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# THE EFFECTS OF NITROGEN FERTILIZATION ON YIELD AND NUTRITIONAL VALUE OF SWISS CHARD

Eugeniusz Kołota, Kamila Czerniak
Wroclaw University of Environmental and Life Sciences

**Abstract**: Swiss chard is recognized as valuable leafy vegetable species with short growing period suitable for cultivation as forecrop and aftercrop in crop rotation .Till now is still a minor crop in Poland and there are not existing any data describing the response of this species to nitrogen fertilization and the effect of this nutrient on plant composition. In a field experiment conducted in 2004–2006, the influence of nitrogen fertilization applied as a single or split dose in the amounts of 50, 100, 100 + 50, 150, 150 + 50 and 200 kg·ha$^{-1}$ on yield and crop quality of Swiss chard was examined. Seeds of Lukullus cv. were sown directly into the field in the half of April in spacing 45 × 25 cm, and single harvest of leaf rosettes was conducted on 8–10 July. In separate samples of leaf blades and petioles there was evaluated the content of dry matter, vitamin C, sugars, total N, nitrates, P, K, Ca, and Mg. Results of the study indicate that the increment of N dose from 50 to 100 kg·ha$^{-1}$ had positive effects on Swiss chard yield but the efficiency of higher nitrogen doses was rather small and not significant. Heavy nitrogen fertilization caused the increment of total N and nitrates in both edible parts and magnesium in leaf petioles, while reduction the sugar content in leaf blades. On the average blades contained higher amounts of dry matter, sugars, total N and Mg, while petioles – calcium and nitrates.

**Key words**: N rate, leaf blades, petioles, chemical composition

## INTRODUCTION

Nitrogen is recognized as one of the major factors influencing yield of vegetables and quality of the crop. Sub optimal supply of this nutrient can lead to delays in maturity and cause a high reduction of the yield [Rahn et al.1998]. As the economic consequences for failing to meat target yield are so large there is always a temptation to apply more nitrogen than it is necessary [Rahn 2002]. By contrast over-supply the N fertiliza-

Corresponding author – Adres do korespondencji: Eugeniusz Kołota, Kamila Czerniak, Department of Horticulture, Wroclaw University of Environmental and Life Sciences, pl. Grunwaldzki 24a, 53-363 Wrocław, tel. (+48) 71 320 17 32, fax: (+48) 71 320 17 32, e-mail: eugeniusz.kolota@up.wroc.pl, kamila.czerniak@up.wroc.pl

tion may negatively affect the nutritional value of the crop, cause high nitrates accumulation and contribute to high nitrates leaching from the soil [Sorensen 1999, Neeteson and Carton 2001, Rahn 2000]. High nitrates content may be expected in leafy vegetables, especially in those of short growing period like spinach, or lettuce even in the case of growing without N-added fertilizer [Greenwood and Hunt 1986].

Swiss chard is a minor vegetable crop in Poland, grown mostly in home gardens, so till now we have not any recommendations for nitrogen fertilization of this crop, as well as acceptable content of nitrates in the leaves at harvest. For red beet which is closely related species to Swiss chard 150 kg $N\cdot ha^{-1}$ is being estimated as the optimum dose of nitrogen for satisfactory yield level of bunches and allows to keep the nitrates content below the acceptable limit of 1500 mg $NO_3\cdot kg^{-1}$ f.w. [Krężel and Kołota 2007].

Taking into account that contents of nitrates in leaves of red beet may reach the level even three times higher in comparison to roots [Cantliffe 1972, Peck 1974] it can be calculated that their accumulation in edible parts of Swiss chard heavy fertilized with nitrogen may be a serious problem. This statement can be supported by the research data obtained by Santamaria et al. [1999] as well as Dzida and Pitura [2008].

The aim of the present study was to determine the response of Swiss chard to nitrogen fertilization and its effects on nutritional value of the crop.

## MATERIALS AND METHODS

Field experiment was conducted in 2004–2006 in Vegetable and Ornamental Plants Research Station located near Wroclaw on a sandy clay soil with pH 6.9 and organic matter content 1.8 %. Swiss chard cv. Lukullus was grown from direct sowing into the field conducted in the half of April in spacing 45 × 25 cm. At the stage of 2–4 leaves the seedlings were thinned to one per spot.

Available forms of phosphorus and potassium were raised up by early spring fertilization to 80 mg P and 200 mg K per 1 $dm^3$ of the soil by using triple superphosphate and potassium chloride. Nitrogen in the form of ammonium nitrate was supplied as one preplant or split dose in the amounts of 50, 100, 100+50, 150, 150+50 and 200 kg $N\cdot ha^{-1}$. In treatments with split N application top dressing of plants was conducted shortly after thinning the plants. The experiment was established as one factorial design in four replications and plot area 5,4 $m^2$ (3 × 1,8 m).

Single harvest of leaves was conducted on 8–10 of July, eleven weeks after seeding. It was arranged in a similar manner as in commercial plantations, by cutting of all leaves above the growing point. During harvest there were collected the samples of edible parts for separate chemical analysis of leaf blades and petioles. There were evaluated the contents of dry matter (drying to the constant weight at 105ºC), total and reducing sugars (Loof-Schoorl's method), total N (Kjeldahl´s method), nitrates (potentiometrically). P and Mg (colorimetric method), K and Ca (photometric method) and additionally vitamin C in leaf blades (Tillman´s method).

The results were evaluated statistically using analysis of variance. The least significant differences were calculated by Tukey test at $\alpha = 0.05$.

## RESULTS AND DISCUSSION

Data of the experiment shown in table 1 as means for there years of the study indicate a significant response of Swiss chard to differentiated nitrogen fertilization, and it is the confirmation of the results obtained by Dzida [2004] in pot experiment. The application 100 kg N·ha$^{-1}$ in a single preplant dose caused a significant yield increment in comparison to the dose of 50 kg N·ha$^{-1}$. Further enhancement of N rate do the level of 150 and 200 kg N·ha$^{-1}$ as well as split application of this nutrient only slightly and not significantly affected the crop yield. Higher demand of Swiss chard for nitrogen fertilization may be probably expected only in the case of prolonged growing period up to 15 weeks from the date of planting, due to much higher biomass of leaves produced at harvest time. In our previous studies it was found that delayed harvest of Swiss chard from 11 to 15 weeks after seeding resulted in the increment of the yield from 42.46 to 105.61 t·ha$^{-1}$ [Czerniak and Kołota 2008].

Content of dry matter, total and reducing sugars in leaf petioles as well as vitamin C in leaf blades was not affected by nitrogen fertilization. High doses of this nutrient over the rate needed for greatest Swiss chard yield had adverse effects on total and reducing sugars in leaf blades, which confirmed the statement of previous study conducted by Hochmuth et al. [1999] with carrot.

Plants supplied with nitrogen at the rate of 100 kg·ha$^{-1}$ contained significantly higher amounts of total nitrogen as compared to those grown in plots where 50 kg·ha$^{-1}$ was used (tab. 2). Leaf blades contained greater level of this nutrient than petioles, but irrespective of the kind of edible part, in plants fertilized with 200 kg·ha$^{-1}$, both in single and split dose, there was observed the highest total N content. Similar effects could be also observed in nitrates accumulation. Plants from treatment with 50 kg·ha$^{-1}$contained at harvest time 255 mg $NO_3$-N· kg$^{-1}$ f.w. in leaf blades and 1290 mg $NO_3$-N·kg$^{-1}$ f.w. in petioles, while at the maximum nitrogen rate used as a single preplant dose 1162 and 5539 mg $NO_3$-N·kg$^{-1}$ f.w., respectively. According to Dzida and Pitura [2008] not only the dose but also the form of nitrogen play an important role in nitrates accumulation. They observed significantly greater concentration of nitrates in treatments where urea or potassium nitrate was used as the source of nitrogen in comparison with ammonium nitrate.

On the average petioles accumulated about 4.8 times more nitrates than blades and even at the moderate N fertilization equal to 100 kg·ha$^{-1}$ their amount exceeded the admitted level for red beet. In the other study conducted by Carranca et al. [2001] with spinach the nitrates content in petioles was four times greater than in the blades, and it was in agreement with the work of Maynard et al.[ 1976], Mengel and Kirgby [1982], Fereira [1997]. Geraldson and Tyler [1990] indicate that petioles, which generally show higher amounts and greater variations in mineral composition between underfed plants and those with adequate nutrient supply, are more suitable for diagnosing the nutritional status of the crop. Beside moderate nitrogen fertilization [Laskovar et al. 2009] the decrease of nitrates in petioles used for consumption may be achieved by the choice of cultivars with low tendecy for accumulation of this compound [Czerniak and Kołota 2007].

Phosphorus and potassium accumulation in Swiss chard was not influenced by the nitrogen rate, term of its application as well as kind of edible part, while magnesium concentration was mostly greater at heavy N application. Similar to our previous study

Table 1. The effect of nitrogen fertilization on yield and content of dry matter, vitamin C and sugars in Swiss chard (mean for 2004–2006)

Tabela 1. Wpływ nawożenia azotem na wielkość plonu oraz zawartość suchej masy, witaminy C i cukrów w buraku liściowym, (średnio za lata 2004–2006)

| N dose<br>Dawka N<br>$kg \cdot ha^{-1}$ | Yield<br>Plon<br>$t \cdot ha^{-1}$ | Dry matter<br>Sucha masa<br>% | | Vitamin C<br>mg 100 $g^{-1}$ f.w. of leaf blades<br>Witamina C<br>mg ·100 $g^{-1}$ św.m.<br>blaszek liściowych | Total sugars<br>% f.w.<br>Cukry ogółem<br>%św. m. | | Reducing sugars<br>% f.w.<br>Cukry redukujące<br>% św. m. | |
|---|---|---|---|---|---|---|---|---|
| | | blades<br>blaszki | petioles<br>ogonki | | blades<br>blaszki | petioles<br>ogonki | blades<br>blaszki | petioles<br>ogonki |
| 50 | 30.90 | 11.28 | 7.76 | 35.10 | 0.89 | 2.67 | 0.74 | 2.42 |
| 100 | 40.51 | 10.83 | 7.25 | 37.52 | 0.85 | 2.71 | 0.69 | 2.38 |
| 100+50 | 44.02 | 11.43 | 7.26 | 34.23 | 0.83 | 2.59 | 0.64 | 2.42 |
| 150 | 42.46 | 10.93 | 7.42 | 38.04 | 0.80 | 2.66 | 0.61 | 2.45 |
| 150+50 | 46.02 | 11.33 | 7.47 | 35.52 | 0.79 | 2.61 | 0.64 | 2.45 |
| 200 | 44.83 | 11.99 | 7.27 | 36.47 | 0.77 | 2.56 | 0.61 | 2.34 |
| Mean – Średnio | 41.46 | 11.30 | 7.41 | 36.15 | 0.82 | 2.63 | 0.65 | 2.41 |
| LSD $\alpha = 0.05$<br>NIR $\alpha = 0,05$ | 7.25 | 0.66 | n.s. – n.i. | n.s. – n.i. | 0.06 | n.s. – n.i. | 0.06 | n.s. – n.i. |

Table 2. Mineral composition of Swiss chard in relation to nitrogen fertilization (mean for 2004–2006)
Tabela 2. Zawartość składników mineralnych w buraku liściowym w zależności od dawki nawożenia (średnio za lata 2004–2006)

| N dose<br>Dawka N<br>$kg \cdot ha^{-1}$ | Total N<br>N ogółem<br>% s.m. | | $NO_3$-N<br>$mg \cdot kg^{-1}$ f.m.<br>N-$NO_3$<br>$mg \cdot kg^{-1}$ św.m. | | % d.m. – % s.m. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | P | | K | | Ca | | Mg | |
| | blades<br>blaszki | petioles<br>ogonki | blades<br>blaszki | petioles<br>ogonki | blades<br>blaszki | petioles<br>ogonki | blades<br>blaszki | petioles<br>ogonki | blades<br>blaszki | petioles<br>ogonki | blades<br>blaszki | petioles<br>ogonki |
| 50 | 3.81 | 1.93 | 255 | 1290 | 0.48 | 0.46 | 6.62 | 6.47 | 0.10 | 0.12 | 0.68 | 0.26 |
| 100 | 4.02 | 2.45 | 530 | 2804 | 0.47 | 0.41 | 6.28 | 6.36 | 0.10 | 0.13 | 0.63 | 0.29 |
| 100+50 | 4.11 | 2.64 | 718 | 3563 | 0.47 | 0.41 | 6.31 | 6.68 | 0.11 | 0.13 | 0.68 | 0.28 |
| 150 | 4.08 | 2.60 | 869 | 4079 | 0.41 | 0.41 | 6.62 | 6.56 | 0.10 | 0.13 | 0.69 | 0.27 |
| 150+50 | 4.63 | 2.86 | 1072 | 4650 | 0.38 | 0.46 | 6.47 | 6.37 | 0.11 | 0.14 | 0.68 | 0.28 |
| 200 | 4.31 | 2.93 | 1162 | 5539 | 0.42 | 0.44 | 6.42 | 6.52 | 0.10 | 0.14 | 0.68 | 0.31 |
| Mean<br>Średnio | 4.16 | 2.57 | 768 | 3654 | 0.44 | 0.43 | 6.45 | 6.49 | 0.10 | 0.13 | 0.67 | 0.28 |
| LSD $\alpha = 0.05$<br>NIR $\alpha = 0,05$ | 0.18 | 0.16 | 105 | 313 | n.s. – n.i. | n.s. – n.i. | n.s. – n.i. | n.s. – n.i. | n.s. – n.i. | n.s. – n.i. | n.s. – n.i. | 0.03 |

[Czerniak and Kołota 2008] in which the effects of the term of harvest was investigated, petioles of Swiss chard were richer in calcium while leaf blades in magnesium.

## CONCLUSIONS

1. The increment of nitrogen fertilization from 50 to 100 kg $N \cdot ha^{-1}$ was favourable for Swiss chard yield, while the positive effects of higher N doses were rather small and not significant.

2. Heavy nitrogen fertilization caused the enhancement of total N and nitrates content, irrespective of the kind of edible part, and magnesium in leaf petioles, while the reduction of sugars in leaf blades.

3. Leaf blades contained higher amounts of dry matter, sugars, total N and magnesium while petioles-calcium and nitrates, which concentration exceeded 4.8 times that in blades.

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## WPŁYW NAWOŻENIA AZOTEM NA PLONOWANIE I WARTOŚĆ ODŻYWCZĄ BURAKA LIŚCIOWEGO

**Streszczenie**. Burak liściowy jest warzywem o krótkim okresie wegetacji, przydatnym zarówno do uprawy przedplonowej, jak i poplonowej. Roślina ta ma nieduże znaczenie gospodarcze w Polsce i jak dotąd brak jest danych w literaturze na temat jej reakcji na nawożenie azotem oraz wpływu tego pierwiastka na skład chemiczny części jadalnych przy zbiorze. W doświadczeniu polowym przeprowadzonych w latach 2004–2006 oceniano wpływ jednorazowych i podzielonych dawek azotu (50, 100, 100 + 50, 150, 150 + 50, 200 kg·ha$^{-1}$) na plonowanie i jakość buraka liściowego. Siew nasion buraka liściowego odmiany Lukullus przeprowadzono w połowie kwietnia, pozostawiając rośliny po przerywce w rozstawie 40 × 25 cm. Jednorazowy zbiór liści wykonywano w dniach 8–10 lipca, pobierając jednocześnie odrębne próbki blaszek i ogonków liściowych do oceny zawartości suchej masy, witaminy C, cukrów, N ogółem, azotanów, P, K, Ca i Mg. Wyniki przeprowadzonych badań wskazują, że wzrost dawki azotu z 50 do 100 kg·ha$^{-1}$ miał korzystny wpływ na plonowanie buraka liściowego, natomiast wyższe dawki tego składnika spowodowały jedynie niewielki i nieistotny wzrost plonu. Rosnące dawki azotu przyczyniły się do zwiększonej zawartości N ogółem i azotanów zarówno w blaszkach, jak i ogonkach, a także magnezu w ogonkach liściowych, przy jednoczesnym obniżeniu zawartości cukrów w blaszkach. Niezależnie od zastosowanej dawki azotu, blaszki liściowe zawierały większe ilości suchej masy, cukrów, N ogółem i Mg, natomiast ogonki – wapnia i azotanów.

**Słowa kluczowe**: dawka N, blaszki liściowe, ogonki , skład chemiczny

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