

RESPONSE OF BUTTER LETTUCE (*LACTUCA SATIVA* L.) TO DIFFERENT FORMS OF NITROGEN FERTILIZERS WITH CHLORINE AND SULPHATES

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Abstract

The objective of the experiment was to determine the effect of nutrients (different doses of chlorine, sulphates and calcium as well as different forms of nitrogen fertilizers: $\text{Ca}(\text{NO}_3)_2 + \text{NH}_4\text{NO}_3$, NH_4NO_3 , $\text{NH}_4\text{NO}_3 + \text{CaCl}_2$, NaNO_3) on yield and content of N-NO_3 , N_{og} , P, K, Ca, Mg and Na in butter lettuce (*Lactuca sativa* L.) cv. Vilmorin. A pot experiment with four replications was repeated three times in 2007 (from 30th January and from 30th March) and in 2008 (from 31st March). It was established in the 'Plant House' of the Chair of Agricultural Chemistry and Environmental Protection UWM in Olsztyn. Lettuce seedlings were planted into pots containing 2 dm³ substratum. Nitrogen was applied three times, every 10 days, each dose consisting of 100 mg N·dm⁻³ of substratum applied to soil; identical doses of phosphorus, potassium and magnesium were introduced to the substratum before planting lettuce. Irradiation period was 12 hours every day. Lettuce was harvested after 6 weeks. Determinations of N_{og} (Kjedahl's method), P (vanadium-molybdenum method), K, Ca, Na (flame photometry – ESA), Mg (atomic absorption spectrophotometry – ASA) were performed having wet mineralised plant samples in H_2SO_4 . Concentration of nitrates (V) was determined in fresh matter (potentiometrically, using a ion-selective electrode) in a 0.03 mol·dm⁻³ CH_3COOH according to NOWOSIELSKI (1988). The smallest number of lettuce heads (statistically significant) was obtained after NaNO_3 fertilization. The concentration of N-NO_3 declined advantageously following an NaNO_3 treatment. In contrast, the highest accumulation of nitrates(V) occurred after application of lime saltpetre in conjunction with ammonium nitrate. The composition of minerals in butter lettuce cv. Vilmorin, such as phosphorus, potassium, magnesium and sodium, was more beneficially affected by fertilization with sulphate compounds ($\text{K}_2\text{SO}_4 + \text{MgSO}_4$) rather than chlorine compounds ($\text{KCl} + \text{MgCl}_2$). Soda nitre significantly depressed the content of magnesium and calcium in plants, had no effect on the concentration of phosphorus and increased accumulation of sodium and potassium.

Key words: *Lactuca sativa* L., macroelements, N-NO_3 , nitrogen fertilizers.

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REAKCJA SAŁATY MASŁOWEJ (*LACTUCA SATIVA* L.) NA RÓŻNE FORMY NAWÓZÓW AZOTOWYCH Z UDZIAŁEM CHLORU I SIARCZANÓW

Abstrakt

Celem pracy było określenie wpływu składników pokarmowych (zróżnicowanych dawek chloru oraz siarczanów i wapnia, a także różnych form nawozów azotowych: $\text{Ca}(\text{NO}_3)_2 + \text{NH}_4\text{NO}_3$, NH_4NO_3 , $\text{NH}_4\text{NO}_3 + \text{CaCl}_2$, NaNO_3) na plon oraz zawartość N- NO_3 , Nog., P, K, Ca, Mg i Na w sałacie masłowej (*Lactuca sativa* L.) odmiany 'Vilmorin'. Doświadczenie wazonowe w 4 powtórzeniach prowadzono 3-krotnie w 2007 r. (od 30.01. i od 30.03) i 2008 r. (od 31.03) w „Rośliniarni” Katedry Chemii Rolnej i Ochrony Środowiska UWM w Olsztynie. Rozsadę sałaty wysadzono do wazonów o pojemności 2 dm³ podłoża. Azot aplikowano 3-krotnie, co 10 dni, w ilości 100 mg N·dm⁻³ podłoża; fosfor, potas i magnez w jednakowych dawkach stosowano przed wysadzeniem sałaty. Długość naswietlania roślin wynosiła 12 h dziennie. Zbiór przeprowadzono po 6 tygodniach. Oznaczenia zawartości Nog. (metodą Kjeldahla), P (metodą wanadowo-molibdenową), K, Ca, Na, (metodą fotometrii płomieniowej – ESA), Mg (metodą absorpcyjnej spektrometrii atomowej – ASA) dokonano po mineralizacji „na mokro” w H_2SO_4 . Koncentrację azotanów(V) oznaczono w świeżej masie (potencjometrycznie z użyciem elektrody jonoselektywnej), w wyciągu 0,03 mol·dm⁻³ CH_3COOH wg NOWOSIELSKIEGO (1988). Najmniejszą masę główek sałaty (istotną statystycznie) otrzymano po nawożeniu NaNO_3 . Korzystne zmniejszenie ilości N- NO_3 nastąpiło po zastosowaniu NaNO_3 , natomiast największe nagromadzenie azotanów(V) stwierdzono po aplikacji saletry wapniowej łącznie z saletrą amonową. Na zawartość składników mineralnych w sałacie masłowej odmiany 'Vilmorin', takich jak fosfor, potas, magnez i sód, korzystniej wpływało nawożenie związkami siarczanowymi ($\text{K}_2\text{SO}_4 + \text{MgSO}_4$) niż chlorkowymi ($\text{KCl} + \text{MgCl}_2$). Saletra sodowa znacząco wpłynęła na zmniejszenie zawartości magnezu i wapnia w roślinach, nie miała wpływu na koncentrację fosforu, jednocześnie zwiększała akumulację sodu i potasu.

Słowa kluczowe: *Lactuca sativa* L., makroelementy, N- NO_3 , nawozy azotowe.

INTRODUCTION

Abundance and availability of mineral components in substratum condition the volume and quality of produced plant biomass. Wrongly balanced fertilization, particularly nitrogen treatments, often leads to unfavourable modifications of the chemical composition of crops. Excessive accumulation of nitrates(V) in green matter of plants is especially dangerous. Relevant references comprise many reports in the effect of substratum, agronomic practice, climatic conditions as well as genetic traits of crops on accumulation of nitrates and their effect on plant produce (DURMAN, CUSTIC 1990, KARIMAEI et al. 2004, JAROSZ, DZIDA 2006, KOWALSKA et al. 2006, KOZIK 2006, WOJCIECHOWSKA et al. 2006).

The purpose of this study has been to determine the effect of nutrients (different doses of chlorine, sulphates and lime as well as different forms of nitrogen: $\text{Ca}(\text{NO}_3)_2 + \text{NH}_4\text{NO}_3$, NH_4NO_3 , $\text{NH}_4\text{NO}_3 + \text{CaCl}_2$, NaNO_3 , on yield and content of N- NO_3 , N_{og.}, P, K, Ca, Mg and Na in butter lettuce (*Lactuca sativa* L.) cv. Vilmorin.

MATERIAL AND METHODS

A two-factor fertilization experiment was established three times, in 2007 (on 30th January and 30th March) and in 2008 (on 31st March) in the Plant House of the Chair of Agricultural Chemistry and Environmental Protection, University of Warmia and Mazury in Olsztyn. Butter lettuce (*Lactuca sativa* L.) cv. Vilmorin served as the test plant. Lettuce seedlings were planted to pots containing 2 dm³ substratum. Nitrogen was applied three times, at ten-day intervals, in doses consisting 100 mg N·dm⁻³ substratum: identical doses of phosphorus, potassium and magnesium were introduced before planting the lettuce (Table 1).

Table 1

Doses of nutrients in mg per dm³ of substratum

| No | Objects | N | P | K | Mg | Ca | Cl | S-SO ₄ | Na | |
|----|---------------------------|--|-----|-----|-----|----|-----|-------------------|--------|-----|
| 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 1 | sulphates or chlorides | Ca(NO ₃) ₂ +NH ₄ NO ₃ | 300 | 100 | 150 | 50 | 429 | 0 (94) | 75 (0) | 0 |
| 2 | | NH ₄ NO ₃ | 300 | 100 | 150 | 50 | 0 | 0 (94) | 75 (0) | 0 |
| 3 | | NH ₄ NO ₃ +CaCl ₂ | 300 | 100 | 150 | 50 | 429 | 381 (475) | 75 (0) | 0 |
| 4 | | NaNO ₃ | 300 | 100 | 150 | 50 | 0 | 0 (94) | 75 (0) | 495 |

The irradiation period was 12 hours daily. Lettuce plants were harvested after 6 weeks. The determinations of N_{og} (Kjeldahl's method), P (vanadium molybdenum method), K, Ca, Na (flame photometry ESA), Mg (atomic absorption spectrophotometry – ASA) were performed after wet mineralization in H₂SO₄. Concentration of nitrates (V) was determined in fresh matter (potentiometrically using an ion selective electrode) in a 0.03 mol·dm⁻³ CH₃COOH extract according to NOWOSIELSKI (1988). The first experimental factor consisted of two forms of potassium and magnesium fertilizer: sulphate and chloride (KH₂PO₄+K₂SO₄+MgSO₄; KH₂PO₄+KCl+MgCl₂). The second factor encompassed 4 variants of nitrogen fertilizers, which involved two forms of nitrogen fertilizers: NO₃⁻ i NH₄⁺; (Ca(NO₃)₂+NH₄NO₃, NH₄NO₃, NH₄NO₃+CaCl₂, NaNO₃). During the harvest, fresh matter of lettuce heads was weighed. The substratum prepared from mineral soil, before fertilization treatments, possessed the following physical and chemical properties: pH_{H2O} – 6.3, EC – 0.51; in 0.03 mol·dm⁻³ CH₃COOH extract: Ca – 1000.2 mg, Mg – 46.3 mg, K – 219.5 mg, Na – 185.6 mg, Cl – 66.1 mg, P – 23.2 mg, S-SO₄ – 218.6 mg, N-NH₄ – 10, N-NO₃ – 58.5 mg dm⁻³ of the substratum.

The results were processed statistically using analysis of variance for a two-factor experiment established in a completely randomized design, with an aid of Statistica 7.0 software.

RESULTS AND DISCUSSION

The fertilization treatments applied in this experiment significantly modified both yields and concentration of minerals in butter lettuce dry matter (Figures 1 and 2). The highest yield of butter lettuce was obtained when lime saltpetre was introduced to the substratum along with ammonium nitrate. The yield obtained when soda nitre had been applied was 18.7% lower compared to the highest yield, but it was still 47.5% higher than the con-

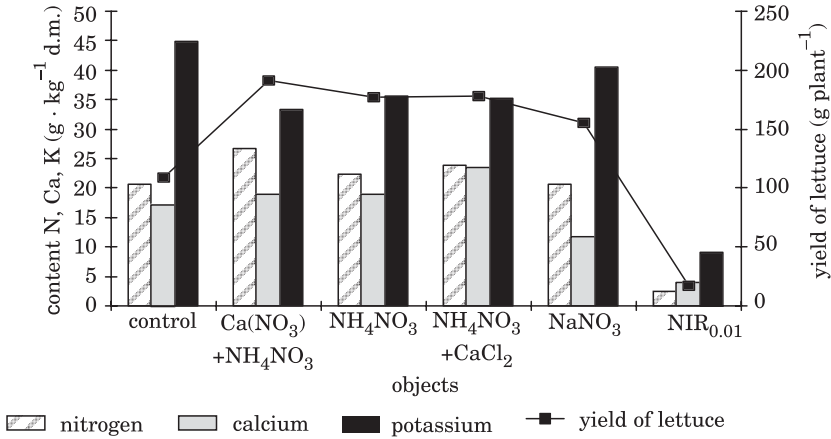


Fig. 1. Yield and content of N, Ca and K in dry matter of butter lettuce leaves depending on the form of nitrogen fertilizers

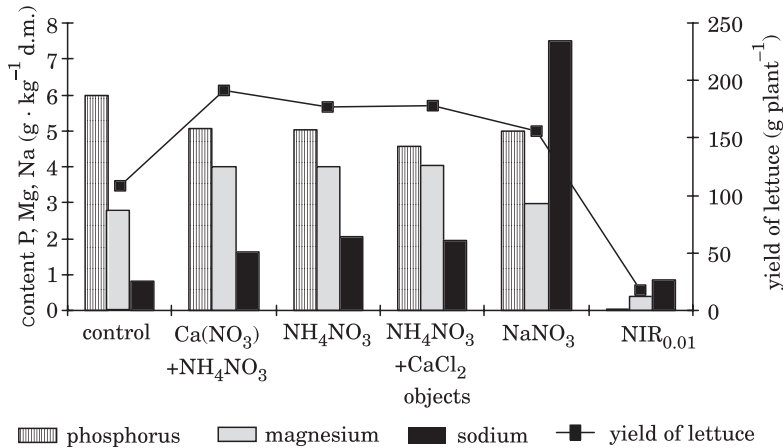


Fig. 2. Yield and content of P, Mg and Na in dry matter of butter lettuce leaves depending on fertilization

trol. Although lettuce is not tolerant to chlorine, in this experiment no significant changes in lettuce yield occurred as a result of introduction of ammonium nitrate or ammonium nitrate with calcium chloride and consequent increase in the concentration of chlorine in the substratum. These results are further confirmed by tests conducted by JAROSZ and DZIDA (2006) involving different forms of potassium fertilizer (KCl , KNO_3 , K_2SO_4).

The level of total nitrogen in lettuce leaves was slightly higher (by $2.75 \text{ g} \cdot \text{kg}^{-1}$ d.m. on average) versus the control (Figure 1). The lowest concentration of this element occurred in the objects fertilized with soda nitre. When this compound was added together with calcium chloride, no further decrease in the total nitrogen concentration in lettuce leaves was recorded. The significantly highest amount of total nitrogen in dry matter was found following the fertilization treatment with $\text{Ca}(\text{NO}_3)_2 + \text{NH}_4\text{NO}_3$, especially in the objects to which sulphates were introduced.

Lime applied as calcium saltpetre did not cause increased levels of calcium in lettuce leaves (Figure 1). Significant increase, however, in the concentration of this element was found after introduction of calcium in the form of CaCl_2 . Significant decrease in the content of calcium occurred after an application of soda nitre (a 31.7% decline versus the control).

The forms of nitrogen fertilizers tested in the current experiment caused a significant drop in the content of potassium in lettuce leaves as compared to the control (Figure 1). Similar results are reported by JAROSZ and DZIDA (2006), who discovered that higher nitrogen rates were associated with decreasing concentrations of potassium in lettuce. The content of potassium in lettuce dry matter was least affected by nitrogen added to the substratum in the form of soda nitre. In the other experimental variants, the concentration of potassium was depressed by 9.4 to 11.7 K kg^{-1} d.m. relative to the zero object.

The content of magnesium in lettuce heads rose significantly (by an average $1.25 \text{ g} \cdot \text{kg}^{-1}$ d.m. versus the unfertilized lettuce) following the introduction of lime saltpetre, ammonium nitrate as well as its combination with calcium chloride (Figure 2). Soda nitre caused a much smaller increase ($0.2 \text{ g} \cdot \text{kg}^{-1}$ d.m.). Similarly to the results reported by PERUCKA et al. (2007), no effect of additionally introduced calcium ions on the concentration of magnesium in lettuce leaves was determined.

The concentration of sodium in butter lettuce leaves depended primarily on the form of nitrogen fertilizers applied (Figure 2). In the objects fertilized with soda nitre, the content of sodium in lettuce leaves rose nearly 9.3-fold relative to the control object. In the other objects, the content of Na was from two- to 2.5-fold higher than in the unfertilized object.

No statistically proven differences were found in the concentration of phosphorus in lettuce, as dependent on the different forms of nitrogen fertilizers tested in this experiment (Figure 2). Significant differences in the magnesium content occurred in the concentration of this element appeared

depending whether the lettuce was fertilized with chlorides or with sulphates (Figure. 3). Sulphates stimulated accumulation of magnesium. The differences in the levels of the other macroelements (N, P, K, Ca, Mg and Na) in lettuce leaves depending on sulphate or chloride fertilization were not significant statistically.

The chloride and sulphate form did not have statistically verified effect on the concentration of nitrates in lettuce. However, it was possible to notice the influence of these two forms on the concentration of nitrates depending on the age of the lettuce organs (Figure 4). The oldest leaves contained more nitrates (V) following an application of chloride rather than sulphate forms, whereas inner leaves accumulated more N-NO₃ under the

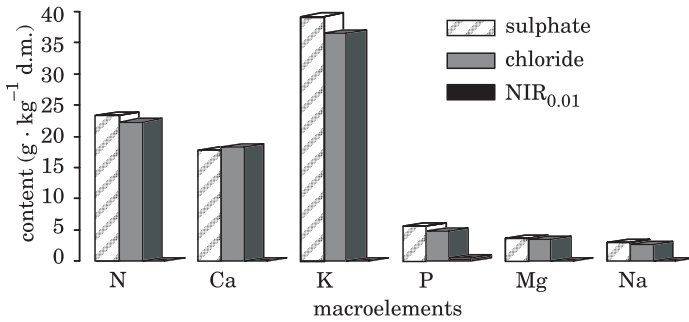


Fig. 3. Yield and content of N, Ca, K, P, Mg and Na in dry matter of butter lettuce leaves depending on the sulphate and chloride fertilization

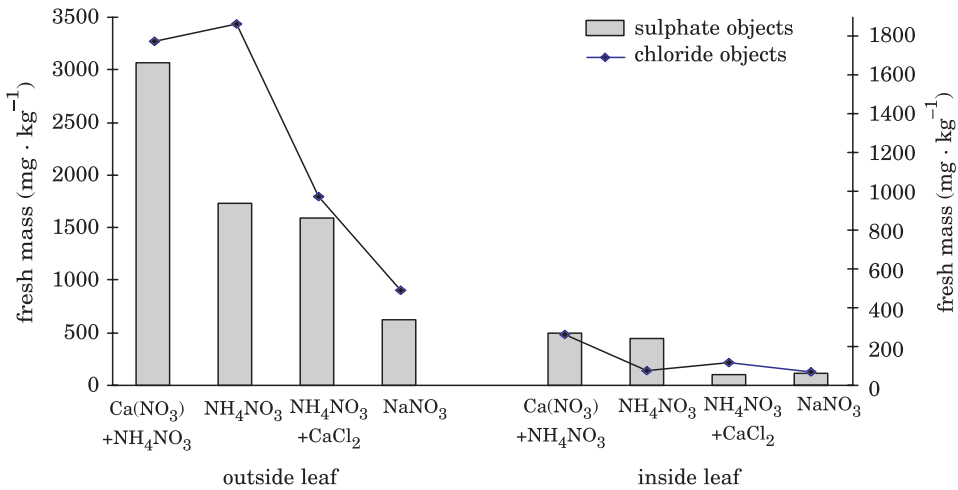


Fig. 4. Concentration of nitrates(V) in outer and inner leaves of butter lettuce in mg · kg⁻¹ fresh matter depending on the experimental factors

influence of sulphate rather than chloride fertilizers. When CaCl_2 was included in a fertilization dose, the amount of N-NO_3 in lettuce leaves was lower than in the ammonium nitrate fertilized objects. There are many reports on the beneficial effect produced by chlorine used as KCl consisting of depressed levels of nitrates in crops (MICHAŁOJĆ 2000, NURZYŃSKI et al. 2001, JAROSZ, DZIDA 2006, KOZIK 2006). The highest levels of nitrates were found in the lettuce fertilized with ammonium nitrate combined with lime saltpetre. The lowest concentration of nitrates, four-fold less than caused by the $\text{Ca(NO}_3)_2 + \text{NH}_4\text{NO}_3$ fertilization treatment, was found in lettuce plants treated with NaNO_3 .

CONCLUSIONS

1. The lowest lettuce yield was produced when the crop had been fertilized with NaNO_3 .

2. Depressed amounts of N-NO_3 occurred as a result of using NaNO_3 . In contrast, the highest accumulation of nitrates(V) was caused by an application of lime saltpetre combined with ammonium nitrate.

3. Fertilization with sulphate compounds ($\text{KH}_2\text{PO}_4 + \text{K}_2\text{SO}_4 + \text{MgSO}_4$) rather than with chloride ones ($\text{KH}_2\text{PO}_4 + \text{KCl} + \text{MgCl}_2$) had a more beneficial effect on the concentration of mineral components in butter lettuce cv. Vilmorin, such as nitrogen, phosphorus, potassium, magnesium and sodium.

4. Soda nitre significantly depressed the concentration of magnesium and calcium in lettuce, increased accumulation of sodium and potassium, but had no effect on the concentration of phosphorus.

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