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Zdzisław CIEĆKO[1], Andrzej C. ŻOŁNOWSKI[1]
and Aneta MIERZEJEWSKA[1]

EFFECT OF FOLIAR NITROGEN AND MAGNESIUM FERTILIZATION ON THE TOTAL, PROTEIN NITROGEN AND NITRATES(V) CONTENT IN POTATO TUBERS

ODDZIAŁYWANIE DOLISTNEGO NAWOŻENIA AZOTEM I MAGNEZEM NA ZAWARTOŚĆ AZOTU OGÓLNEGO, BIAŁKOWEGO ORAZ AZOTANÓW(V) W BULWACH ZIEMNIAKA

Abstract: The paper's aim has been to clarify the effect of foliar fertilization with nitrogen and magnesium on the content of total and protein nitrogen in tubers of medium-early potato cv. Zebra. The experiment was conducted in three series; in the first series, in which potatoes were fertilized only with nitrogen in the total dose of 80 kg N · ha^{-1}, the contribution of foliar treatment steadily increased (0, 10, 20, 30, 40 and 50 %) at the expense of soil fertilization (80, 72, 64, 48 and 40 kg N · ha^{-1}); in the other two series included additional magnesium fertilization. In the second series, magnesium at a rate of 7.5 kg Mg · ha^{-1} was sprayed over potato leaves; in the third series, 15 kg Mg · ha^{-1} was introduced to soil. The highest average content of total and protein nitrogen was determined in potato tubers which had received exclusive nitrogen fertilization, both as foliar sprays and to soil, whereas in the variants including addition of magnesium, a slight decrease in amounts of both nitrogen forms occurred. The highest increase in the total and protein nitrogen content in potato tubers was obtained at the 10 % contribution of foliar nitrogen application. Magnesium nutrition, either as foliar or soil treatments, did not have any significant influence on the content of total and protein nitrogen in tubers. Increasing share of foliar nitrogen fertilization led to a decreased content of nitrates(V) in potato tubers tested after harvest. A similar effect appeared under the influence of additional foliar application of magnesium, whereas the same nutrient added to soil produced a reverse effect. Magnesium sprayed over leaves tended to lower the concentration of nitrates in potato tubers. When introduced to soil, it raised the content of nitrates(V) in potato tubers.

Keywords: total N, protein N, nitrates(V), potato tubers, foliar fertilization, magnesium

The size of fertilization rates as well as treatment dates and techniques play a dominant role in shaping the volume and quality of crop yields. Nitrogen is the element which largely determines the course of growth and development processes in

[1] Department of Environmental Chemistry, University of Warmia and Mazury in Olsztyn, pl. Łódzki 4, 10–727 Olsztyn, Poland, phone +48 89 523 35 66, email: zdzislaw.ciecko@uwm.edu.pl

plants, therefore crops which receive proper nitrogen nutrition produce high quality yields, which are safe to consumers' health. Mineral fertilization of potatoes can improve the nutritional quality of potato yields. However, inadequate nitrogen fertilization can prolong the vegetative growth of potatoes, deteriorate storability of potato tubers and cause accumulation of harmful nitrogen compounds in tubers. The literature contains many reports on beneficial effects of nitrogen applied in foliar treatments on quality characteristics of potato tubers [1, 2]. Nitrogen sprayed over leaves is assimilated by plants 50–100 % more efficiently than nitrogen introduced to soil, and other fertilizers, including magnesium, used in conjunction with nitrogen improve the efficiency of fertilization treatments. Considering the above aspects, it seems useful to design such a growing technology that would take into account not only yield volumes but also yield quality, including concentrations of particular forms of nitrogen.

The aim of this study has been to determine the effect of foliar fertilization with nitrogen and magnesium introduced to soil or sprayed over leaves on accumulation of total nitrogen, protein nitrogen and nitrates(V) in tubers of cv. Zebra potato.

Material and methods

In a three-year field trial, conducted at the Experimental Station in Tomaszkowo near Olsztyn, the effect of foliar nitrogen fertilization in combination with foliar or soil magnesium nutrition was examined on the content of total nitrogen, protein nitrogen and nitrates(V) in tubers of the medium-early potato cultivar Zebra (the Crop Breeding Station in Szyldak).

The testes involved a two-factor experiment in a random block design with four replications, including different variants of nitrogen and magnesium fertilization, applied as foliar or soil treatments. The experiment consisted of three series; in the first one potatoes received only nitrogen fertilization, in total 80 kg N · ha^{-1}, with foliar treatments on the increase (0, 10, 20, 30, 40 and 50 %) at the expense of soil application (80, 72, 64, 48 and 40 kg N · ha^{-1}); the other two series involved additional magnesium nutrition. In the second series, magnesium was applied in a dose of 7.5 kg Mg · ha^{-1} as a foliar treatment and in the third series it was introduced to soil in the amount of 15 kg Mg · ha^{-1}. Phosphorus and potassium fertilization was identical in all the treatments and equaled 35 kg P and 100 kg K · ha^{-1}. Nitrogen was used as urea (46 % N) and magnesium was applied in the form of magnesium sulphate (9.5 % Mg). Fertilizers introduced to soil were applied in whole rates before planting potatoes and the foliar application consisted of 5 sprays during the vegetative growth of plants. The first spraying was performed after the rows became compact and potato plants formed first floral buds, and the following treatments took place at seven-day intervals. Once the potatoes had completed their vegetative growth, tubers were collected and samples were fragmented, dried at 60 ^{o}C and stored in sealed containers. In the material thus prepared, total and protein nitrogen content was determined with Kjeldhal's method [3], and a 24 % solution of trichloroacetic acid was used for titration of proteins while determining protein nitrogen.

Content of nitrates(V) was determined in fresh material, according to the standard analytical method recommended by the company Orion [4], with an aid of an Ionanalyzer® Orion model 407 potentiometer and ionoselective nitrate electrode, Thermo Orion model 9307^{TM}. For determinations, reference solutions of NO_3^- supplied by Orion were used. The content of nitrates(V) in potato tubers was also determined during the storage time at monthly intervals. Ten kilos of healthy tubers, 3.5–6.0 cm in diameter, from each fertilization treatment were stored. Tubers were stored in a storage chamber 12 m^3 in capacity (PPUCH Tarczyn) at 6 ^{o}C (±0.5 ^{o}C) and relative air humidity (RH) at the level of 90–95 %. Potatoes were stored for six months (from September to March).

Discussion of the results

The tests on the effect of foliar application of nitrogen together with magnesium in foliar or soil treatments on the content of total and protein nitrogen have demonstrated that the level of these components in potato tubers was modified primarily by nitrogen fertilization and to a lesser extent – by application of magnesium (Fig. 1). The effect produced by the fertilizers was also dependent on the application technique. Swiniarski et al [5] reported that high nitrogen fertilization of potatoes had an evident influence on the content of total and protein nitrogen, which sometimes even doubled compared with their concentrations in tubers from control treatments (without nitrogen fertilization). Ciecko et al [6] did not demonstrate such a strong effect of nitrogen fertilizers. Under the maximum rate of nitrogen, which was 200 kg N · ha^{-1}, total nitrogen in tubers rose by just 0.39–0.48 % versus the control. Such results were confirmed in a study completed by Wyszkowski [7], who noticed that the content of total nitrogen rose clearly under the effect of increasing rates of nitrogen fertilizer. Wyszkowski examined four potato cultivars fertilized with 200 kg N · ha^{-1} and noticed that the total nitrogen content in tubers increased from 3.4 to 6.1 g N · kg^{-1}, depending on a cultivar. Distinct correlation between nitrogen fertilization and the content of total and protein nitrogen in

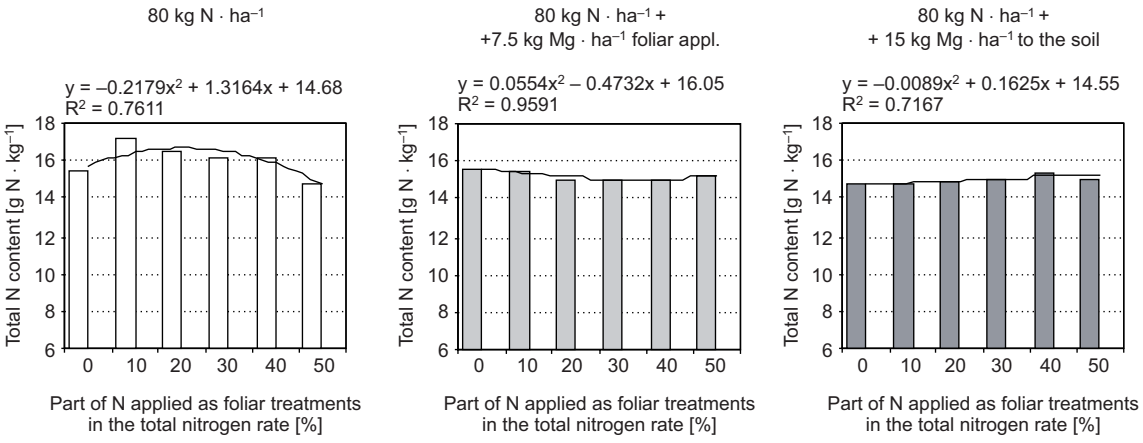

Fig. 1. Effect of foliar nitrogen fertilization and two technologies of magnesium fertilization on total nitrogen content in potato tubers of cv. Zebra

potato tubers has also been indicated by Roztropowicz [8]. In her study, as the rates of nitrogen rose from 40 to 200 kg N · ha^{-1}, the content of total and protein nitrogen rose steadily, too.

In the present study, there was only one rate of nitrogen, in which the amount of N applied in a foliar treatment increased. Foliar application of nitrogen had a varied effect on the total nitrogen content in potato tubers, which reached 15.5 g · kg^{-1} when nitrogen was introduced to soil. By substituting 10 % of nitrogen from the total rate with fertilizer sprayed over leaves, the content of total N in tubers was raised by 1.6 g, up to 17.1 g · kg^{-1}. Further increase in the contribution of foliar application of nitrogen to the total rate of nitrogen fertilizer led to a gradual decrease in the content of total nitrogen in tubers.

In her experiment, Boliglowa [9] found out that the content of total nitrogen in tubers was positively affected by foliar application of 6 % urea solution. The author discovered a higher increase in the total nitrogen concentration in tubers when urea was sprayed over leaves of potato plants rather than introduced to soil.

In our tests, it has been demonstrated that an increase in total N in potato tubers can be achieved by substituting nitrogen soil fertilization up to 40 % of the total nitrogen rate with foliar treatments. Further increase in the proportion of foliar application contributed to depressed N-total content in tubers.

Similar relationships were shown by Jablonski [10]. In his experiment, the total nitrogen content in tubers fell as the contribution of foliar nitrogen fertilization increased.

Foliar magnesium treatments included in the second series of our experiment blurred the determined effect of foliar application of nitrogen. Foliar application of 7.5 kg Mg · ha^{-1} led to a decrease in the total nitrogen content but when the percentage of nitrogen rate supplied as foliar treatments exceeded 30 %, the same magnesium treatment resulted in a small increase in the content of this element in tubers. Tubers collected from the series fertilized with magnesium introduced to soil were characterized by ca 6 % lower average content of total N than tubers from plots not fertilized with magnesium. Although the content of total N in tubers from that series was somewhat lower, its content increased as the foliar application of nitrogen reached higher percentage relative to the total fertilization rate.

With respect to protein nitrogen, foliar application of nitrogen equaled 20 % of the total N rate raised the content of protein N by about 1.1 g · kg^{-1} versus tubers from the treatment, where this nutrient was not sprayed over leaves. Further increase in foliar N fertilization did not produce any effect on the content of protein nitrogen (Fig. 2). Likewise, magnesium fertilization treatments were not found to produce any influence on protein nitrogen in tubers.

Such a relatively weak effect of magnesium fertilization on protein N may be due to the moderate abundance of soil in this element, but can also be attributed to organic fertilization (identical on all plots) with farmyard manure.

Slightly different from ours are the results reported by Rogozinska and Wojdyla [11], who discovered that besides nitrogen fertilization, application of larger quantities of

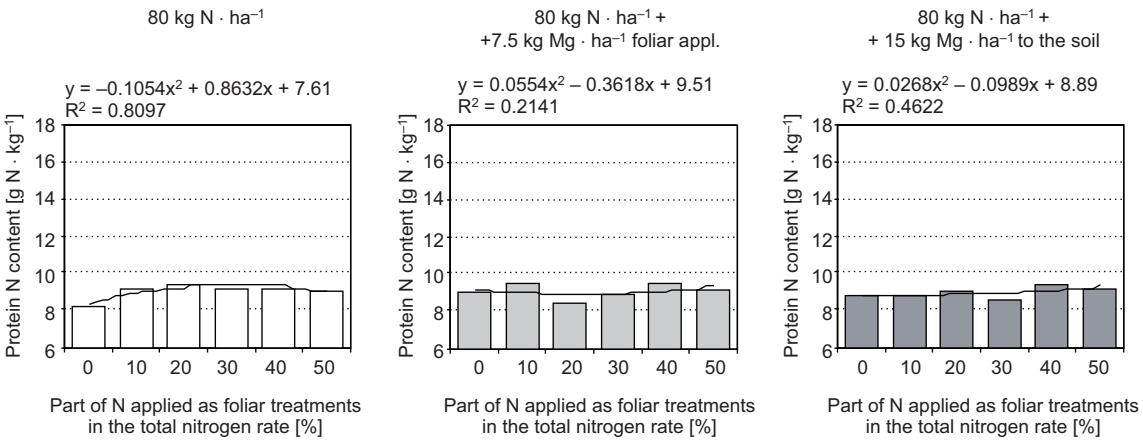

Fig. 2. Effect of foliar nitrogen fertilization and two technologies of magnesium fertilization on protein nitrogen content in potato tubers of cv. Zebra

magnesium also led to elevated total nitrogen content in potato tubers. In this study, no such effect has been obtained.

While analyzing the chemical composition of tubers for the content of total and protein nitrogen, one must not neglect another form of this element, ie nitrates(V), which affects human health. Although nitrates are relatively non-toxic to people, they can be easily reduced to nitrates(III) in a human body, and these may produce a series of unwanted changes, such as anaemia, methemoglobinemia or decomposition of vitamin A and carotenes. Moreover, nitrates are precursors of toxic N-nitroso compounds occurring in food products, for example 1,2-dimethylnitrosamine, which is responsible for liver damage and can induce cancer [12]. According to Mohler [13] and Karlowski [14], potato belongs to plants which do not readily accumulate nitrates. However, both in field experiments and in chemical analyses of commercially available potatoes, a highly diverse content of these compounds can be determined, ranging from tens to several thousands of milligrams [15–18].

In the present study, the determined amounts of nitrates(V) were re-calculated to sodium nitrate (Fig. 3). According to the currently binding regulations [19], the content of nitrates(V) in edible potato should not exceed 200 mg $NO_3^- \cdot kg^{-1}$ fresh matter of tubers. This amount corresponds to 275 mg $NaNO_3$ per 1 kg of tubers. The mineral fertilization tested in this experiment, ie 80 kg N · ha^{-1}, caused excessive accumulation of nitrate nitrogen(V) in all treatments. Foliar application of magnesium in general contributed to depressing the level of nitrates in tubers at harvest time, which however rose again after 2 and 3 months' storage (November and December) irrespective of the experimental fertilization variant. Tubers from treatments fertilized with nitrogen introduced to soil had a higher content of nitrates(V) than tubers from plots not fertilized with this nutrient. In later months of storage, the content of nitrates(V) in tubers continued to rise. This increase was due to relatively large water transpiration from surface of tubers and the enzymatic activity of tubers, which increased at the end of the storage period. Transpiration caused some kind of 'concentration' of nitrates(V) in tubers. In March (at the termination of storage) it was found out that the lowest quantities of this form of nitrogen appeared in tubers collected from the fertilization

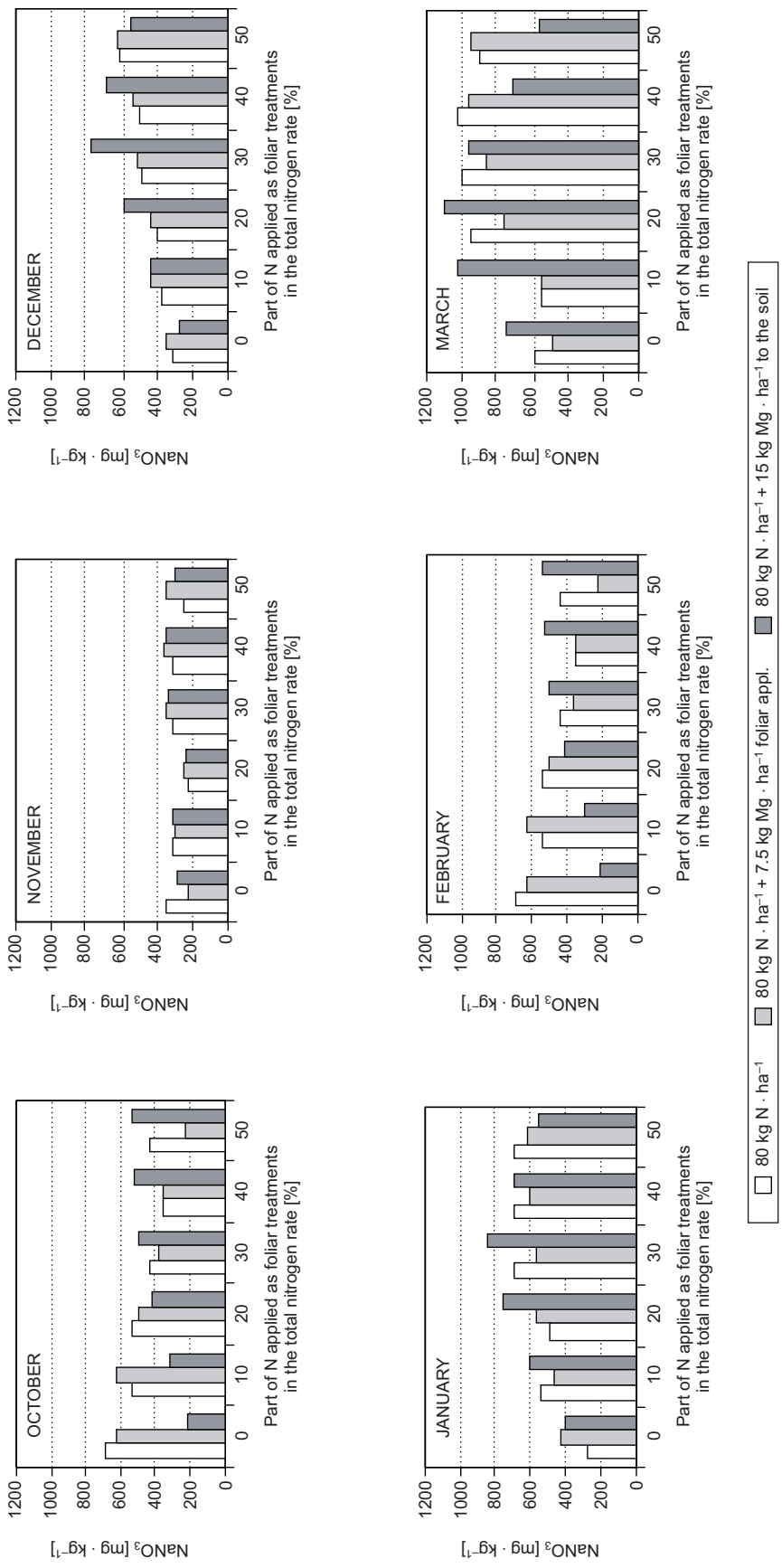

Fig. 3. Content of nitrates(V) in potato tubers of cv. Zebra, in consecutive months of storage

treatments which did not receive foliar nitrogen fertilization. Magnesium applied in a dose of 7.5 kg Mg · ha^{-1} as a foliar treatment in combination with a small percentage of foliar nitrogen application to total nitrogen rate had a beneficial effect on decreasing nitrates in tubers. In treatments receiving higher percentages of total nitrogen sprayed over leaves, superior effect was produced by magnesium applied in a dose of 15 kg Mg · ha^{-1} to soil.

Conclusions

1. The highest total and protein nitrogen content occurred in tubers from the series without magnesium addition, in contrast to the ones receiving additional magnesium nutrition, in which there was a slight increase in the concentration of both nitrogen forms.

2. The application of 10 % of supplied nitrogen as a foliar treatment caused the highest increase in the content of total nitrogen; by increasing the contribution of foliar nitrogen fertilization, the total nitrogen level in potato tubers was depressed.

3. Foliar and soil magnesium nutrition eliminated the effect produced by foliar nitrogen fertilization with respect to total nitrogen in tubers. The content of protein nitrogen in the analyzed tubers was not modified under the influence of the applied magnesium fertilization.

4. The increasing contribution of foliar nitrogen application versus the total rate of this nutrient resulted in a lower concentration of nitrates(V) in potato tubers after harvest. A similar effect was obtained when additional foliar application of magnesium was introduced. However, soil fertilization with magnesium had a reverse effect, raising this form of nitrogen in tubers.

5. The content of nitrates(V) in tubers considerably increased during storage. Magnesium applied in foliar treatments depressed the content of nitrates(V) in tubers, but when introduced to soil, it lowered the level of these compounds.

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ODDZIAŁYWANIE DOLISTNEGO NAWOŻENIA AZOTEM I MAGNEZEM NA ZAWARTOŚĆ AZOTU OGÓLNEGO, BIAŁKOWEGO ORAZ AZOTANÓW(V) W BULWACH ZIEMNIAKA

Katedra Chemii Środowiska
Uniwersytet Warmińsko-Mazurski w Olsztynie

Abstrakt: Pracę poświęcono wyjaśnieniu oddziaływania dolistnego nawożenia azotem i magnezem na zawartość azotu ogólnego i białkowego w bulwach ziemniaka średnio-wczesnego odmiany Zebra. Doświadczenie przeprowadzono z uwzględnieniem 3 serii: w pierwszej stosowano tylko nawożenie azotem – 80 kg $N \cdot ha^{-1}$, gdzie systematycznie zwiększał się udział nawożenia dolistnego (0, 10 %, 20 %, 30 %, 40 %, 50 %) kosztem doglebowego (80, 72, 64, 56, 48 i 40 kg $N \cdot ha^{-1}$), a w dwóch następnych seriach uwzględniono dodatkowo nawożenie magnezem. W drugiej serii magnez stosowano dolistnie w ilości 7,5 kg $Mg \cdot ha^{-1}$, a w trzeciej doglebowo w dawce 15 kg $Mg \cdot ha^{-1}$. Największą średnią zawartość azotu ogólnego i białkowego stwierdzono w bulwach nawożonych samym azotem – dolistnie i doglebowo, a w wariantach z dodatkiem magnezu nastąpił nieznaczny spadek koncentracji obu tych form azotu. Większy wzrost zawartości N-ogólnego i N-białkowego w bulwach ziemniaka uzyskano przy 10 % udziale nawożenia dolistnego azotem. Nawożenie magnezem zastosowane dolistnie jak i doglebowo, nie miało znaczącego wpływu na zawartość N-ogólnego i N-białkowego w bulwach ziemniaka. Zwiększający się udział dolistnego nawożenia azotem spowodował zmniejszenie zawartości azotanów(V) w bulwach ziemniaka po zbiorze bulw. Podobny efekt uzyskano podczas dodatkowej dolistnej aplikacji magnezu, natomiast składnik ten zastosowany doglebowo działał odwrotnie. Zawartość azotanów(V) w bulwach uległa znacznemu wzrostowi w okresie przechowywania. Magnez stosowany dolistnie przeważnie zmniejszał, a wprowadzany doglebowo zwiększał zawartość azotanów(V) w bulwach.

Słowa kluczowe: N-ogólny, N-białkowy, azotany(V), bulwy ziemniaka, nawożenie dolistne, magnez