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Effect of different mineral nitrogen and compost nutrition on some compounds of corn salad (*Valerianella locusta* (L.) Latter.)

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During spring and autumn in 2007 corn salad 'Noordhollandse' was grown in containers under shading cloth. The containers were filled with the clay loam soil. Before the both sowing dates mineral nutrition was supplemented to the level of 250 kg NPK · ha^{-1} in ratio 2 : 1 : 2. Mineral fertilizers and compost of the known composition were used as a source of nitrogen. The following treatments were applied in the experiment: 1 – control (without fertilization), 2 – $Ca(NO_3)_2$, 3 – NH_4NO_3, 4 – compost. In both dates of growth climatic conditions were different.

Contents of phenols, soluble sugars, chlorophylls *a* and *b* and carotenoids were analysed in fresh material. Corn salad leaves harvested in autumn contained significantly more sugars and phenols than the spring ones. Mineral and compost fertilization decreased soluble sugar concentration as compared with control sample in both growing cycles, but only mineral fertilization decreased content of phenols. Compost treatment significantly increased content of phenols in corn salad in comparison with mineral fertilization and increased soluble sugar concentration as related to $Ca(NO_3)_2$ application. Corn salad leaves of spring experiment had more chlorophyll and carotenoids than those of autumn one. During both growing periods, mineral fertilization increased carotenoid and chlorophyll concentrations as compared to control. In spring the level of pigments was higher in the case of compost treatment than in the control sample, however, in autumn no significant differences were observed. Cultivation of corn salad fertilized with either mineral or compost may bring high quality yield both in spring and autumn growing cycles.

Key words: corn salad, nitrogen fertilizers, soluble sugars, chlorophyll, carotenoids.

Introduction. Leafy vegetables are an important element of human diet. They are an excellent source of vitamins, minerals, sugars, folic acid and they have not much calories. The everyday consumption of leafy vegetables lowers risk of cancer and heart diseases, prevents tiredness, helps keeping well condition, prevents senescence. Unfortunately, the consumption of leafy vegetables is still too little (Orłowski, 2000; Wierzbicka, 2002).

Corn salad belongs to the family of *Valerianaceae*. It is an annual plant, which leaves form a rosette (Martyniak-Przybyszewska, 2005).

Corn salad is not very popular in Poland. It is eaten like other salads. Leaves of corn salad are delicate, without bitter flavor, with large amount of ascorbic acid, carotenoids, folic acid, carbohydrates and mineral salts (Fajkowska, Wolfowa, 1985). Corn salad leaves may accumulate large amounts of nitrates but there are known methods of cultivation to decrease level of nitrates (Rożek, 2000). For every leafy vegeTable an important factor of quality is the concentration of chlorophyll (Kaukounaras et al., 2007; Michałek, Rukasz, 1998). Corn salad could be grown either under covers in many cycles or in the field conditions – being frost resistant (Gapiński, 1993; Gonnella et al., 2004)

Green leafy vegetables are healthy in human diet. Some researchers have found that vegeTable extract with chlorophyll is antimutagenic and anticarcinogenic and also has some antioxidant properties (Ma, Dolphin, 1999). Thus, chlorophyll and carotenoids have specific dietary activities and these pigments are sensitive to growing conditions (Caldwell, Britz, 2006).

Vegetables are source of naturally occurring antioxidants, which plays an important role as a health protecting factors such as phenols, considered as more powerful antioxidants than vitamin C or carotenoids to decrease disease risk (Larson et al., 1988; Vinson et al., 1998).

There are a lot of data concerning method of growth, nitrate accumulation in leaves and shelf life of corn salad (Fontana et al., 2004). However, study about effect of different nitrogen fertilizers on the crop quality is incomplete. Growing of corn salad is an important production in Italy, France, Netherlads, Germany, Belgium (Nicola et al., 2004; Martyniak-Przybyszewska, 2005) and most of available corn salad in Poland is from these countries.

The aim of the study was to investigate the effect of different nitrogen fertilizers (mineral in two form of nitrogen and compost) on content of soluble sugars, chlorophylls *a* and *b*, carotenoids and total phenols in corn salad 'Noordhollandse'.

Object, methods and conditions. The study was carried out at the Agricultural University in Krakyw in 2007. The experiment included growing of corn salad (*Valerianella locusta* (L.) Latter.) 'Noordhollandse' in openwork containers. The dimension of containers was: 60 Ч 40 Ч 20 cm and one container contained 45 dm^3 of soil. The containers were kept under clothing shadow. There were two growing periods in 2007: the first one started on April 10th (sowing date) and finished on June 19th (harvest date). The second started on July 20th and finished on October 3rd. Containers were filled with clay loam soil (3 % of sand, 28 % of silt, 37 % of clay). Before both sowing dates, the soil was analyzed. According to corn salad requirements the soil was rich enough in P, K, Ca, mg, and the pH in KCl was about 6.5 in both growing periods. Soil nitrogen was supplemented to the level of 2.25 g N · 45 dm^{-3} before sowing. Mineral fertilizers ($Ca(NO_3)_2$, NH_4NO_3) and compost (made by Ekokonsorcjum Efekt Sp. z o. o. in Krakyw) were used as a source of nitrogen for plants. Compost was made from green waste and contained macro and micronutrients necessary for plants. The concentrations of minerals in compost were known (in g · kg^{-1} of compost dry matter: N = 25, P_2O_5 = 7, K_2O = 35, Ca = 32, mg = 5). The

experiment included four treatments with regard to form of nitrogen fertilization:

1 – control – without any fertilization

2 – fertilized with $Ca(NO_3)_2$

3 – fertilized with NH_4NO_3

4 – fertilized with compost.

Experiment was randomly arranged in four replications of each treatment. The spacing of plants and nursing were done in accordance with recommendation (Orłowski, 2000; Rekowska, 2001). Depending on weather conditions plants were irrigated. Some climate factors were collected and analyzed (Table). Climate factors in both growing periods were similar but not the same. During first growing period ground frost was recorded. However, first growth period started with low and finished with high temperatures, while during the second growing period the temperature conditions were opposite. Mean temperature was similar for both growing cycles; however, in the second period the higher relative humidity was noticed. Total rainfalls in first growing period (from April to June) were nearly twice lower than in the second growing period (from July to September) – 143.7 and 261.2 mm, respectively. Only in September rainfalls were more intensive than during the whole first growing cycle. Insolation was slightly higher during first growing period (674.3 and 609.3 hours, respectively). The lowest insolation was observed in September.

Table. Climate factors during corn salad growth in 2007 (from IMGW and own sensors)

Lentelė. Meteorologinės sąlygos salotinės sultenės auginimo 2007 m. metu (iš IMGW ir savų jutiklių)

Climate factor Klimato veiksniai		April Balandis	May Gegužė	June Birželis	July Liepa	August Rugpjūtis	September Rugsėjis
		first growing period pirmasis auginimo periodas			second growing period antrasis auginimo periodas		
Temperature Temperatūra (°C)	Min Minimalus	0.29	-0.61	7.43	5.81	7.83	2.89
	Max Maksimalus	28.7	35.27	35.7	41.05	35.27	26.34
	Mean Vidutiniškas	12.69	16.96	20.39	19.99	20.13	12.68
Relative humidity Santykinė drėgmė (%)	Mean Vidutiniškas	52.59	66.61	73.6	81.17	69.66	83.3
Rainfalls Krituliai (mm)	Total Suminis	15.4	51.7	76.6	56.8	24.6	179.8
Insolation (h) Insoliacija (val.)	Total Suminis	213	223.3	237.8	263.3	207.1	138.9

Immediately after harvest leaves of corn salad were randomly collected for chemical analysis. Soluble sugars were determined by colorimetric method with anthron reagent (Yemm, Wills, 1954). Total phenols were estimated according to the photometric method with Folin's reagent (Swain, Hillis, 1959). Chlorophylls *a* and *b* and total carotenoids were determined by spectophotometric methods in acetone solvent (Wellburn, 1994). Results of analysis (all in three replications) were statistically evaluated using ANOVA and Fisher (LSD) test for the significance $\alpha = 0.05$.

Results. A. Soluble sugars. Corn salad leaves harvested in autumn (second growing period) accumulated significantly more sugars than the spring ones (first growing period). Mineral and compost fertilization significantly decreased accumulation of sugars in comparison with control treatment. Compost significantly increased concentration of soluble sugars as compared to $Ca(NO_3)_2$ fertilization in both periods but only during first growing cycle as related to NH_4NO_3 fertilization. Mean soluble sugar concentration for spring cycle was 580.31 mg · 100 g^{-1} f. w. and for autumn harvest – 906.25 mg · 100 g^{-1} f. w. (Fig. 1).

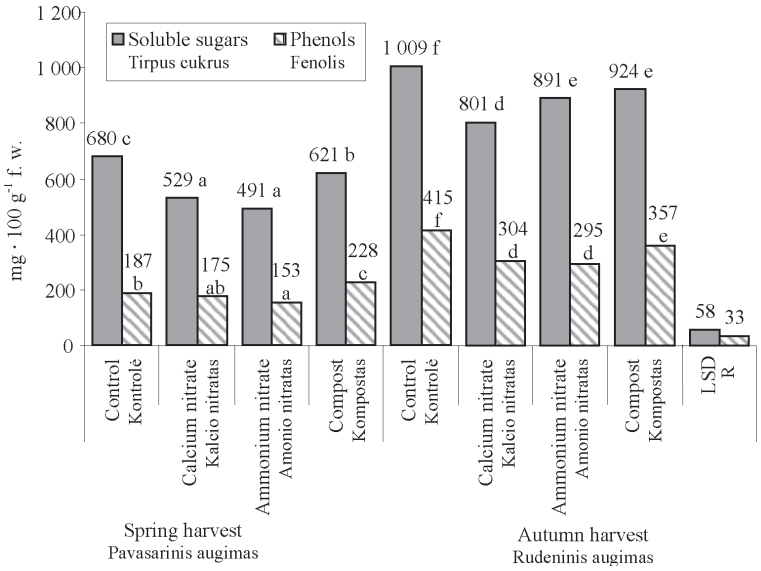

Fig. 1. Content of soluble sugars and total phenols in corn salad leaves depending on nitrogen fertilization in 2007
(letters represented homogenous groups, LSD for α = 0.05)
1 pav. Tirpių cukrų ir bendras fenolių kiekis sultingosios saulenės lapuose priklausomai nuo tręšimo azotu, 2007 m.
(raidės rodo homogenines grupes, R α = 0.05)

B. Total phenols. Similarly like in the case of sugars corn salad leaves accumulated significantly more phenols in autumn than in spring and mean concentration was 342.96 and 185.66 mg · 100 g^{-1} f. w., respectively. During first growing cycle the highest content of phenols contained leaves from compost treatment but in the second one – thus of control. Mineral fertilization significantly decreased accumulation of phenols in comparison with compost treatment in both growth periods (Fig. 1).

C. Chlorophylls *a* and *b* and carotenoids. Spring corn salad leaves contained significantly more pigments than those harvested in autumn. Mean concentration for first and second growth period was respectively: chlorophyll *a*: 0.415 and 0.272 mg · g^{-1} f. w., chlorophyll *b*: 0.249 and 0.185 mg · g^{-1} f. w., total chlorophyll (*a* + *b*): 0.664 and 0.457 mg · g^{-1} f. w. and carotenoids 0.157 and 0.121 mg · g^{-1} f. w. Mineral fertilization

significantly increased concentration of chlorophyll in comparison with control in both periods. In most cases corn salad leaves from compost treatment had similar chlorophyll concentration as control, except of chlorophyll *b* and total chlorophyll from spring harvest (Fig. 2).

Concentration of carotenoids in corn salad leaves from spring harvest was significantly higher in the case of mineral and compost fertilization. However, in leaves from autumn harvest only mineral fertilization affected increase of carotenoids. Plants from compost and control treatments in second growing period had the same concentration of carotenoids (Fig. 2).

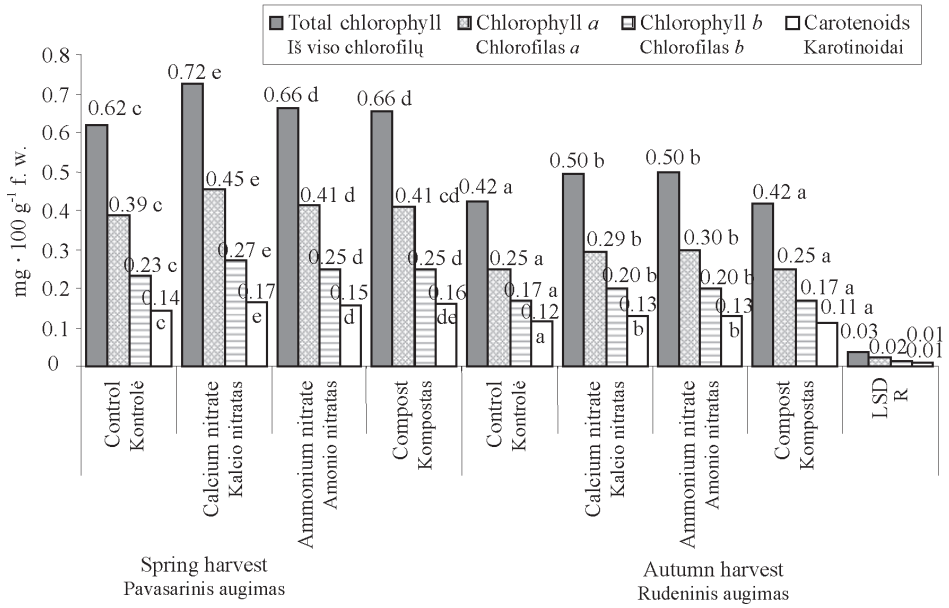

Fig. 2. Content of chlorophylls *a* and *b*, total chlorophyll and carotenoids in corn salad leaves depending on nitrogen fertilization in 2007 (letters represented homogenous groups, LSD for α = 0.05)

1 pav. Chlorofilo *a* bei *b*, bendras chlorofilo ir karotinoidų kiekis sultingosios saulenės lapuose priklausomai nuo tręšimo azotu, 2007 m. (raidės rodo homogenines grupes, R, kai a = 0,05)

Discussion. Form of nitrogen fertilizer could have on important influence on the accumulation of chlorophyll in plants. Lettuce plants fertilized with two form of nitrogen (NO_3 + NH_4) had significantly more chlorophylls *a* and *b* than that fertilized with nitrate nitrogen; and plants fertilized with ammonium nitrogen had the highest concentration of chlorophylls (Michałek, Rukasz, 1998). In the present experiment results did not confirm that dependence. Higher radiation increased concentration of chlorophylls (Caldwell, Britz, 2006). Corn salad plants from spring period where the insolation was higher had higher chlorophylls content in presented study. Nitrogen fertilization stimulates accumulation of chlorophyll. Mihalovic et al. (1997) reported

that ammonium ions in nutrient solution increased concentration of chlorophylls *a* and *b* in wheat leaves in comparison with nitrate ions. Presented results did not confirm that conclusion, however, in the present experiment mixed nitrogen fertilizer was used (not only NH_4 form) and drought stress was not observed. The higher total chlorophyll concentration of marigold leaves was observed when compost or vermicompost were added to the commercial horticultural plant growth medium than in pure medium (Atiyeh et al., 2000). According to these authors, compost and vermicompost had a potential for improving plant growth. However, they observed differences between specific vermicomposts and composts. In the present experiment compost improved soluble sugars and phenols content as compared with mineral fertilization, but this effect was not observed in the case of pigment accumulations. Michałek and Rukosz (1998) found that ammonium nitrogen increased accumulation of phenols. Influence of ammonium and nitrate nitrogen applied together on phenol concentration depended on cultivar. In some cases using the pure nitrate form or both forms of nitrogen (NO_3 + NH_4) as fertilizers may bring the same results, which were observed in the present study. Total phenol content in lettuce was in good correlation with antioxidant activity but might increase browning of lettuce (Altunkaya, Gökmen, 2008). Low temperature caused higher carbohydrate accumulation in timothy leaves (Thorsteinsson et al., 2002) and also in leaves of pelargonium cuttings (Druege, Kadner, 2008). The same effect was observed in corn salad leaves. Rożek et al. (1994) reported that fertilization with reduced form of nitrogen increased content of sugars in leaves of lettuce in comparison to plants fertilized only with NO_3. The same effect was observed in corn salad leaves in the case of second growing period. Quality of lettuce crop was better when treated with vermicompost and compost than with minral fertilization (higher vitamin C concentration and lower nitrate accumulation) (Premuzic et al., 2002). In presented experiment other quality factors increased in the case of compost treatments.

Conclusions. 1. Nitrogen fertilization and weather conditions together influenced quality of corn salad.

2. Mineral fertilization increased carotenoid and chlorophyll concentrations as compared to control.

3. Compost treatment increased content of phenols in corn salad in comparison with mineral fertilization.

4. Corn salad leaves harvested in autumn contained more sugars and phenols than the spring ones.

5. Cultivation of corn salad fertilized with either mineral nutritives or with compost may bring high quality yield both in spring and autumn growing cycles.

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Skirtingo mineralinio azoto ir kompostinių trąšų poveikis salotinės sultenės (*Valerianella locusta* (L.) Latter.) biocheminei sudėčiai

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Santrauka

2007 m. pavasarį ir rudenį *Valerianella locusta* (L.) Latter. veislė ‘Noordhollandse’ buvo auginama uždengtuose konteineriuose. Jie buvo pripildyti priemoliu. Ir prieš viena, ir prieš kita sėja buvo tręšta 250 kg NPK · ha^{-1} santykiu 2 : 1 : 2. Mineralinės trąšos ir žinomos sudėties kompostas buvo naudojamas kaip azoto šaltinis. Bandymo schema buvo tokia: 1 – kontrolė (be trąšų), 2 – $Ca(NO_3)_2$, 3 – NH_4NO_3, 4 – kompostas. Klimato sąlygos abejais auginimo laikotarpiais skyrėsi.

Žaliuose augaluose nustatytas fenolių, tirpių cukrų, chlorofilo *a* ir *b* bei karotinoidų kiekis.

Salotinės sultenės, augintos rudenį, turėjo žymiai daugiau cukrų ir fenolių negu pavasarinės. Mineralinis ir kompostinis tręšimas sumažino tirpių cukrų koncentracija jose palyginus su kontrolės pavyzdžiais abejų auginimo ciklų metu, tačiau tik mineralinis tręšimas sumažino fenolių kiekį. Salotinės sultenės lapai pavasarinio eksperimento metu turėjo daugiau chlorofilų ir karotinoidų negu augintos rudenį. Abejais auginimo periodais mineralinis tręšimas padidino karotinoidų ir chlorofilų koncentracija palyginus su netręštais augalais. Tręšiant kompostu, tik pavasarį šių augalų lapuose buvo daugiau pigmentų palyginus su kontrole. Salotinės sultenės auginimas, naudojant ir mineralinį trąšą, ir komposta, leidžia gauti aukštos kokybės derlių per abu auginimo ciklus.

Reikšminiai žodžiai: azoto trąšos, chlorofilai, karotinoidai, salotinė sultenė, tirpūs cukrūs.