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

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Key words: biological and marketable yield, nitrates, soluble sugars, ascorbic acid, foliar urea nutrition, mineral nitrogen

ABSTRACT

The results of a three-year experiment with broccoli ‘Lord F1’ 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 ($N_{\text{min}}$) 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 $N_{\text{min}}$ 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\textsubscript{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-NH\textsubscript{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\textsuperscript{2+} content up to 1500 mg of Ca dm\textsuperscript{-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 Fi’ 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-NO₃ + N-NH₄), 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 ionselective 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<sub>min</sub> level of soil (mg dm<sup>-3</sup>) | Without foliar nutrition | With foliar nutrition | | | |
|---|---|---|---|---|---|---|---|
| | Biological yield (t ha<sup>-1</sup>) | Marketable yield (t ha<sup>-1</sup>) | Cc<sup>**</sup> (g cm<sup>-1</sup>) | Biological yield (t ha<sup>-1</sup>) | Marketable yield (t ha<sup>-1</sup>) | Cc (g cm<sup>-1</sup>) |
| Control | 31.81<sup>a</sup> | 13.34<sup>a</sup> | 19.38<sup>a</sup> | 35.62<sup>a</sup> | 14.99<sup>a</sup> | 21.63<sup>ab</sup> |
| 75 | 53.20<sup>b</sup> | 20.41<sup>bc</sup> | 25.22<sup>b</sup> | 52.30<sup>b</sup> | 20.63<sup>b</sup> | 25.12<sup>b</sup> |
| 75 + 75 | 53.40<sup>b</sup> | 19.56<sup>b</sup> | 24.91<sup>b</sup> | 54.91<sup>b</sup> | 21.72<sup>b</sup> | 26.15<sup>b</sup> |
| 150 | 51.27<sup>b</sup> | 22.47<sup>bc</sup> | 26.53<sup>b</sup> | 59.22<sup>b</sup> | 23.31<sup>c</sup> | 26.91<sup>b</sup> |

* 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

<table>
<thead>
<tr>
<th>N&lt;sub&gt;min&lt;/sub&gt; level of soil (mg dm&lt;sup&gt;-3&lt;/sup&gt;)</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Marketable yield (t ha&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>Cc (g cm&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>Biological yield (t ha&lt;sup&gt;-1&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Control</td>
<td>15.05&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>20.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26.54&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>75</td>
<td>18.66&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>23.13&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>47.57&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>75 + 75</td>
<td>16.84&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>21.45&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.51&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>150</td>
<td>19.21&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>22.65&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>48.05&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>N&lt;sub&gt;min&lt;/sub&gt; level of soil (mg dm&lt;sup&gt;-3&lt;/sup&gt;)</th>
<th>Without foliar nutrition</th>
<th>With foliar nutrition</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrates (mg NO&lt;sub&gt;3&lt;/sub&gt;-N kg&lt;sup&gt;-1&lt;/sup&gt; f.w.)</td>
<td>Soluble sugars (mg 100 g&lt;sup&gt;-1&lt;/sup&gt; f.w.)</td>
<td>Ascorbic acid (mg 100 g&lt;sup&gt;-1&lt;/sup&gt; f.w.)</td>
<td>Dry matter (%)</td>
<td>Nitrates (mg NO&lt;sub&gt;3&lt;/sub&gt;-N kg&lt;sup&gt;-1&lt;/sup&gt; f.w.)</td>
<td>Soluble sugars (mg 100 g&lt;sup&gt;-1&lt;/sup&gt; f.w.)</td>
</tr>
<tr>
<td>Control</td>
<td>826.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1436&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>72.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.81&lt;sup&gt;a&lt;/sup&gt;</td>
<td>592.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1555&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>75</td>
<td>1051.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1345&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>64.63&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.65&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>956.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1622&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>75 + 75</td>
<td>1560.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1338&lt;sup&gt;a&lt;/sup&gt;</td>
<td>63.75&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>8.51&lt;sup&gt;b&lt;/sup&gt;</td>
<td>965.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1535&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>150</td>
<td>1446.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1359&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>60.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.37&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>1120.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1598&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Nmin level of soil (mg dm⁻³)</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrate (mg NO₃ kg⁻¹ f.w.)</td>
<td>Soluble sugars (mg 100 g⁻¹ f.w.)</td>
<td>Ascorbic acid (mg 100 g⁻¹ f.w.)</td>
</tr>
<tr>
<td>Control</td>
<td>502.2 a 1643 d 65.95 a 8.31 a</td>
<td>796.4 ab 1363 abc 70.84 a 8.58 a</td>
<td>829.9 ab 1480 bcde 71.58 a 8.65 a</td>
</tr>
<tr>
<td>75</td>
<td>838.7 ab 1570 d 65.34 a 8.42 a</td>
<td>1189.1 cd 1306 ab 66.59 a 8.46 a</td>
<td>984.7 bc 1575 d 67.38 a 8.67 a</td>
</tr>
<tr>
<td>75 + 75</td>
<td>712.4 ab 1579 d 62.26 a 8.18 a</td>
<td>1674.5 e 1176 a 70.70 a 8.53 a</td>
<td>1401.5 de 1555 cd 60.36 a 8.12 a</td>
</tr>
<tr>
<td>150</td>
<td>835.0 ab 1553 cd 59.99 a 8.19 a</td>
<td>1562 c 1257 a 67.47 a 8.56 a</td>
<td>1454 de 1625 d 62.75 a 8.05 a</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Year of study</th>
<th>Without foliar nutrition</th>
<th>With foliar nutrition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrate (mg NO₃ kg⁻¹ f.w.)</td>
<td>Soluble sugars (mg 100 g⁻¹ f.w.)</td>
</tr>
<tr>
<td>1999</td>
<td>705.8 a 1571 c 61.06 a 17.27 a</td>
<td>738.7 a 1601 cd 65.71 bc 17.61 a</td>
</tr>
<tr>
<td>2000</td>
<td>1559.1 c 1073 a 71.87 d 18.46 ab</td>
<td>1051.8 b 1464 b 65.93 bc 20.13 abc</td>
</tr>
<tr>
<td>2001</td>
<td>1399.3 c 1464 b 63.01 ab 21.11 bc</td>
<td>935.8 ab 1653 d 68.02 c 22.75 c</td>
</tr>
</tbody>
</table>

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

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

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

<table>
<thead>
<tr>
<th>Year</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>7</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>2001</td>
<td>14</td>
<td>19</td>
<td>11</td>
</tr>
</tbody>
</table>

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 NO₃⁻ 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


Broccoli yield and its quality


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

Streszczenie: Przedstawiono wyniki trzyletniego doświadczenia z brokułem ‘Lord F1’ 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 roślinach. 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 Nmin 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 dolistnym mocznikiem istotnie obniżyło zawartość azotanów w roślinach w porównaniu z roślinami nie dokarmianym. 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 różańch brokułu traktowanego mocznikiem wykazywano wzrost zawartości kwasu askorbinowego.

Received April 8, 2005; accepted September 5, 2005