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CONTENT OF VARIOUS FORMS OF NITROGEN AND ABSORPTION OF THIS ELEMENT BY COCKSFOOT GRASS, DEPENDING ON METEOROLOGICAL CONDITIONS

Wiesław Bednarek[1], Hanna Bednarek[2], Sławomir Dresler[1]

[1]Department of Agricultural and Environmental Chemistry
[2]Department of Agrometeorology
University of Life Sciences in Lublin

Abstract

The dependence of the content of various forms of nitrogen and absorption of N by cocksfoot grass on meteorological conditions was established in a field experiment. Correlations between the content of total nitrogen, protein nitrogen, N-NH_4, and N-NO_3 in sward and roots of cocksfoot grass and some meteorological elements, i.e. maximum temperature, minimum temperature, average daily temperature measured at 5 and 200 cm, air relative humidity, cloud cover, sum of precipitation, sum of evaporation and soil temperature measured at a depth of 2, 5, 10, 20 cm were analyzed. Correlation coefficients between the forms of nitrogen in the plant and the above meteorological elements were calculated, as well as multiple regression equations, multiple correlation coefficients and determination coefficients.

No significant relationship between the forms of N (N_{total}, $N_{protein}$, N-NH_4, N-NO_3) in sward and roots of cocksfoot grass and the course of meteorological conditions was clearly stated. The relationship between the content of N-NH_4 in sward and N_{total} and N-NO_3 in roots, and certain meteorological elements is relatively small and can be characterized by the value of determination coefficients, i.e. 0.166, 0.106 and 0.151, respectively. According to the statistical analysis, the absorption of nitrogen by cocksfoot grass depends to a relatively small though significant extent (R^2=0.249) on certain meteorological elements. However, further research is still recommended.

Key words: nitrogen forms, N uptake, cocksfoot grass, meteorological conditions.

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prof. Wiesław Bednarek, PhD, Department of Agricultural and Environmental Chemistry, University of Life Sciences in Lublin, Akademicka 15, 20-950 Lublin, Poland, e-mail: wieslaw.bednarek@up.lublin.pl

ZAWARTOŚĆ RÓŻNYCH FORM AZOTU ORAZ POBRANIE TEGO SKŁADNIKA PRZEZ KUPKÓWKĘ POSPOLITĄ W ZALEŻNOŚCI OD PRZEBIEGU WARUNKÓW METEOROLOGICZNYCH

Abstrakt

Na podstawie wyników ze ścisłego doświadczenia polowego określono zależność zawartości różnych form azotu oraz pobranie N przez kupkówkę pospolitą od przebiegu warunków meteorologicznych. Rozpatrywano korelacje między zawartością azotu ogółem, azotu białkowego, N-NH_4 i N-NO_3 w runi i korzeniach kupkówki a niektórymi elementami meteorologicznymi: temperaturą powietrza maksymalną, minimalną, średnią dobową mierzoną na wysokości 5 i 200 cm, wilgotnością względną powietrza, zachmurzeniem, sumą opadu atmosferycznego, sumą parowania i temperaturą gleby mierzoną na głębokości 2, 5, 10, 20 cm. Obliczono współczynniki korelacji między formami azotu w roślinie a przebiegiem wymienionych elementów meteorologicznych oraz równania regresji wielokrotnej, współczynniki korelacji wielokrotnej i determinacji.

Nie stwierdzono jednoznacznie, że istniała istotna zależność zawartości form azotu ($N_{og.}$, $N_{biał.}$, N-NH_4, N-NO_3) w runi i korzeniach kupkówki pospolitej od przebiegu warunków meteorologicznych. Zależność, która wystąpiła między zawartością N-NH_4 w runi oraz $N_{og.}$ i N-NO_3 w korzeniach a niektórymi elementami meteorologicznymi, jest stosunkowo niewielka i można ją scharakteryzować wielkością współczynników determinacji, kolejno: 0,166; 0,106 i 0,151. Pobranie azotu przez kupkówkę pospolitą zależało w stosunkowo niewielkim, lecz istotnym, stopniu (R^2=0,249) od przebiegu niektórych elementów meteorologicznych. Wskazują na to rezultaty obliczeń statystycznych; nieodzowne jest kontynuowanie prac dotyczących omawianych zagadnień.

Słowa kluczowe: formy azotu, pobranie N, kupkówka pospolita, warunki meteorologiczne.

INTRODUCTION

The chemical composition of plants depends on various factors. Above all, the content of organic and mineral compounds is influenced by agrotechnical factors (mainly mineral fertilization) and natural elements, e.g. soil quality, mainly its richness in available forms of nutrients, light, air and soil temperature, as well as precipitation (Clarkson and Warner 1979, Krzywy et al. 1985, Bednarek 2005, Bednarek et al. 2008, Wojciechowska 2004). The accumulation of protein, starch and dry matter in plants may significantly depend on certain meteorological elements (Solecka 1994, Kubik-Dobosz 1998, Ciepiela et al. 2001, Puła and Skowera 2004, Skowera et al. 2007).

Air temperature dropping to 5-6°C and below favours starch conversions into soluble carbohydrates. Accordingly, the osmotic potential of cells increases and, as a consequence, the freezing resistance of plants rises. The sweetish flavour of frostbitten potato bulbs is also connected with these conversions. In contrast, a temperature increase within the range of 0-30°C, with an optimal temperature of 20-30°C, accelerates enzymatic reactions. Numerous complex processes related to the absorption and reduction of NO_3^- ions and the assimilation of NH_4^+ ions affect the content of nitrates in plants

(CLARKSON, WARNER 1979, HASEGAWA 1990, KUBIK-DOBOSZ 1998, WOJCIECHOWSKA 2004).

The aim of the research was to determine the relationships occurring between the content of various nitrogen forms in sward and roots of cocksfoot grass or the absorption of N by this plant and the local meteorological conditions.

MATERIAL AND METHODS

The paper is based on results obtained from a field experiment carried out on an experimental farm in Elizówka between 1987 and 1989. The experiment concerned the influence of fertilization with diversified doses of NPK on the yield and quality of cocksfoot grass. The content of macro- and microelements depends to a considerable degree on the richness of soil in nutrients as well as on the agrotechnical treatments. The presence of various forms of N (N_{total}, $N_{protein}$, N-NH_4, N-NO_3) in the aerial parts (sward) and roots of cocksfoot grass and the uptake of this element depended mainly on mineral fertilization, including N. This part of the experiment was presented in a previous article, which contains detailed information on the experiment and the chemical methods used in order to determine the examined forms of N in the plant (BEDNAREK 2005). The results of meteorological measurements and observations used here are decade average values, which include the period from March to October, and, in the authors' opinion, have the most significant influence on the chemical composition of the plants shown in Figures 1 and 2. The following factors were taken into consideration in the experiment: the maximum temperature marked in the figures as $T_{max.}$; minimum temperature $T_{min.}$; average daily temperature measured at 200 cm $T_{average\ at\ 200cm}$; average daily temperature measured at 5 cm $T_{average\ at\ 5\ cm}$; relative air humidity; cloud cover measured on a scale of 1-10; precipitation; evaporation; soil temperature measured at a depth of 2 cm, $T_{at\ depth\ 2\ cm}$; soil temperature measured at a depth of 5 cm $T_{at\ depth\ 5cm}$; soil temperature measured at a depth of 10 cm $T_{at\ depth\ 10\ cm}$; soil temperature measured at a depth of 20 cm $T_{at\ depth\ 20\ cm}$. The correlation coefficient was calculated between the determined forms of N and the meteorological conditions (the figures and the text include only the essential values). Additionally, multiple regression equations, multiple correlation coefficients (R), determination (R^2) and the significance level (p) were calculated. The dependent variables y were the content of the determined forms of N in sward and roots and N uptake by cocksfoot grass, respectively. The independent variables x were the meteorological elements in the region of the experiment (x_1 – air temperature measured at 5 cm, x_2 – air relative humidity, x_3 – cloud cover, x_4 – precipitation, x_5 – sum of evaporation, x_6 –

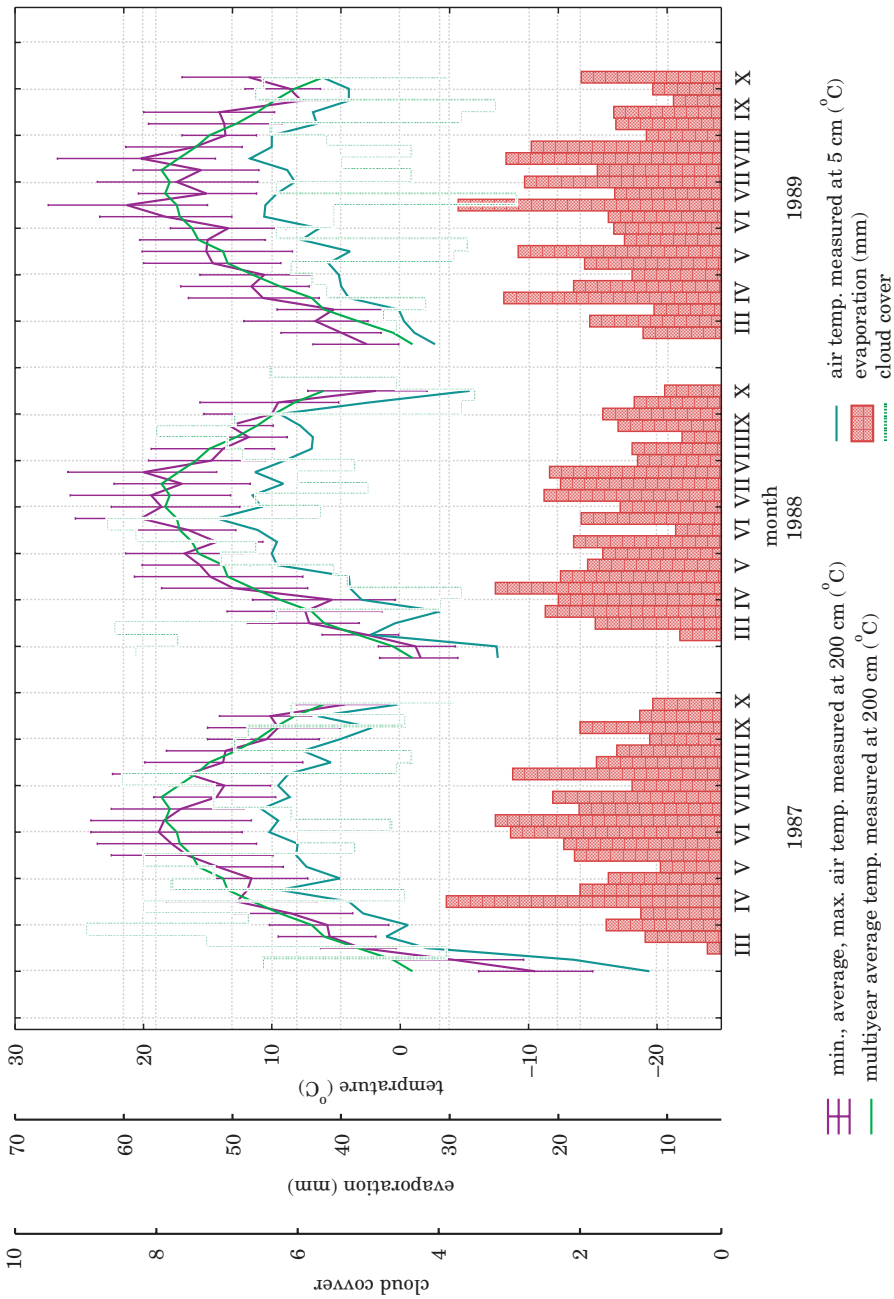

Fig. 1. Air temperature, precipitation and cloud cover in the area of the experiment

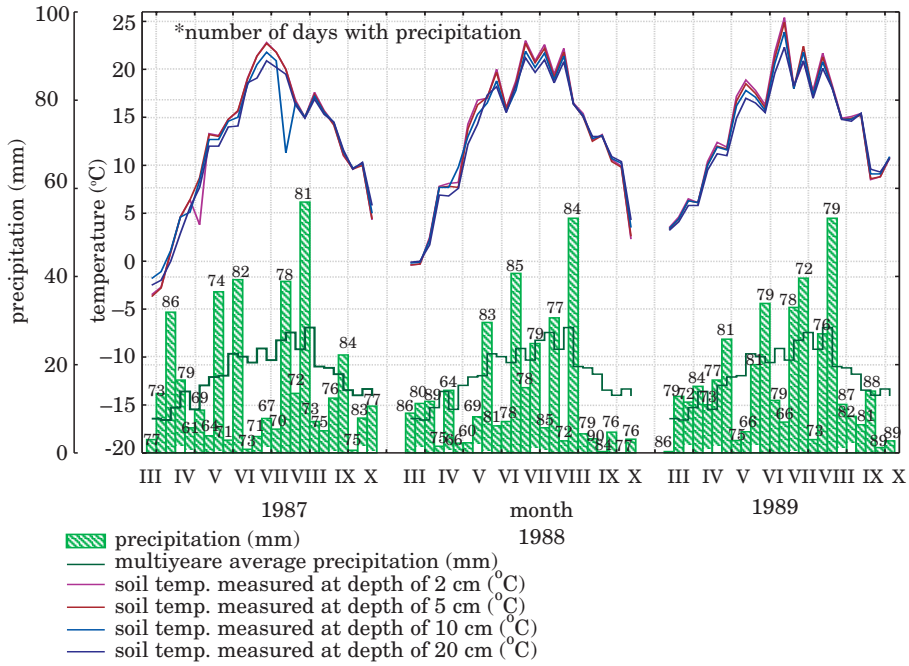

Fig. 2. Soil temperature, precipitation and the number of days with precipitation in the area of the experiment

soil temperature measured at 5 cm). In order to eliminate collinearity and on account of the high correlation between the variables, one of the four variables which characterise air temperature and one of the four variables which characterise soil temperature at various depths were chosen for further analysis. The calculations were made using Statistica ver. 6.0 and Statgraphics Plus 5.0.

RESULTS AND DISCUSSION

The yield and the chemical composition of plants are influenced not only by anthropogenic elements but also by meteorological conditions dominating in the region of the experiment (Kubik-Dobosz 1998, Puła and Skowera 2004, Wojciechowska 2004, Skowera et al. 2007, Bednarek et al. 2008).

The content of the forms of N in cocksfoot grass significantly depended on mineral fertilization, especially with nitrogen. In sward, the total content of N ranged from 1.76 to 2.84% in dry matter, and in roots – from 0.88 to 1.41% in dry matter. The content of protein nitrogen in sward ranged from 1.15 to 1.79% in dry matter, and in roots from 0.72 to 1.02% in dry matter.

The content of ammonium nitrogen in sward ranged from 0.11 to 0.27% in dry matter, and in roots from 0.10 to 0.21% in dry matter. The content of nitrate nitrogen (V) in sward ranged from 0.03 to 0.10% in dry matter, and in roots from 0.019 to 0.02% in dry matter (BEDNAREK 2005). The correlation coefficients between the meteorological elements shown in Figures 1 and 2 and the content of various forms of nitrogen in sward (aerial parts) and roots of cocksfoot grass indicates that the relationships were non-significant.

There was only one statistically proven positive correlation (r_{xy}=0.25; p=0.034; n=72), between cloud cover and content of ammonium nitrogen in sward. On the other hand, there is a significant negative correlation between N uptake by cocksfoot grass and air temperature (T_{max}., r_{xy}=-0.34; p=0.04; T_{min}., r_{xy}=-0.33; p=0.04; $T_{average}$, r_{xy}=-0.32; p=0.007; $T_{5\ cm}$, r_{xy}=-0.27; p=0.022) and soil ($T_{at\ depth\ of\ 2cm}$, r_{xy}=-0.34, p=0.004; $T_{at\ depth\ of\ 5\ cm}$, r_{xy}=-0.29, p=0.013; $T_{at\ depth\ of\ 10\ cm}$, r_{xy}=-0.30, p=0.009; $T_{at\ depth\ of\ 20\ cm}$, r_{xy}=-0.33, p=0.005) and the sum of evaporation (r_{xy}=-0.24, p=0.042), whereas for cloud cover there is a statistically proven positive correlation (r_{xy}=0.30, p=0.01) – Figures 3 and 4.

It seems, however, that multiple regression is a better measure of the relationship between the content of various nitrogen forms in plants and meteorological elements.

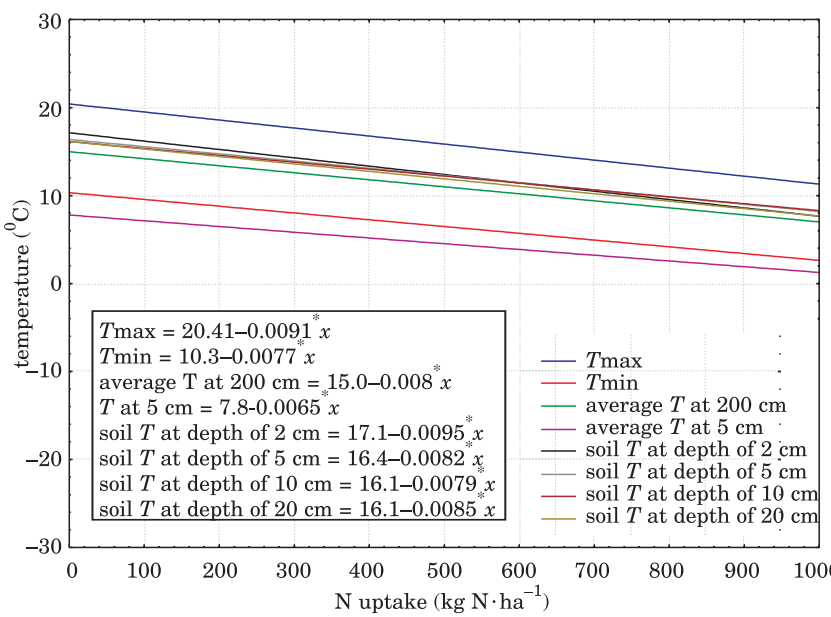

Fig. 3. Relationship between N uptake and air and soil temperature

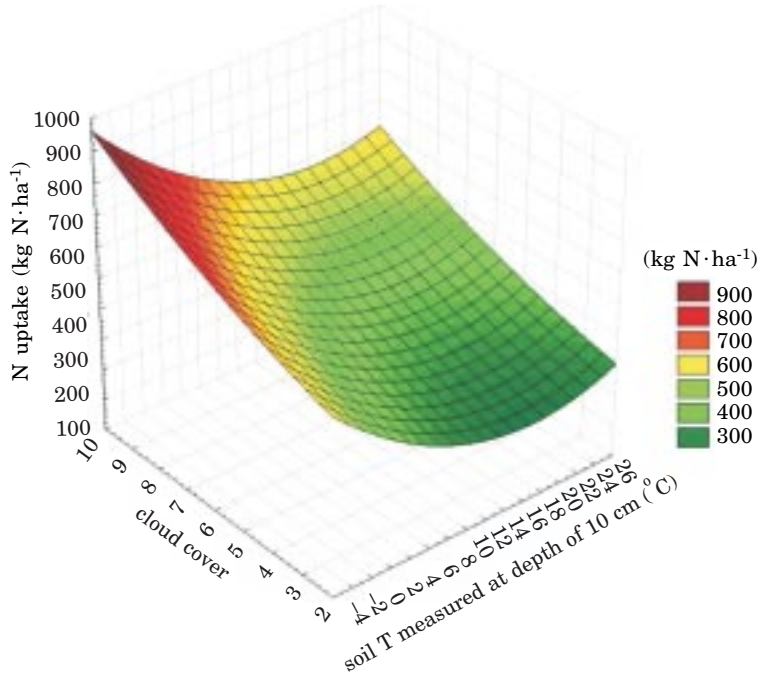

Fig. 4. Relationship between N uptake and cloud cover and average soil temperature measured at a depth of 10 cm

This calculation showed the content of NH_4 in sward to be significantly dependent on certain meteorological elements (R=0.407; R^2=0.166; p=0.0317). This relationship may be described by the following equation: $Y=0.487+0.019x_3-0.005x_2+0.005x_1-0.004x_5$; ($Y$ – the content of N-NH_4 in cocksfoot grass sward in % N in dry matter; notations of independent variables – see Methodology). However, it needs to be highlighted that certain meteorological elements (cloud cover, air relative humidity, $T_{5\ cm}$, evaporation) determined the content of NH_4 only in approx. 17%. The content of the remaining forms of nitrogen (N_{total}, $N_{protein.}$, N-NO_3) did not significantly depend on the examined meteorological elements. PUŁA and SKOWERA (2004) stated that a considerable amount of precipitation during the vegetation season of potato significantly limited the content of starch and dry matter, but favoured the accumulation of total protein in tubers. At the same time, the yields of starch, total protein and dry matter were significantly lower in the year receiving the largest amount of precipitation (1997). In other studies, SKOWERA et al. (2007) report that the content of total protein in chickpea seeds significantly depended on the sum of precipitation and the sums of effective temperatures in the ripening phase of pods.

The content of starch depended on the sum of precipitation in the bloom phase, the sums of effective temperatures in the phase of pod setting and the number of days with precipitation during the vegetation season. At the same time, CIEPIELA et al. (2001) reported that the length of the low temperature stress had influenced changes in the content of total and soluble protein in cv. Kargo spring triticale seedlings. Comparing the electrophoretic images of winter and spring wheat seedling proteins which have different frost resistance, SOLECKA (1994) stated that most of low temperature induced proteins were found in both types of plants. The only difference was the presence of a protein with a mass of 200 kDa in the winter variety, more resistant to low temperature. It suggests that most changes caused in cells by this factor are not connected with water freezing tolerance but with adjustment of the plant metabolism to low temperature. Analysis of protein distribution in leaves, nodes and roots of wheat showed that the 200 kDa protein is present in all tissues, but accumulates in much higher amounts in aerial tissues, which are much more frost-resistant than roots. In other words, the higher degree of synthesis of this protein is closely connected with the higher frost-resistance.

In addition, statistical calculations show that the content of total and nitrate nitrogen in roots of cocksfoot grass significantly depended on certain meteorological elements. The content of the former (N_{total}) can be described as follows: R=0.326; R^2=0.106; p=0.05. The multiple regression equation with the choice of the best subset of independent variables has the following form: $Y=0.128–0.184x_3+0.027x_2+0.027x_1$; (y – the content of N_{total} in roots in % N in dry matter; independent variables notations – see methodology). However, it needs to be highlighted that the independent variables x in the equation determined the content of total nitrogen in roots of cocksfoot grass only in approx. 11%. Moreover, statistical calculations show that there is some small but important relationship between the content of nitrate nitrogen in roots of cocksfoot grass and certain meteorological elements. It can be described in the following way: R=0.388; R^2=0.151; p=0.0107. The calculated multiple regression equation has the following form: $Y=0.034–0.0007x_1+0.0004x_4–0.0029x_3$; ($y$ – the content of N-NO_3 in roots in % N in dry matter; independent variables notations – see methodology). It needs to be underlined, however, that these meteorological elements determine the content of N-NO_3 in roots only in approx. 15%. KRZYWY et al. (1985) stated that the highest content of total nitrogen was found in sward gathered in the dry year 1983; nitrate nitrogen (V) in the control – also in dry years, and on the fertilizing objects – in the wet year.

The statistical calculations also showed that there is a particularly important relationship between N uptake by cocksfoot grass and some meteorological elements (Figures 3 and 4). It can be determined as follows: R=0.499; R^2=0.249; p=0.0017. Accordingly, the multiple regression equation has the following form: $Y=1635.9+50.2x_3+5.38x_1–16.0x_2–11.3x_5–9.33x_6$; (y – N uptake

in kg·ha^{-1}; notations of independent variables – see methodology). However, it needs to be highlighted that the features taken into consideration in the equation determined N uptake by cocksfoot grass only in approx. 25%.

KUBIK-DOBOSZ (1998) stated that there is little evidence connecting NH_4^+ uptake by plants and the presence of light. Prolonged exposure to dark results in a decreased uptake of ammonium ions and especially the rate at which these ions enter cells. At the same time, there is little inhibition of their outflow. On the other hand, no influence of temperature changes on NH_4^+ ion uptake by *Lolium multiflorum* and *Lolium perenne* was reported (CLARKSON and WARNER 1979), and its increase from 10° to 35°C slightly stimulated the uptake of these ions by seedlings of *Ceratonia siliqua*. The uptake rate increased rapidly after a temperature increase to 40°C (KUBIK-DOBOSZ 1998). WOJCIECHOWSKA (2004), reports that, apart from agrotechnical factors, the intensity of light, water supply and temperature have an important influence on the accumulation of nitrates in plants. Low light intensity connected with low photosynthesis intensity influences the increase in the content of nitrates in plants. The main reason for this relationship is the inductive influence of light on the activity of nitrate reductase, which is the key enzyme in the metabolism of nitrates, and on the production of assimilates in the process of photosynthesis which act as acceptors of the reduced form of nitrogen. The content of nitrates in plants during the vegetation season is modified to a larger degree by water relations. Periods of drought during cultivation of plants causes an increase in the content of nitrates, mainly because their reduction is largely inhibited. Increased accumulation of nitrates in plants growing under negative water balance is connected with a rapid decrease in photosynthesis resulting from limited access to CO_2, which is caused by stomatal closure. The assimilation of nitrates by plants decreased under substantial limited water content in soil and lower air relative humidity. Lower soil temperature usually inhibits nitrate uptake. At a soil temperature of 16°C some rice varieties take up half the amount of NO_3^- ions absorbed at a temperature of 28°C (HASEGAWA 1990). Temperature influences metabolic processes; it affects the intensity of photosynthesis and respiration and the activity of enzymes responsible for the reduction of nitrates and the synthesis of organic nitrogen compounds. The content of nitrates in plants is influenced by the efficiency of numerous complex processes connected with the uptake and reduction of nitrate ions and the assimilation of ammonium ions.

CONCLUSIONS

1. No significant relationship between the forms of N (N_{total}, $N_{protein}$, N-NH_4, N-NO_3) in sward and roots of cocksfoot grass and the course of

meteorological conditions was clearly stated. The relationship between the content of $N\text{-}NH_4$ in sward and N_{total} and $N\text{-}NO_3$ in roots and certain meteorological elements is relatively slight and can be characterised by the determination coefficients: 0.166; 0.106 and 0.151.

2. The statistical analysis showed that the N uptake by cocksfoot grass depends to a relatively small though significant extent (R^2=0.249) on certain meteorological elements. However, further research is still recommended.

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