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Broccoli yield and its quality in spring growing cycle as dependent on nitrogen fertilization

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ABSTRACT

The results of a three-year experiment with broccoli 'Lord F_1' grown under field conditions in the spring growing cycle are presented. The aim of the study was to determine the effect of mineral nitrogen fertilization and foliar urea nutrition on the yield and content of some compounds in broccoli heads. Four different levels of mineral nitrogen (N_{min}) in the soil were used: natural content (12-25.5 mg N dm^{-3}), fertilization with half of the full rate supplemented to the level of 75 mg N dm^{-3}, fertilization with the full rate divided into halves (75 + 75 mg N dm^{-3}), and with the single full rate of N supplemented to the level of 150 mg N dm^{-3}. In each N_{min} treatment additionally two combinations were applied: without and with foliar application of 2% urea solution. According to the investigation, generally no significant effect of the mineral nitrogen rate on the biological and marketable yield of broccoli as well as on its quality was observed. The foliar urea application significantly lowered concentration of nitrates in broccoli heads in comparison with the plants not treated with urea. Additionally, irrespective of the year of study the foliar nutrition increased soluble sugar content in all N_{min} treatments. Moreover in each year of the experiment the increase of ascorbic acid content in broccoli heads treated with urea was showed.

INTRODUCTION

During last decades the dynamic development of investigations concerning improvement of biological food quality, used both for consumption and processing was observed. One of the essential problems connected with the cultivated plant quality is the excessive accumulation of hazardous nitrates and nitrites. In many research centers the causes of nitrate increasing in plants are examined, particularly in vegetables. The following factors affect the nitrate accumulation in vegetables: genetics, soil, nutrition and climate. Among the nutritive factors the special attention should be paid to the rate of nitrogen fertilizer, the form of the applied nitrogen, the way and date of fertilization as well as the balanced fertilization with the other nutrients such as P, K, Ca, Mg, and microelements.

The increase of the nitrogen fertilizer dose nearly always induces increase of nitrate content in plant tissue, which was found in lettuce (McCall and Willumsen 1998, 1999), in radish (Nieuwhof and Jansen 1993) and in broccoli (Zebarth et al. 1995). Apart from the level of the nitrogen nutrient also its form decisively affects nitrate accumulation in the vegetable crop. In the earlier studies (Myczkowski et al. 1991, Hahndel et al. 1994, McCall and Willumsen 1998, Rożek et al. 1994, 1999) the application of the reduced nitrogen form (ammonium or urea) significantly reduced nitrate content in the vegetables. In the case of treatment with the reduced nitrogen (mainly $N\text{-}NH_4$) as only source of this element, Sady and Rożek (1995) proposed not to admit to the soil acidification and to adjust the soil pH before fertilization to 6.7-6.9, as well as Ca^{2+} content up to 1500 mg of Ca dm^{-3} of the soil. The decisive factor affecting nitrate accumulation in the vegetable crop is a method of nitrogen fertilization. Sommer (2000) together with his research group elaborated the alternative (regarding the broadcast fertilization) placement nutrition, commonly known as CULTAN (Controlled Uptake Long Term Ammonium Nutrition). The placement fertilization with the reduced nitrogen forms guarantees the better possibility of its using during the whole growing period and allows to obtain high yield of the nitrate level reduced by 20-30% (Kranz and Lenz 1991, Rożek et al. 1999, Wojciechowska 2002). According to the preliminary investigations as well as to results of few reports, foliar nutrition of vegetables together with the precisely maintained soil fertilization can be very efficient method to obtain the crop of reduced nitrate content. It has been commonly known that plants can absorb through leaves all the available nitrogen forms with the particular advantage of amid (urea) nitrogen (Bernard et al. 1996). The foliar application of nitrogen positively influenced the quality of lettuce (Kowalska 1997). The similar effect was observed in the case of multiple nutrient applied in cultivation of cabbage, cucumber and onion (Kołota and Osińska 2001).

The aim of this study was to evaluate the effect of foliar nutrition of the plants with urea together with differentiated level of mineral nitrogen fertilization on broccoli yield and its quality.

MATERIAL AND METHODS

The three year (1999 – 2001) field experiment was carried out in the Agricultural University experimental station in the Kraków area. Broccoli of 'Lord F_1' was cultivated in spring growing cycle on brown soil of pH 6.95 containing of 2.2% of organic matter. Mineral fertilization was based on the results of chemical analyses of the soil samples. The content of soil nutritives N ($N\text{-}NO_3$ + $N\text{-}NH_4$), P, K, Ca and Mg was supplemented to the level of 150 (the full rate), 60, 200, 1150, and 125 mg dm^{-3}, respectively.

The following N levels in soil were established in the experiment: 1. control (natural nitrogen content in soil: 12-25.5 mg N dm^{-3} depending on the year of study), 2. half of the full calculated rate of N supplemented to the level of 75 mg N dm^{-3} introduced to the soil before planting of seedlings (broadcast), 3. half of the full calculated rate of N introduced to the soil before planting of seedlings (broadcast) and another dose during the growth (top-dressing) (75 + 75 mg N dm^3), 4. the single full rate of N supplemented to the level of 150 mg dm^{-3} introduced to the soil before planting of seedlings. The form of nitrogen fertilizer was ammonium nitrate. In every level of N fertilization broccoli plants were treated or not with 2% urea.

The foliar nutrition with 2% urea was carried out five times during the growing cycle. Broccoli seedlings were planted on 30.03.1999, 3.04.2000, 3.04.2001 and harvested on 10.06.1999, 13.06.2000 and 11.06.2001.The experiment was carried out in four replications, each treatment consisting of 100 plants. During the harvest biological yield (the yield of whole plants: shoots and roots) and marketable yield (heads of marketable size) were determined. Six plants in four replications were randomly taken from each treatment. In 1999 biological yield was not measured. In broccoli heads harvested from each treatment the content of nitrates, soluble sugars, ascorbic acid and dry matter were determined.

The nutritive macroelements of the soil were detected in the 0.03 M acetic acid extract (Nowosielski 1988). The organic carbon content in the soil was determined with the use of Tiurim`s method and the organic matter was calculated according to Lityński et al. (1976). Nitrogen level in the soil was measured by the microdestillation method of Bremner; K, Mg and Ca content was determined spectrometrically with the use of the Carl Zeiss AAS-1 apparatus, while P level was detected colorimetrically.

Nitrate level was determined with the use of an ionoselective electrode in cooperation with a UNICAM-9460 ionometer. Soluble sugar content was estimated with anthrone reagent by the photometric method described by Yemm and Wills (1954), while ascorbic acid level was determined by the iodate method of Samotus at al. (1982). All analyses were statistically evaluated using Duncan`s test, at a significance level $p = 0.05$.

RESULTS

The lowest biological and marketable yields of broccoli were obtained in the control (the natural mineral soil nitrogen level) treatment (Table 1). Foliar urea application did not change this value. The compactness of the heads was also lower in the controlled samples in comparison with those treated with mineral nitrogen. The higher yields of broccoli heads harvested in the case of nitrogen fertilization were not differentiated regarding the rate of nutrient (Table 1). The higher variability of the crops was found when evaluated with respect to mineral nutrition with nitrogen in the individual years of experiment, excluding the foliar application factor (Table 2). This method of estimation of the obtained results showed that in all years of the experiment the lowest yield was observed in the control treatments. No effect of the mineral nitrogen rate on the biological and marketable yield in 1999 – 2000 was observed. In 2001, however, marketable yield increased with the increase of the N mineral dose introduced into the soil. In general the highest marketable yield of broccoli was obtained in 2001 in the case of the full rate of mineral nitrogen applied once before planting (Table 2). According to results presented in Table 2, the poorest and the best yielding of broccoli heads was observed in 1999 and 2001, respectively, except of the control plants. It is worth noticing, that in 2001 with the increase of the marketable yields of the broccoli depending on the nitrogen rate, the compactness of the heads also increased.

In Table 3, the three-year average results of some quality parameters are presented. The increasing dose of nitrogen fertilizer did not affect significantly soluble sugar and dry matter contents in broccoli heads. The similar effect was observed in the foliar urea treatment regarding ascorbic acid.

Table 1. Effect of soil nitrogen fertilization and foliar urea application on broccoli yield and compactness coefficient of broccoli heads in spring growing cycle (means of three year studies)

N_{min} level of soil (mg dm^{-3})	Without foliar nutrition			With foliar nutrition		
	Biological yield (t ha^{-1})	Marketable yield (t ha^{-1})	Cc** (g cm^{-1})	Biological yield (t ha^{-1})	Marketable yield (t ha^{-1})	Cc (g cm^{-1})
Control	31.81 a*	13.34 a	19.38 a	35.62 a	14.99 a	21.63 ab
75	53.20 b	20.41 bc	25.22 b	52.30 b	20.63 bc	25.12 b
75 + 75	53.40 b	19.56 b	24.91 b	54.91 b	21.72 bc	26.15 b
150	51.27 b	22.47 bc	26.53 b	59.22 b	23.31 c	26.91 b

* Means followed by the same letters referring to the respective indices are not significantly different

** Cc, compactness coefficient (ratio of head weight to diameter)

Table 2. Effect of mineral nitrogen level of soil in successive years of study on broccoli yield and compactness coefficient of broccoli heads in spring growing cycle irrespective of foliar urea application

N_{min} level of soil (mg dm^{-3})	1999		2000			2001		
	Marketable yield (t ha^{-1})	Cc (g cm^{-1})	Biological yield (t ha^{-1})	Marketable yield (t ha^{-1})	Cc (g cm^{-1})	Biological yield (t ha^{-1})	Marketable yield (t ha^{-1})	Cc (g cm^{-1})
Control	15.05 ab	20.18 a	26.54 a	14.66 ab	21.56 a	40.90 b	12.79 a	19.78 a
75	18.66 cd	23.13 abc	47.57 c	20.67 de	26.06 bcd	57.92 d	22.22 e	26.33 bcd
75 + 75	16.84 bc	21.45 a	46.51 c	19.96 de	25.67 bcd	61.80 d	25.12 f	28.75 de
150	19.21 cd	22.65 ab	48.05 c	21.87 e	27.03 cde	62.45 d	27.57 g	30.50 e

Note: see Table 1

Table 3. Effect of soil nitrogen fertilization and foliar urea application on the quality of broccoli yield in spring growing cycle (means of the three year studies)

N_{min} level of soil (mg dm^{-3})	Without foliar nutrition				With foliar nutrition			
	Nitrates (mg NO_3^- kg^{-1} f.w.)	Soluble sugars (mg 100 g^{-1} f.w.)	Ascorbic acid (mg 100 g^{-1} f.w.)	Dry matter (%)	Nitrates (mg NO_3^- kg^{-1} f.w.)	Soluble sugars (mg 100 g^{-1} f.w.)	Ascorbic acid (mg 100 g^{-1} f.w.)	Dry matter (%)
Control	826.3 ab	1436 abc	72.81 c	8.81 c	592.7 a	1555 c	66.09 b	8.21 ab
75	1051.8 b	1345 ab	64.63 b	8.65 bc	956.9 b	1622 c	68.24 b	8.38 abc
75 + 75	1560.9 c	1338 a	63.75 ab	8.51 abc	965.0 b	1535 bc	65.12 b	8.03 a
150	1446.7 c	1359 ab	60.06 a	8.37 abc	1120.4 b	1598 c	66.74 b	8.16 ab

Note: see Table 1

Full nutrition with mineral nitrogen considerably increased nitrate content and simultaneously decreased ascorbic acid level in broccoli plants which were not treated with urea. It seems to be interesting, that in the heads originated from the full dose nitrogen treatment and fertilized with urea, significantly lower concentration of nitrates was determined, in comparison with those non-treated with urea. Additionally, foliar application of urea increased soluble sugar content in all treatments fertilized with mineral nitrogen (Table 3).

The mineral nitrogen rate, irrespective of urea foliar application (Table 4) did not influence soluble sugar, ascorbic acid and dry matter contents significantly in any year of the experiment. In 2000 and 2001 the distinct interdependence between nitrogen fertilizer dose and accumulation of nitrates was found: broccoli heads treated with the full nitrogen rate, either applied once or divided, contained significantly highest level of these constituents. According to the obtained results, the strong effect of variability of climate conditions in the individual years seemed to be of great importance. For example, in broccoli heads grown in 2000 the lowest level of soluble sugars was observed in comparison with those of 1999 and 2001. Moreover, the lowest content of nitrates was determined in plants harvested in the first year of studies (Table 4).

The effect of foliar application of urea irrespective of mineral nitrogen level on broccoli yield and its quality is presented in Table 5. The results showed that foliar nutrition significantly lowered nitrate level in broccoli heads and simultaneously increased soluble sugar content in 2000 and 2001. Moreover, the ascorbic acid content increased after urea treatment in 1999 and in 2001. In every year of study no significant dependence between marketable yield and foliar fertilization was observed.

DISCUSSION AND CONCLUSIONS

Evaluation of the average broccoli yields, obtained in 1999 – 2001 showed the better yielding of plants fertilized with the mineral nitrogen as compared to the control. The significant differentiation of the biological and marketable yields regarding the nitrogen dose and the way of its application into the soil was, however, not found.

According to the obtained results, the growth of broccoli on the soil abundant in organic matter (2.2% on average) which after mineralization can be the source of nitrogen, supplementation of N to the level of 75 mg N dm^{-3} seems to be sufficient. The low crops, harvested from the control treatments are due to the insufficient supply of plants in nitrogen, leading at first to limitation of carbon assimilation, resulting in reduction of plant productivity (Shangguan et al. 2000, Lawlor 2002). The results presented in many reports, concerning the optimization

Table 4. Effect of mineral nitrogen level in soil in the successive years of study on quality of broccoli yield in spring growing cycle irrespective of foliar urea application

N_{min} level of soil (mg dm^{-3})	1999				2000				2001			
	Nitrates (mg NO_3^- kg^{-1} f.w.)	Soluble sugars (mg 100 g^{-1} f.w.)	Ascorbic acid (mg 100 g^{-1} f.w.)	Dry matter (%)	Nitrates (mg NO_3^- kg^{-1} f.w.)	Soluble sugars (mg 100 g^{-1} f.w.)	Ascorbic acid (mg 100 g^{-1} f.w.)	Dry matter (%)	Nitrates (mg NO_3^- kg^{-1} f.w.)	Soluble sugars (mg 100 g^{-1} f.w.)	Ascorbic acid (mg 100 g^{-1} f.w.)	Dry matter (%)
Control	502.2 a	1643 d	65.95 a	8.31 a	796.4 ab	1363 abc	70.84 a	8.58 a	829.9 ab	1480 bcd	71.58 a	8.65 a
75	838.7 ab	1570 d	65.34 a	8.42 a	1189.1 cd	1306 ab	66.59 a	8.46 a	984.7 bc	1575 d	67.38 a	8.67 a
75 + 75	712.4 ab	1579 d	62.26 a	8.18 a	1674.5 e	1176 a	70.70 a	8.53 a	1401.5 de	1555 cd	60.36 a	8.12 a
150	835.0 ab	1553 cd	59.99 a	8.19 a	1562 e	1257 a	67.47 a	8.56 a	1454 de	1625 d	62.75 a	8.05 a

Note: see Table 1

Table 5. Effect of foliar urea application in the successive years of study on broccoli yield and its quality irrespective of soil nitrogen fertilization

Year of study	Without foliar nutrition				With foliar nutrition			
	Nitrates (mg NO_3^- kg^{-1} f.w.)	Soluble sugars (mg 100 g^{-1} f.w.)	Ascorbic acid (mg 100 g^{-1} f.w.)	Market-able yield (t ha^{-1})	Nitrates (mg NO_3^- kg^{-1} f.w.)	Soluble sugars (mg 100 g^{-1} f.w.)	Ascorbic acid (mg 100 g^{-1} f.w.)	Market-able yield (t ha^{-1})
1999	705.8 a	1571 c	61.06 a	17.27 a	738.7 a	1601 cd	65.71 bc	17.61 a
2000	1559.1 c	1073 a	71.87 d	18.46 ab	1051.8 b	1464 b	65.93 bc	20.13 abc
2001	1399.3 c	1464 b	63.01 ab	21.11 bc	935.8 ab	1653 d	68.02 c	22.75 c

Note: see Table 1

of the nitrogen dose to receive the maximum broccoli yield (usually without regarding the nitrate content), are very divergent. Greenwood et al. (1980) recommended doses from 175-252 kg N ha^{-1}, while Zebarth et al. (1995) obtained the highest yields at the nitrogen fertilization as high as 435-560 kg N ha $^{-1}$. In experiment of Goodlass et al. (1997) the most effective nitrogen rate in broccoli fertilization was 300 kg N ha^{-1}.

The lack of variability in the yields of broccoli as related to nutritive factors does not reflect the distinct influence of the weather conditions in the individual years of experiment. The lowest and the highest marketable yields of broccoli heads were found in 1999 and in 2001, respectively. It is worth noticing, that once only, in 2001, the positive effect of increasing dose of mineral nitrogen, introduced to the soil, on the marketable yield was observed. The above results are probably due to the differentiated weather conditions in the individual years of the study (Table 6, Fig. 1). According to the presented data from 1999 in two most important months for growing (i.e. in April and May) the dry weather caused by the very low rainfalls prevailed. The poor supply of water to plants was accompanied by very low insolation; in the whole growing period in 1999 only 7 sunny days were noted. The best conditions in broccoli cultivation, regarding water supply and number of the sunny days (44), were observed in 2001. In this year the highest yield of broccoli heads was harvested. Similarly, the positive effect of good water supply and insolation on the lettuce yielding were reported by De Pinheiro Henriques and Marcelis (2000) as well as by Wojciechowska (2004).

The results of the present study showed the great effectiveness of urea foliar application in reduction of nitrate content in broccoli heads. This treatment caused the lowering of nitrate level only by 9% in the case of nitrogen supplementation to 75 mg N dm^{-3}, however, by 22 and 39% after fertilization with the only rate applied before planting and with the full rate divided into two parts (used before planting and as the top dressing), respectively. The foliar nutrition of broccoli improved additionally quality of the harvested heads by increasing the soluble sugar content, and in the case of the only application of the full nitrogen rate also ascorbic acid level. The question of the effect of foliar application in reducing the nitrate accumulation in vegetables has not been solved so far. The first reports concerning this problems appeared in experiments with lettuce, presented by Kowalska (1997) and Wojciechowska (2004).

Investigations of the effect of the increasing rate of nitrogen fertilizers (excluding foliar application) on nitrates in broccoli heads in the individual years of experiment showed the poorest accumulation of them in 1999. This result seemed to be surprising because of the dry weather and too low insolation in this year; such conditions lead usually to the enhanced nitrate accumulation in plants. The low level of nitrates found in the broccoli heads grown in 1999 might have been due to limiting the possibility of uptaking them from the soil, like in the research of Buljovcic and Engels (2001). This phenomenon is possible during prolonged water deficit. The same interdependence was noted in the reports of Cardenas-Navarro et al. (1999), who found very high, positive correlation between water and nitrate contents in the leaves of lettuce and tomato. These authors suggested simply the particular homeostasis between nitrates and water content in plant tissues.

Table 6. Number of sunny days (cloudiness below 20%) during growing period of broccoli in 1999 – 2001

	Month		
Year	April	May	June
1999	3	4	0
2000	7	9	8
2001	14	19	11

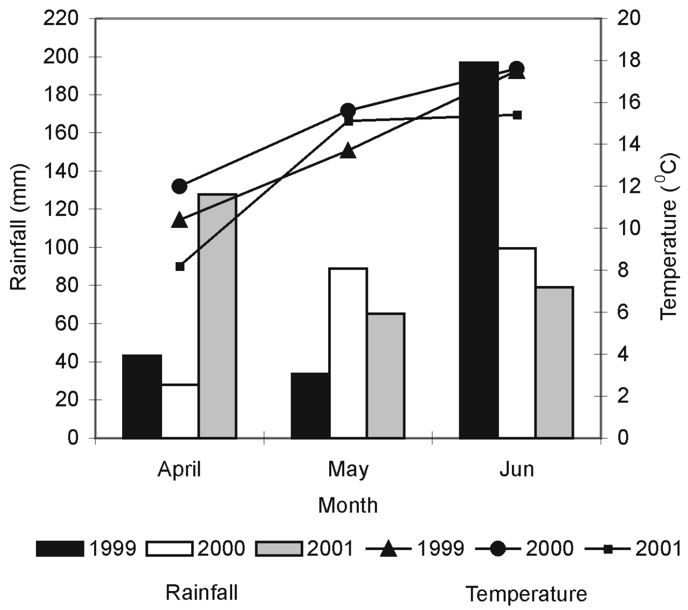

Figure 1. Mean monthly air temperatures and sums of rainfall during growing period of broccoli in 1999 – 2001

To explain more precisely changes of nitrate content in broccoli heads, caused by nutritive factors applied in the present experiment, the influence of the endogenous factors affecting the rate of NO_3^- ions reduction within the plant tissue, particularly activity of nitrate and nitrite reductases should be taken into consideration. These problems were the subject of investigations and would be presented in the other publication.

The results showed effectiveness of the urea foliar application in improvement of the quality of broccoli heads in spring growing cycle. Especially advantageous effect of foliar nutrition with urea on the decrease in nitrates and increase in soluble sugars or ascorbic acid in comparison with non-treated plants was observed.

REFERENCES

BERNARD A.L., BLOOM N., BLOOM A.J., 1996. Absorption and assimilation of foliary applied urea in tomato. J. Amer. Soc. Hort. Sci. 121(6): 1117-1121.

BULJOVCIC Z., ENGELS C., 2001. Nitrate uptake ability by maize roots during and after drought stress. Plant Soil 229(1): 125-135.

CARDENAS-NAVARRO R., ADAMOWICZ S., ROBIN P., 1999. Nitrate accumulation in plants: a role for water. J. Exp. Bot. 50(334): 613-624.

DE PINHEIRO HENRIQUES A.R., MARCELIS L.F.M., 2000. Regulation of growth at steady-state nitrogen nutrition in lettuce (*Lactuca sativa* L.): interactive effects of nitrogen and irradiance. Ann. Bot. 86: 1073-1080.

GOODLASS G., RAHN C., SHEPHERD M.A., CHALMERS A.G., SEENEY F.M., 1997. The nitrogen requirement of vegetables: comparisons of yield response models and recommendation systems. J. Hort. Sci. 72(2): 239-254.

GREENWOOD D.J., CLEAVER T.J., TURNER M.K., HUNT J., NIENDORF K.B., LOQUENS S.M.H., 1980. Comparison of the effects of nitrogen fertilizer on the yield, nitrogen content and quality of 21 different vegetable and agricultural crops. J. Agric. Sci. 95: 471-585.

HAHNDEL R., LANG H., HERMANN P., 1994. Wirkung von Ammonium-stabilisierten Düngern auf Ertrag und Qualität von Gemüse. Agribiological Res., 47(2): 101-109.

KOŁOTA E., OSIŃSKA M., 2001. Efficiency of foliar nutrition of field vegetables grown at different nitrogen rates. Acta Hort. 563: 83-86.

KOWALSKA I., 1997. Effects of urea, ammonium, and nitrate nitrogen on the yield and quality of greenhouse lettuce grown on different media. Folia Hort. 9(2): 31-40.

KRANZ P., LENZ F., 1991. Ausnutzung von Ammonium-Depots durch Gemüsekulturen. Umweltverträgliche Stickstoffdüngung bei gärterischen Nutzpflanzen. Forschungsberichte, 1: 34-43.

LITYŃSKI T., JURKOWSKA H., GORLACH E., 1976. Analiza chemiczno-rolnicza. Przewodnik metodyczny do analizy gleby i nawozów. PWN, Warszawa.

LAWLOR D.W., 2002. Carbon and nitrogen assimilation in relation to yield: mechanisms are the key to understanding production systems. J. Exp. Bot. 53(370): 773-787.

MCCALL D., WILLUMSEN J., 1998. Effects of nitrate, ammonium and chloride application on the yield and nitrate content of soil-grown lettuce. J. Hort. Sci. Biotechnol. 73(5): 698-703.

MCCALL D., WILLUMSEN J., 1999. Effects of nitrogen availability and supplementary light on the nitrate content of soil-grown lettuce. J. Hort. Sci. Biotechnol. 74(4): 458-463.

MYCZKOWSKI J., ROŻEK S., SADY W., 1991. The effect of fertilization with different forms of nitrogen on yield and nitrate metabolism in leaves of greenhouse lettuce. II. Effect of growth regulators. Folia Hort. 3(1): 13-25.

NIEUWHOF M., JANSEN R.C., 1993. Effect of nitrogen fertilization on nitrate content of radish. Gartenbauwissenschaft, 58(3): 130-134.

NOWOSIELSKI O., 1988. Metody opracowywania zaleceń nawozowych w ogrodnictwie. PWRiL, Warszawa.

ROŻEK S., LEJA M., WOJCIECHOWSKA R., SADY W., 1999. Nitrate and nitrite contents in spring cabbage as related to nitrogen fertilizer type, method of fertilizer application and to nitrate and nitrite reductase activity. Acta Hort. 506: 153-157.

ROŻEK S., SADY W., LEJA M., MYCZKOWSKI J., 1994. The effect of fertilization with different forms of nitrogen on greenhouse lettuce quality and its changes during storage. II. Nitrate and nitrite content. Folia Hort. 6(1): 53-62.

SADY W., ROŻEK S., 1995. Sposoby obniżenia zawartości azotanów w marchwi. Agrotechniczne Materiały Wdrożeniowe. Alima-Gerber, Rzeszów.

SAMOTUS B., LEJA M., ŚCIGALSKI A., 1982. Porównanie czterech metod oznaczania kwasu askorbinowego w owocach i warzywach. Acta Agr. Silv., Ser. Agr. 21: 105-122.

SHANGGUAN Z., SHAO M., DYCKMANS J., 2000. Effects of nitrogen nutrition and water deficit on net photosynthetic rate and chlorophyll fluorescence in winter wheat. J. Plant Physiol. 156: 46-51.

SOMMER K., 2000. „CULTAN" cropping system: fundamentals, state of development and perspectives. In: Nitrogen in a sustainable ecosystem: from the cell to the plant. M.A. Martins-Loucao, S.H. Lips (eds), Backhuys Publ., Leiden, The Netherlands, 361-375.

WOJCIECHOWSKA R., 2002. The nitrate and nitrite reductase activity in cabbage (*Brassica oleracea* var. *capitata*) as related to nitrate content modified by different nitrogen fertilization. Veg. Crops Res. Bull. 56: 31-38.

WOJCIECHOWSKA R., 2004. Wybrane aspekty metabolizmu azotanów w warzywach ze szczególnym uwzględnieniem sałaty masłowej 'Sprinter F_1'. Zesz. Nauk. AR Kraków. Ser. Rozprawy, 297.

YEMM E.W., WILLS A.J., 1954. The estimation of carbohydrates in plant extracts by antrone. Biochem. J. 57: 508-514.

ZEBARTH B.J., BOWEN P.A., TOIVONEN P.M.A., 1995. Influence of nitrogen fertilization on broccoli yield, nitrogen accumulation and apparent fertilizer-nitrogen recovery. Canad. J. Plant Sci. 75(3): 717-725.

WYSOKOŚĆ I JAKOŚĆ PLONU BROKUŁU W UPRAWIE WIOSENNEJ W ZALEŻNOŚCI OD NAWOŻENIA AZOTEM I CZYNNIKÓW KLIMATYCZNYCH

Streszczenie: Przedstawiono wyniki trzyletniego doświadczenia z brokułem 'Lord F_1' uprawianym w warunkach polowych w cyklu wiosennym. Celem badań było ustalenie wpływu nawożenia mineralnego azotem i dokarmiania dolistnego mocznikiem na wysokość plonu oraz zawartość wybranych składników w różach. Zastosowano cztery poziomy azotu mineralnego w glebie: zawartość naturalna (12-25,5 mg N dm^{-3} zależnie od roku badań), nawożenie połową dawki azotu do poziomu 75 mg N dm^{-3} , nawożenie pełną dawką podzieloną na dwie połowy (75 + 75 mg N dm^{-3}) oraz nawożenie pełną dawką do poziomu 150 mg N dm^{-3} zastosowaną jednorazowo. Ponadto w każdym obiekcie z N_{min} wprowadzono dwie kombinacje: bez dokarmiania dolistnego i z dokarmianiem dolistnym 2-procentowym roztworem mocznika. Generalnie badania nie wykazały istotnego wpływu dawki azotu mineralnego na wielkość plonu biologicznego i handlowego brokułu, jak również na jego jakość. Stwierdzono, że dokarmianie dolistne mocznikiem istotnie obniżyło zawartość azotanów w różach w porównaniu z roślinami nie dokarmianymi. Dodatkowo, niezależnie od roku badań dokarmianie dolistne wpłynęło na istotne zwiększenie zawartości cukrów rozpuszczalnych w każdej kombinacji z nawożeniem mineralnym azotem. Ponadto we wszystkich latach eksperymentu w różach brokułu traktowanego mocznikiem wykazywano wzrost zawartości kwasu askorbinowego.

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