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EFFECT OF LIMING AND FERTILIZATION WITH VARIOUS NITROGEN FORMS ON THE CONTENT OF SOME CATIONS IN SPRING BARLEY

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A b s t r a c t. The influence of fertilization with various nitrogen forms on cation composition of spring barley cultivated on acid and limed soil was determined in two-year pot experiment. The factors of the study were: liming, fertilization with two nitrogen forms at two levels and fertilization with phosphorus at two levels. The test plant was harvested at its full ripeness. The obtained results indicated that liming of very acid soil contributed to significant increase of calcium, magnesium and sodium ions in spring barley as well as to decrease of potassium ions content. Plants fertilized with calcium nitrate had higher concentrations of calcium, magnesium and sodium than plants fertilized with ammonium sulphate. A different situation was observed in the case of potassium content. The applications of differentiated rates of nitrogen and phosphorus did not cause as significant changes in the content of these elements as liming and fertilization with various nitrogen forms. Liming as well as use of calcium nitrate positively influenced the cation composition of spring barley and contributed to improvement of its fodder value.

K e y w o r d s : cation composition, spring barley, liming, nitrogen forms

INTRODUCTION

The availability of a specific ion for plants depends on whether the soil is abundant with the component, as well as on the occurrence or lack of other ions. Nitrogen is absorbed by plants both in the form of NO_3^- ions and NH_4^+ ions. The form in which nitrogen is taken up by plants affects not only their growth, but also their chemical composition, and their ionic composition in particular. Intense fertilization with nitrogen in the form of nitrates enhances the uptake of univalent and bivalent cations, which may lead to upsetting the ionic equilibrium in the plant and, consequently, to a decrease of yield use value. Besides, in plants fertilized with N-NO_3 there is increased accumulation of non-protein nitrogen forms which pose a threat to human and animal health. On the other hand, according to many researchers, fertilization with nitrogen in its ammonium form limits the growth of plants, impedes the process of photosynthesis, inhibits the formation of ATP and the reduction of NADP, as well as decreases the absorption of inorganic cations (Borowski *et al.* 1991, Britto and Kronzucker 2002, Irshad *et al*. 2002, Jurkowska *et al*. 1981, Sapek and Sapek 1994, Wesołowski *et al.* 2002).

Fertilization with differentiated forms of nitrogen has also an indirect effect on the ionic composition of plants through influencing the soil reaction. Plants cultivated on acid soils reveal shortages of many nutrients, including calcium and magnesium in particular. The basic and most effective way of diminishing negative effects of low soil pH is liming (Filipek-Mazur *et al.* 1999, Karaivazoglou *et al.* 2007, Kotowska and Maciejewska 2001, Sapek *et al*. 2000).

The aim of the conducted studies was to assess the effect of fertilization with various forms of nitrogen on the cation composition of spring barley cultivated on acid and limed soil.

MATERIAL AND METHODS

The studies were conducted on the basis of a two-year pot experiment. The test plant was spring barley, Bryl variety. The experiment was established on soil material with grain size composition of light loamy sand. The soil was characterized with very acid reaction (pH_{KCl} 4.00), low level of available phosphorus and potassium and very low content of available magnesium. The experiment was conducted in pots containing 5 kg of soil material. Pots were located in vegetation hall. The height of pot measured 22 cm. In each pot there was ten plants. The scheme of the experiment comprised 9 combinations in 4 replications on limed (G2) and non-limed soil (G1). The experimental factors were: liming, fertilization with two forms of nitrogen: ammonium – F1 or nitrate – F2, two levels of fertilization with nitrogen: N1 – 0.1 g N kg^{-1}, N2 – 0.2 g N kg^{-1} and fertilization with phosphorus in two rates: P1 – 0.06 g P kg^{-1}, P2 – 0.12 g P kg^{-1}. The above-mentioned experimental factors were applied against the background of control object. In all combinations there was permanent application of potassium (0.1 g K kg^{-1}) and magnesium (0.025 g Mg kg^{-1}). Fertilization with $CaCO_3$ was applied once, before establishing the experiment, in an amount equivalent to 1Hh. Fertilization with nitrogen, phosphorus, potassium and magnesium was applied in each year of the study before sowing the plants. Phosphorus was added in the form of triple granulated superphosphate (20.1% P), nitrogen in the form of ammonium sulphate (20% N) or calcium nitrate (15.5% N), potassium in the form of high-percentage potash salt (49.8% K), and magnesium – as magnesium sulphate (9.6% Mg). During vegetation constant soil moisture was maintained on the level of 60%

of field water capacity. The harvesting of spring barley was conducted in the phase of its full ripeness.

The dry matter content was determined by means of the drier method, by drying the plant material at the temperature of 105 °C. The plant material was mineralised in concentrated sulphuric acid (VI) with an addition of perhydrol. In mineralisates we determined the content of potassium, magnesium, calcium and sodium by means of AAS method, with the use of Hitachi Z-8200 spectrophotometer with Zeeman polarization.

The influence of experimental factors on the formation of K^+, Na^+, Ca^{2+} and Mg^{2+} content in plants was determined by means of variance analysis with the application of Turkey half-intervals of confidence. The results presented in Tables constitute mean values from the two-year experiment. Only significant LSD values are given in the Tables.

RESULTS AND DISSCUSION

From among the applied experimental factors, the greatest and most important influence on the formation of cation composition of spring barley grain was that of liming and fertilization with differentiated forms of nitrogen (Tab. 1). The use of calcium carbonate contributed to increase of calcium, magnesium and sodium concentrations, but also to a decrease of potassium content. The observed lower content of Ca^{2+} and Mg^{2+} in the grain of plants cultivated on acid soil was most probably related to increased amount of H^+ and Al^{3+} ions in the soil solution. The hydrated Al^{3+} cation has a much smaller ionic radius than Mg^{2+} and Ca^{2+}, and thus it penetrates the root zone more easily, blocking the place in the apparent free space (AFS), which causes a decrease in the rate of these ions uptake. Besides, aluminium limits calcium uptake by blocking channels in the plasmatic membrane, and magnesium uptake - through blocking protein transport places. High content of potassium ions in the grain of barley cultivated on non-limed soil, as compared to the content of calcium and magnesium, leads to an extension of K ratio (Ca + Mg) and, consequently, to deterioration of fodder quality. Higher concentration of K^+ ions in the grain of plants cultivated on acid soil, as compared to its amount gathered from limed soil, could have been caused by great difference in plant yield (Bednarek and Reszka 2007). Plants cultivated in the conditions of high concentration of potassium in soil solution take this nutrient in amounts much greater than they need - so-called luxury potassium consumption. However, in the studies conducted by Rutkowska *et al.* (2001), after the application of liming no significant changes were observed in potassium and calcium levels, but a significant increase of magnesium content was noticed. Similarly, Kotowska and Maciejewska (2001) did not find any statistically proven influence of this procedure on the content of calcium and potassium in spring barley grain.

In this experiment, application of calcium nitrate contributed to a significant increase of calcium, magnesium and sodium content in dry matter of the tested grain, as compared to their concentrations in the grain of plants fertilized with ammonium sulphate. The increase in the amount of Ca^{2+} and Mg^{2+} ions was undoubtedly a consequence of the increase of soil pH under the influence of $Ca(NO_3)_2$. Another significant fact was that in the form of calcium nitrate the plants get easily available calcium (Sapek and Sapek 1994). It seems interesting that the concentration of potassium is lower in the grain of spring barley fertilized by nitrate than by ammonium form of nitrogen, both on acid and limed soil. Most probably the reason for that was the “dilution effect”, because in the object fertilized with calcium nitrate much greater yield of spring barley grain was found (Bednarek and Reszka 2007). Similarly, Warchołowa and Mroczkowski (1982), having applied the ammonium form of nitrogen, observed a distinct decrease of bivalent cation concentrations (Ca^{2+}, Mg^{2+}) in plants, with simultaneous increase of K^+ content, whereas Jurkowska *et. al.* (1981), analysing the aboveground parts of plants fertilized with calcium nitrate, found that concentrations of both bivalent and univalent cations increased compared to their content in plants fertilized with ammonium sulphate.

The increase of phosphorus rates significantly affected the increase of calcium and potassium content. This fact can be explained by cooperation between phosphorus and calcium in the formation of phytin, the grain resave substance. Different study results were obtained by Bednarek and Tkaczyk (2001). Those authors did not observe any increase of calcium concentration in plants with the increase of phosphorus rates. Similarly, Rutkowska *et al.* (2002) did not find any significant effect of phosphorus fertilization on the concentrations of potassium and calcium ions in the grain of tested plant.

The conducted statistical analysis revealed that the increase of nitrogen rates in the form of ammonium sulphate contributed to significant decrease of calcium content in the spring barley grain, whereas the increase of N rates in the form of calcium nitrate caused an increase in the concentration of the discussed component by 10%. The increase of calcium content in plants with increase of $Ca(NO_3)_2$ rates is also indicated by study results obtained by Sapek *et al.* (2000).

The main factors causing changes in the cation composition of spring barley straw was liming and fertilization with various forms of nitrogen (Tab. 2). The straw of plants harvested from limed soil contained 80% more calcium, 16% more magnesium and 23% more sodium than the straw of plants gathered from acid soil. A different situation was observed in the case of potassium. The results of studies conducted by other authors, concerning the influence of liming on the ca-

Tab. 2

tion content of plants are not unambiguous. Karaivazoglou *et al.* (2007) demonstrated an increase of Ca^{2+} concentration, but also a decrease of the amount of K^+ ions. Filipek-Mazur *et al.* (1999) found that there was an increase in calcium content, but they did not observe any distinct effect of this procedure on magnesium concentration, whereas Filipek (2001) reported an increase in magnesium concentration in plants together with the increase of soil pH and lack of distinct dependence on the reaction of potassium and calcium content. According to Rutkowska *et al.* (2001), liming does not significantly affect the content of K^+, Mg^{2+} and Ca^{2+} ions in the straw.

The use of calcium nitrate enhanced the increase of calcium, magnesium and sodium content in the dry matter of spring barley straw, which can be explained by synergism between the ions of NO_3^-, and Ca^{2+}, Mg^{2+} and Na^+. However, we did not find any positive effect of nitrate ions on the concentrations of K^+ ions in the straw. Increase of calcium content and decrease of potassium content as a result of fertilization with $Ca(NO_3)_2$ was also demonstrated by Sapek and Sapek (1994) and Sapek *et al*. (2000). Wesołowski *et al.* (2002), after the application of calcium nitrate, observed an increase of calcium content, but no distinct differences in the concentrations of potassium and sodium, whereas Borowski *et al.* (1991), Irshad *et al*. (2002), Uziak *et al.* (1991) and Karaivazoglou *et al.* (2007) demonstrated an increase in the amount of both Ca^{2+}, Mg^{2+} ions, and K^+ ions in plants fertilized with $Ca(NO_3)_2$, as compared to plants fertilized with $(NH_4)_2SO_4$.

In this experiment, fertilization with differentiated rates of nitrogen and phosphorus did not significantly affect the concentrations of discussed cations in spring barley straw. Rutkowska *et al.* (2001), when analysing the ionic content of triticale straw, did not find any significant changes under the influence of nitrogen fertilization, either.

The dependences observed in the cation composition of barley roots under the effect of the experimental factors were similar to the changes found in the above-ground parts of the tested plant (Tab. 3). The application of $CaCO_3$ and $Ca(NO_3)_2$ caused a significant increase in the root concentrations of Ca^{2+}, Mg^{2+} and Na^+ ions. A different situation was observed in the case of K^+ ions. However, the prevailing opinion in literature is that of positive influence of those procedures on the content of analysed ions in plant roots (Bednarek and Tkaczyk 2001, Borowski *et al.* 1991, Jurkowska *et al.* 1981, Uziak *et al.* 1991, Warchołowa and Mroczkowski 1982).

Tab. 3

CONCLUSIONS

1. Liming very acid soil contributed to a significant increase of calcium, magnesium and sodium ions in spring barley as well as to a decrease of potassium ions content.
2. Greater content of calcium, magnesium and sodium was characteristic of plants fertilized with calcium nitrate than of those fertilized with ammonium sulphate. A different situation was observed in the analysis of potassium concentration.
3. The application of varied rates of nitrogen and phosphorus did not affect the content of the discussed ions as significantly as liming and fertilization with different forms of nitrogen.
4. Both liming and application of calcium nitrate positively influenced the content of some cations in spring barley, increasing its fodder value.

REFERENCES

Bednarek W., Reszka R., 2007. Influence of liming and fertilization with various nitrogen forms on yielding and utilisation of phosphorus by spring barley (in Polish). Annales UMCS Sec. E LXII, 1, 69-76.

Bednarek W., Tkaczyk P., 2001. Influence of mineral fertilization on the content of calcium in soil and orchard grass (in Polish). Biul. Magnezol., 6(3), 199-205.

Borowski E., Blamowski Z., Uziak Z., 1991. Influence of nitrogen forms on the formation of ionic composition and the content of free amino-acids in rape and maize plants (in Polish). Annales UMCS Sec. E, XLVI, 193-201.

Britto D.T., Kronzucker H.J., 2002. NH_4^+ toxicity in higher plants: a critical review. J. Plant Physiol., 159, 567-584.

Filipek T., 2001. Effect of acidification on the content of potassium and magnesium and K : Mg ratio in soils and cereal plants (in Polish). Zesz. Probl. Post. Nauk Roln., 480, 43-49.

Filipek-Mazur B., Mazur K., Kasperczyk M., Gondek K., 1999. Effect of long-term mineral fertilization and liming on chemical composition of plant species selected from meadow sward under static experiment at Czarny Potok (in Polish). Zesz. Probl. Post. Nauk Roln., 465, 585-595.

Irshad M., Honna T., Enejl A.E., Yamamoto S., 2002. Wheat response to nitrogen source under saline conditions. J. Plant Nutrition, 25, 12, 2603-2612.

Jurkowska H., Wiśniowska-Kielian B., Wojciechowicz T., 1981. Effect of the form of nitrogen and its dose on the content of macro- and microelements in plants. Part I, Macroelements (in Polish). Acta Agrar. Silv., Sc. Agrar., 20, 107-119.

Karaivazoglou N. A., Tsotsoils N.C., Tsadilas C.D. 2007. Influence of liming and form of nitrogen fertilizer on nutrient uptake, growth, yield and quality of Virginia (flue-cured) tobacco. Field Crops Research, 100, 52-60.

Kotowska J., Maciejewska M., 2001. Influence of liming and NPK fertilization of a very acid soil on the content and quantitative ratios of macroelements in potato tubers and barley grain (in Polish). Biul. Magnezol., 6(4), 575-581.

Rutkowska B., Szulc W., Łabętowicz J., 2001. Influence of long-term unbalanced mineral fertilization on magnesium content in cultivated plants (in Polish). Biul. Magnezol., 6 (3), 360-366.

Sapek B., Sapek A., 1994. Perspektywy stosowania saletry wapniowej „Hydro” na trwałe użytki zielone. Wiad. Melior., 2, 92-95.

Sapek B., Sapek A., Barszczewski J., 2000. The field and selected minerals content in the herbage of permanent meadow on the background of ammonium and calcium nitrate fertilization (in Polish). Wiad. IMUZ, 21, 1, 67-87.

Uziak Z., Borowski E., Blamowski Z. K., 1991. State of ionic equilibrium in plants of spring rape and maize at varied ratios of $N\text{-}NO_3$ and $N\text{-}NH_4$ in the nutrient solution. Pol. J. Soil Sci., 24, 1, 79-86.

Warchołowa M., Mroczkowski W., 1982. The effect of nitrogen source on mineral composition of plants (in Polish). Pam. Puł., 78, 63-76.

Wesołowski P., Sapek B., Durkowski T., 2002. Comparing the effect of calcium nitrate with ammonium nitrate on meadow productivity located on peat-moors soil (in Polish). Woda-Środowisko-Obszary Wiejskie, 2, 1, 57-64.

ODDZIAŁYWANIE WAPNOWANIA ORAZ NAWOŻENIA RÓŻNYMI FORMAMI AZOTU NA ZAWARTOŚĆ NIEKTÓRYCH KATIONÓW W JĘCZMIENIU JARYM

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Streszczenie. W dwuletnim doświadczeniu wazonowym oceniano wpływ nawożenia różnymi formami azotu na skład kationowy jęczmienia jarego uprawianego na glebie kwaśnej i wapnowanej. Czynnikami doświadczalnymi było wapnowanie, nawożenie dwoma formami azotu stosowane w dwóch dawkach oraz nawożenie fosforem na dwóch poziomach. Roślinę testową zbierano w fazie dojrzałości pełnej. Wapnowanie gleby bardzo kwaśnej przyczyniło się do istotnego zwiększenia w jęczmieniu jarym zawartości jonów wapnia, magnezu i sodu oraz do zmniejszenia ilości jonów potasu. Większą koncentracją wapnia, magnezu i sodu charakteryzowały się rośliny nawożone saletrą wapniową niż siarczanem amonu. Odmienną sytuację zaobserwowano w przypadku zawartości potasu. Zastosowanie zróżnicowanych dawek azotu i fosforu nie wpływało tak znacząco na zawartość omawianych jonów jak wapnowanie i nawożenie różnymi formami azotu. Wapnowanie, jak i użycie saletry wapniowej, wpływało dodatnio na skład kationowy testowanej rośliny poprawiając jej wartość paszową.

Słowa kluczowe: skład kationowy, jęczmień jary, wapnowanie, formy azotu