequences for calculating nitrogen doses applied in mineral fertilisation with due attention paid to time periods and techniques of its application. The aim of the pot experiment was to determine the uptake of ^{15}N and its distribution in the spring barley plants.

MATERIAL AND METHODS

The 10 kg of soil for filling the pots was drawn from the humus layer of a lessive soil, good rye soil agricultural suitability complex. The soil contained 6.29 $g \cdot kg^{-1}$ of C in organic compounds and 0.56 $g \cdot kg^{-1}$ of total nitrogen as well as following available quantities of: P – 10.2 mg, of K - 14.1 mg, of Mg - 5.2 mg in 100 g of soil; pH in KCl $1 mol \cdot dm^{-3}$ – 6.2.

20 grains of 'Goma' spring barley cultivar were sown per pot, and after the emergence, 5 plants were uprooted and left to decay in the pot, whereas the remaining 15 plants were allowed to grow and develop. Against the fertilisation regime involving P – 0.56 $g \cdot pot^{-1}$, K – 0.82 $g \cdot pot^{-1}$, Mg – 1.20 $g \cdot pot^{-1}$ and S – 0.20 $g \cdot pot^{-1}$, 1.21 g of N was applied at two doses: a) two thirds before the sowing and one third at the tillering phase; b) two thirds before the sowing and one third at the stalk-shooting phase. The nitrogen isotope NH_4NO_3, applied before the sowing and as a top fertiliser, contained 2.51 at $\%^{15}N$.

The moisture of the soil over the barley-growing season was kept at the level of 60% total water-holding capacity. The barley plants were harvested at the full ripeness phase. Grain, awns, leaves, straw, and roots were isolated from each plant. Nitrogen content in the separated parts of the plants was measured with the modified Kjeldahl method, which allows to take fully into account the $N0_3$ ion [6]. Total nitrogen content was determined by distilling ammonia off to 2% boracic acid with the mixed tracer, and then back titration was applied using the 0.25 $mol \cdot dm^{-3}$ solution of H_2SO_4. The sample for determining the isotopic composition was provided by the third distillate, from which ammonia was distilled off and fixed by HCl of 0.1 $mol \cdot dm^{-3}$ concentration. The enrichment with the ^{15}N isotope of total nitrogen, contained in the separated parts of the plants, was estimated by determining ^{14}N and ^{15}N with the method of emission spectrometry on the emission spectrometer, releasing N_2 nitrogen molecules containing $^{14}N_2$, ^{14}N, ^{15}N and $^{15}N_2$ from the sample by the "dry method" [5].

Values of the nitrogen utilisation coefficient were calculated with:

1. the difference method, according to the formula:

$$WW_N = \frac{TN_F - TN_C}{N_A} \cdot 100$$

2. the isotopic dilution method, according to the formula:

$$WW_N = \frac{TN_F\left(\frac{B-C}{D}\right)}{N_A} \cdot 100$$

where:

WW_N – value of nitrogen utilisation coefficient,
TN_F – quantity of nitrogen uptake by the plants (the parts) subjected to nitrogen fertilisation,
TN_C – quantity of nitrogen uptake by the plants (the parts) not subjected to nitrogen fertilisation,

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N_A – quantity of nitrogen applied,
B – at%^{15}N in the plants (the parts) treated with ^{15}N nitrogen,
C – at%^{15}N in the plants (the parts) not treated with ^{15}N nitrogen,
D – enrichment of nitrogen with ^{15}N expressed at%^{15}N.

The significance of differences in the mean total nitrogen contents, ^{15}N enrichment and in the nitrogen utilisation coefficients in separate spring barley plants were estimated with ANOVA procedures (the F Fischer-Snedecor test), whereas $LSD_{0.05}$ was calculated with the Tukey test. Relationships between the examined features were established on the basis of correlation coefficients and simple regression equations.

RESULTS

Nitrogen fertilisation has been the most influential factor in increasing the yield of the examined barley cultivar (Table 1). The application of nitrogen, irrespective of when it had been carried out, led to significant increase in dry matter yield from all the parts of the plant, compared to that obtained for the control. Delaying of nitrogen fertilisation until the stalk-shooting phase brought about a significant decrease in straw and roots dry matter yields, while for the other barley parts the decrease was not significant. Out of all the analysed barley plant parts, as a result of delayed nitrogen application, the largest decrease in dry matter yield was observed for straw (3.24 g·pot $^{-1}$), and the least – for leaves (0.1 g·pot $^{-1}$). Nitrogen fertilisation and its application time differed the nitrogen content in the analysed barley parts. A significant difference in the content of this element was noted in roots, whereas grain was not significantly affected by the examined factors. For the remaining barley plant parts, only nitrogen fertilisation itself led to a significant increase in nitrogen content, whereas the time of its application was irrelevant. The enrichment with the ^{15}N isotope of total nitrogen content, determined for the separate parts of the barley plants, was significantly differentiated by the date of nitrogen application and varied according to each represented part. Delaying the time of nitrogen application led to a significant increase in ^{15}N content in all the analysed barley parts with the exception of roots, where it was lower than that achieved by applying nitrogen at the tillering phase. The highest increase of the ^{15}N isotope enrichment as a result of delayed nitrogen application was found in leaves (+ 0.070 at %^{15}N), while the lowest – in straw (+ 0.010 at %^{15}N).

Table 1. Crop yield, nitrogen content and ^{15}N enrichment for the particular spring barley parts

Object	Spring barley plant parts					Total
	grain	awns	leaves	straw	roots	
Yield, g·pot $^{-1}$						
PK	9.97	0.91	6.33	3.93	0.91	22.05
PKN_k	29.30	3.84	15.80	13.10	8.97	71.01
PKN_s	28.37	3.50	15.70	9.86	6.73	64.16
$LSD_{0.05}$	4.32	0.69	1.89	2.06	1.12	10.2
Nitrogen content, g·kg^{-1} Mean						
PK	28.9	7.90	12.5	8.9	17.9	15.2
PKN_k	29.2	15.2	19.7	16.4	9.0	17.9
PKN_s	30.1	14.4	18.0	17.0	11.8	18.3
$LSD_{0.05}$	ns	1.9	2.5	1.8	2.2	1.9
^{15}N enrichment, at %^{15}N						
PK $^{15}N_k$	0.208	0.169	0.160	0.194	0.162	
PK $^{15}N_s$	0.233	0.224	0.230	0.204	0.148	
PK $^{15}N_S$ / PK^{15} N_K	+ 0.025	+ 0.055	+ 0.070	+ 0.010	- 0.014	
$LSD_{0.05}$	0.017	0.029	0.031	0.009	0.010	

ns – difference non-significant
PKN_K - phosphorus-potassium fertilisation + 1/3 nitrogen dose at the tillering phase
PKN_S - phosphorus-potassium fertilisation + 1/3 nitrogen dose at the stalk-shooting phase

The nitrogen utilisation coefficient value (%) arrived with both methods was significantly different: it was higher for the difference method than for the isotope dilution method (Table 2). The differentiation occurred irrespective of when nitrogen had been applied, and it was higher for nitrogen application at the tillering phase (+32.3%) than at the stalk-shooting phase (+19.4%). The nitrogen utilisation coefficient value (%) for the separate barley parts was differentiated by the method of its estimation and by nitrogen application time. For the difference method, nitrogen application time did not affect its value in grain and roots. The largest differences

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were established for leaves and straw, with the preponderant result of nitrogen application at the tillering phase. For the isotopic dilution method, delayed nitrogen application brought about an increase in the N utilisation coefficient in grain and leaves, and its decrease in straw.

Table 2. Values of nitrogen utilisation coefficients arrived at the difference and the isotopic dilution methods

Method and time Of nitrogen application	Spring barley plant parts					
	grain	awns	leaves	straw	roots	total
A. Difference method						
tillering phase	46.8	4.2	19.2	14.9	5.4	90.5
stalk-shooting phase	46.7	3.5	16.9	11.0	5.2	83.3
B. Isotopic dilution						
tillering phase	35.4	2.0	9.9	8.3	2.6	58.2
stalk-shooting phase	39.6	2.2	13.0	6.8	2.3	63.9
$A_1 - B_1$	+ 11.4	+ 2.2	+ 9.3	+ 6.6	+ 2.8	+ 32.3
$A_2 - B_2$	+ 7.1	+ 1.3	+ 3.9	+ 4.2	+ 2.9	+ 19.4

The distribution of nitrogen applied in the form of ammonium nitrate enriched with the ^{15}N isotope in the particular parts of the barley plant depended on the time of N application (Table 3). Nitrogen applied at the stalk-shooting phase was accumulated in large quantities in leaves and awns, and in still larger quantities in grain, whereas when applied at the tillering phase – in straw and roots. Correlation coefficient values for the analysed features were found to be significant and as follows:

$r = +0.97^{**}$ and $Y = - 12.4 + 2.40x$, for the correlation between dry matter yields from the separate barley parts and the distribution of nitrogen from ammonium nitrate,
$r = +0.95^{**}$ and $Y = - 37.3 + 3.17x$, for the correlation between nitrogen content in the separate barley parts and the distribution of nitrogen from ammonium nitrate;
$r = +0.91^{**}$ and $Y = 8.92 + 0.68x$, for the correlation between crop yield and nitrogen content in the separate barley parts.

Table 3. Distribution (%) of ammonia nitrogen (=100%) in particular parts of spring barley plants analysed with the isotopic dilution method

Plant development phase of NH_4NO_3 application	Spring barley plant parts					
	grain	awns	leaves	straw	roots	total
- tillering	60.9	3.3	17.0	14.3	4.5	100
- stalk-shooting	62.0	3.5	20.3	10.6	3.6	100
$LSD_{0.05}$	ns	ns	2.6	1.5	ns	-

DISCUSSION

The nitrogen utilisation coefficient value (%), higher for the difference method than for the isotopic dilution method determined in the present study, corroborates the findings obtained under different conditions and for other tested plants [4,11]; however some other researches proved the reversed relation [8]. Higher nitrogen utilisation coefficient values arrived with the difference method may result in the accelerated and augmented mineralisation of the soil organic matter as a result of higher nitrogen quantities brought into the soil in ammonium nitrate. This phenomenon has already been described in the literature [5] and called “the priming effect” [1,3,10]. As a result of this process more nitrogen available to plants appears in the soil. Its quantity is in direct proportion to nitrogen content in organic compounds contained in the soil, as well as to nitrogen doses applied in mineral fertilisation [5].

CONCLUSIONS

3. Nitrogen fertilisation significantly increased the dry matter yields in all the analysed parts of the barley plants.
4. Postponing the application of one third of the total nitrogen dose from the tillering phase to the stalk-shooting phase resulted in a significant decrease in straw yield and root biomass.
5. Dose and time of nitrogen fertilisation did not affect significantly nitrogen content in grain, whereas in the other parts of the spring barley plants they effect was significant.
6. Delaying the time of nitrogen applying in the form of ^{15}N led to its higher enrichment in the analysed spring barley parts.

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7. Values of nitrogen utilisation were found to be higher when arrived at the difference method than those provided by the isotopic dilution, irrespective of nitrogen application time. The difference was +32.3%, when applying one third of the total nitrogen dose at the tillering phase, and +19.4%, when nitrogen was applied at the stalk-shooting phase.
8. The distribution of nitrogen uptake from ammonium nitrate by the barley plant parts differed considerably; the highest uptake was observed in grain (61.5%) and the lowest one in roots (4%).

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