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The effect of transplant age and storage time in a cold room on chemical composition of broccoli heads

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ABSTRACT

In the experiment carried out for 3 years at the Agricultural University in Kraków, the effect of transplant age and storage time in a cold room on the yield and nutritive value of broccoli 'Lord F_1' heads was investigated. Transplants were stored in freon cold room without access to light at 2°C at relative humidity of 80-85%.

It was demonstrated that only the duration of the storing time had essential influence on dry matter content. Higher level of this component was found in the broccoli heads of the plants the transplants of which were not stored or stored for one week in the cold room (11.49 and 11.17% respectively) than from those kept for two weeks (10.36%). Neither the age of transplants nor the time of storing had any significant influence on the content of L-ascorbic acid in broccoli heads.

The significant effect of the investigated factors on the content of the selected elements in the broccoli heads was affirmed. In the case of the transplants age it

concerned phosphorus, calcium, magnesium, sodium, iron and in the case of the time of storage – calcium, zinc and manganese.

Transplant age had not significant effect on the content of nitrates in the broccoli heads, however, considering the time of storage, more nitrates were found in the plants whose transplants were stored by 1 and 2 weeks in a cold room.

INTRODUCTION

The constantly increasing demand for broccoli both from fresh vegetable market and food industry, common in Europe in recent years has led to a systematic growth of the cultivation area of this vegetable (Kunicki 2004). In Poland, in the last dozen years broccoli, initially a little known vegetable, has become one of most popular ones. The necessity occurred to work out such a method of broccoli cultivation that would ensure good yield both in quantity and quality, with the simultaneous maximal possible decrease of production cost. Broccoli is a vegetable of high nutritional and biological value due to its high protein, fat, vitamin, mineral salts and fiber content (Fenwick et al. 1983). Broccoli is a valuable source of elements necessary for proper functioning of a human body, among the others calcium, phosphorus, potassium and iron (Kunachowicz et al. 1999, Kunicki and Capecka 2000). In respect to the contents of protein, mineral salts and vitamins A, B_1, and B_2, broccoli significantly exceeds cauliflower and white head cabbage (Yamaguchi 1983). Broccoli is considered to be one of the most precious vegetables of significant health properties.

Proper timing in broccoli cultivation may be obtained by the use of transplants of various age or by storing in a cool room. It was confirmed by Grabowska et al. (2007). There are incompatible dates of transplant age influence on the quality of broccoli yield. The aim of the study was to investigate the influence of transplant age and storage time in cool room on broccoli quality in autumn cultivation.

MATERIAL AND METHODS

In the experiment carried out in 2002 – 2004, a medium-late 'Lord F_1' broccoli cultivar was used. The two-factor experiment was established in randomized blocks with four replications, (1) transplant age (4, 6, 8 and 10 weeks) and (2) the time of storage in a cold room (1 and 2 weeks). The transplants were planted into field in 67.5 × 40 cm distance.

Seeds were sown in April and May (Table 1) to multipots filled with peat substrate of pH 6.5, including a standard content of micro- and macroelements. Watering and fertilizing with water solutions of multicomponent fertilizers were carried out systematically starting with the two-leaf phase. Before planting into

field, transplants were stored in freon cold room without access to light at 2°C and a relative air humidity of 80-85%. Watering was carried out once a week.

Fertilization with potassium and phosphorus mineral fertilizers was carried out in autumn according to the results of soil analyses. Nitrogen was used in experimental field before the planting of transplants in the form of nitrochalk (100 kg N ha^{-1}). In the second and fourth week after transplant planting, fertilization with ammonium nitrate was carried out (75 kg N ha^{-1} each time). Weeds were eliminated using herbicide containing trifluralin (2 dm^3 ha^{-1}). During the vegetation, whenever necessary, the plants were subjected to sprinkling irrigation. Plants were protected against diseases and pests in accordance with current recommendations for broccoli.

Table 1. Dates of seed sowing and transplant planting of broccoli in 2002 – 2004

Transplant age (in weeks)	2002	2003	2004
	Sowing date		
10	12 April	11 April	14 April
8	27 April	25 April	28 April
6	11 May	09 May	11 May
4	25 May	23 May	25 May
Storage time (weeks)	Planting date		
0	25 June	26 June	27 June
1	03 July	04 July	05 July
2	10 July	11 July	11 July

Broccoli heads were cropped two times a week on average, depending on the year of the experiment, from the second decade of August to the second decade of October, when flower buds reached harvesting size together with a fleshy shoot of ca. 25 cm length. Total and marketable yields were determined. Their sizes were stated in the previous work of Grabowska et al. (2007).

Following the crop, broccoli heads were subjected to laboratory analyses concerning the contents of:

- dry matter (%) determined with the dryer method acc. to Pijanowski et al. (1973),
- L-ascorbic acid (mg kg^{-1}) determined with Tillman's method,
- nitrates (mg NO_3 kg^{-1} fresh matter) with the use of ion-selective electrode connected with UNICAM – 9460 ionometer,
- calcium, potassium, magnesium, sodium, iron, manganese and zinc determined using the method of atom absorption in Varian Spectr AA-20 spectophotometer (Pinta 1977),
- phosphorus determined with colorimetric method.

The obtained results were processed statistically with the method of variance analysis at a significance level of $p = 0.05$ and presented as averages of data from the three years of the experiment.

RESULTS

Dry matter

Transplant age had no significant effect on the dry matter content in broccoli heads (Table 2). Considering the second of the investigated factors, it can be stated that higher dry matter content was determined in the heads of the plants obtained from non-stored transplants and stored for 1 week as compared to transplants stored for 2 weeks.

Table 2. Dry matter content (%) in broccoli heads depending on transplant age and storage time in a cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	10.90 a-c	10.80 a-c	12.02 bc	12.45 c	11.49 B
1	11.27 a-c	11.24 a-c	11.29 a-c	10.90 a-c	11.17 B
2	10.41 ab	9.81 a	10.53 a-c	10.71 a-c	10.36 A
Mean	10.86 A	10.54 A	11.28 A	11.35 A	-

Explanation: Different letters within the same column indicate significant differences between the means, capital letters – the effect of investigated factors, small letters – the effect of interaction of the investigated factors.

L-ascorbic acid

Both investigated factors had no significant effect on L-ascorbic acid content in broccoli heads (Table 3). Its content varied from 68.07 mg g^{-1} in the heads of the plants from 4-week transplants to 70.31 mg kg^{-1} from 8-week transplants and from 67.10 to 70.13 mg kg^{-1} depending on the time of storing.

Table 3. L-ascorbic acid content (mg kg^{-1}) in broccoli heads depending on transplant age and storage time in a cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	63.28 a	66.72 ab	69.68 ab	68.70 ab	67.10 A
1	70.20 ab	69.90 ab	72.27 b	67.23 ab	69.90 A
2	70.74 ab	69.81 ab	68.98 ab	70.98 ab	70.13 A
Mean	68.07 A	68.81 A	70.31 A	68.97 A	-

Explanation: see Table 2

Phosphorus

Significant differences in the content of phosphorus in broccoli heads were demonstrated only in the case of the transplant age (Table 4). Higher phosphorus content was found in the heads of the plants obtained from 10-week transplants and the lowest from 6-week transplants.

Table 4. Phosphorus content (mg kg^{-1} d.m.) in broccoli heads depending on transplant age and storage time in a cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	6091 a	5593 a	6019 a	6093 a	5724 A
1	5684 a	5389 a	6090 a	5838 a	5750 A
2	5820 a	5743 a	5560 a	5774 a	5724 A
Mean	5865 AB	5575 A	5890 AB	5901 B	-

Explanation: see Table 2

Potassium

No significant effect of the studied factors on the content of potassium in broccoli heads was determined (Table 5). Its amount varied from 20710 mg kg^{-1} d.m. (8-week transplants) to 23049 mg kg^{-1} d.m. (10-week transplants).

Table 5. Potassium content (mg kg^{-1} d.m.) in broccoli heads depending on transplant age and storage time in a cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	23126 a	22050 a	20618 a	20899 a	21673 A
1	22528 a	23326 a	21881 a	24208 a	22986 A
2	23479 a	23488 a	19630 a	24039 a	22659 A
Mean	23044 A	22955 A	20710 A	23049 A	-

Explanation: see Table 2

Calcium

In respect to calcium content (Table 6), the heads of the plants obtained from 10-week transplants (4122 mg kg^{-1} d.m.) differed significantly from the heads of the plants obtained from 4-week transplants (3772 mg kg^{-1} d.m.). Significant differences in the calcium level were also found in the heads of the plants obtained from transplants stored for 1 week as compared to the heads of the plants obtained from non-stored transplants.

Table 6. Calcium content (mg kg^{-1} d.m.) in broccoli heads depending on transplant age and storage time in a cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	3763 ab	3637 a	3642 a	3870 ab	3728 A
1	3890 ab	3719 ab	4211 ab	4460 b	4070 B
2	3664 a	4084 ab	3861 ab	4035 ab	3911 AB
Mean	3772 A	3813 AB	3904 AB	4122 B	-

Explanation: see Table 2

Magnesium

Irrespective of cooling, the heads of the plants obtained from 10-week transplants contained significantly more magnesium than the heads of the plants from 6-week transplants – Table 7. Irrespective of the cooling time, the amount of magnesium remained on the same level.

Table 7. Magnesium content (mg kg^{-1} d.m.) in broccoli heads depending on transplant age and storage time in a cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	1582 ab	1550 ab	1648 ab	1605 ab	1596 A
1	1513 ab	1400 a	1656 ab	1750 b	1579 A
2	1533 ab	1544 ab	1525 ab	1590 ab	1548 A
Mean	1543 AB	1498 A	1610 AB	1648 B	-

Explanation: see Table 2

Iron

Transplant age had a significant effect on the iron content in broccoli heads (Table 8). Its contents were highest in the heads of the plants cultivated from 10-week transplants (67.16 mg kg^{-1} d.m.) and lowest in the plants obtained from 6-week transplants (60.65 mg kg^{-1} d.m.). Irrespective of the cooling time, the amount of iron remained on the same level.

Table 8. Iron content (mg kg^{-1} d.m.) in broccoli heads depending on transplant age and storage time in a cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	65.31 a	63.63 a	67.52 a	64.52 a	65.25 A
1	66.86 a	59.59 a	67.75 a	69.98 a	66.04 A
2	64.25 a	58.73 a	60.35 a	66.98 a	62.58 A
Mean	65.47 AB	60.65 A	65.21 AB	67.16 B	-

Explanation: see Table 2

Sodium

Sodium content in the heads of broccoli significantly depended on the transplant age (Table 9), as its content was higher in the heads of the plants obtained from 8-week transplants as compared to the plants obtained from 4 and 6-week transplants. However, no significant differences in sodium content were found depending on the cooling time.

Table 9. Sodium content (mg kg^{-1} d.m.) in broccoli heads depending on transplant age and storage time in a cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	2352 ab	2341 ab	2574 ab	2341 ab	2402 A
1	2192 ab	2259 ab	2693 a	2539 ab	2421 A
2	1975 b	2273 ab	2729 a	2267 ab	2311 A
Mean	2173 A	2291 A	2665 B	2382 AB	-

Explanation: see Table 2

Zinc

Transplant age had no significant effect on zinc content in broccoli heads – Table 10. The storage time of the transplants had a significant effect on the level of this element – its content was higher (62.72 mg kg^{-1} d.m.) in the heads of the plants cultivated from non-stored transplants than from the transplants stored for one week (59.53 mg kg^{-1} d.m.).

Table 10. Zinc content (mg kg^{-1} d.m.) in broccoli heads depending on transplant age and storage time in a cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	61.71 ab	63.11 a	63.73 a	62.31 ab	62.72 B
1	62.60 ab	55.27 b	60.61 ab	59.64 ab	59.53 A
2	63.46 a	59.52 ab	58.96 ab	59.56 ab	60.37 AB
Mean	62.59 A	59.30 A	62.00 A	60.51 A	-

Explanation: see Table 2

Manganese

No significant differences were demonstrated in average contents of manganese in the heads of broccoli depending on the transplant age (Table 11). Following the analysis of the second factor, highest manganese content was found in the heads of the plants cultivated from non-stored transplants and the lowest one in the heads of the plants cultivated both from transplants stored both for 1 and 2 weeks.

Table 11. Manganese content (mg kg^{-1} d.m.) in broccoli heads depending on transplant age and storage time in a cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	20.44 ab	24.61 c	23.78 bc	23.92 bc	23.19 B
1	22.21 a-c	20.06 ab	21.79 a-c	19.75 a	20.95 A
2	19.96 ab	20.23 ab	19.34 a	19.13 a	19.66 A
Mean	20.87 A	21.63 A	21.63 A	20.93 A	-

Explanation: see Table 2

Nitrates

Transplant age had no significant effect on nitrate content in the heads of broccoli (Table 12). However, nitrate content in the heads of broccoli plants cultivated from transplants stored for one and two weeks was significantly higher than in the plants cultivated from non-stored transplants.

Table 12. Nitrate content in the heads of broccoli (mg NO_3 kg^{-1} f.m.) depending on transplant age and the storage time in the cold room

Storage time (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	146.38 a	147.21 a	162.17 a-c	158.92 ab	153.67 A
1	200.25 de	166.63 a-d	187.38 b-e	195.25 c-e	187.38 B
2	220.42 e	211.67 e	202.83 e	162.4 a-c	199.37 B
Mean	189.01 A	175.17 A	184.12 A	172.4 A	-

DISCUSSION

Depending on the storage time in a cooling room, higher dry matter content was found in the heads of the plants obtained from non-stored transplants and transplants stored for one week than from transplants stored for two weeks. A similar dependence was demonstrated by the authors in earlier studies (Wlazło and Kunicki 2003). The heads of the plants obtained from non-stored transplants and transplants stored for one week had a higher dry matter content (11.49 and 11.17% respectively) in comparison with the transplants stored for two weeks (10.36%). In the present experiment, slightly higher dry matter contents were obtained than the ones cited by other authors. For instance, according to Kmiecik and Budnik (1997) dry matter content in the heads of broccoli plants ranged from 8.37 to 10.68 while Lisiewska (1987) reported 10.01%.

In the present experiment transplant age and the storage time had no significant effect on L-ascorbic acid content in the heads of broccoli. On the other hand, Wlazło and Kunicki (2003) report that L-ascorbic acid content ranged from 80.4

mg g^{-1} in the heads obtained from 10-week transplants to 85.0 mg g^{-1} in the heads from 6-week transplants in the first year of the experiment and from 62.7 mg g^{-1} in the heads obtained from 8-week seedlings to 69.3 mg g^{-1} from 4-week transplants in the second year. Generally, L-ascorbic contents found in both experiments were lower than the ones cited by other authors, i.e. from 107 to 136 mg in 100 g f.m. (Lisiewska 1987, Lisiewska and Kmiecik 1996, Kmiecik and Budnik 1997).

In this study, a significant effect of the transplant age on the content of phosphorus, calcium, magnesium, sodium and iron in broccoli heads was demonstrated as well as the effect of transplant storage on calcium, zinc and manganese. Lisiewska (1986) demonstrated the following chemical composition in the heads of eight broccoli varieties: potassium – 399 mg, phosphorus – 74 mg, calcium – 46 mg, magnesium – 17.4 mg and iron – 2.0 mg in 100 g fresh matter. Kunicki (2005) found higher content of potassium, calcium, magnesium and iron in the heads than in the shoots, the fact that may indicate the tendency to store higher amounts of these elements in the younger, upper part of the head. Similarly, Rekowska (2002) and Gębczyński (2003) claim that side heads, younger than the main ones, were richer in calcium, magnesium and phosphorus. Most probably it results from the fact that these elements accumulate mostly in these organs of the plant in which the processes of growth and metabolism are most intensive (Marska and Nowak 2001).

No significant effect of the transplant age on nitrate content was demonstrated. However, taking into consideration transplant storing in the cooling room, lower content of these compounds was found in the heads of the plants cultivated from non-stored transplants (153.67 mg $NaNO_3$ kg^{-1} f.m.) than from transplants stored for one and two weeks (187.38 and 199.37 mg $NaNO_3$ kg^{-1} f.m.). Sady and Rożek (1995) demonstrated that plants of shorter growing season accumulate more nitrates than plants which require longer cultivation period. Rożek (2000) reported that nitrate content changes with plant age. Highest contents of these compounds are characteristic for young plants as the reduction process does not keep up with their intake. Lisiewska and Kmiecik (1991) also claim that nitrate content in vegetables depends on the advancement of the plant's growth. Highest nitrate concentrations are found at early development stages, the fact that should be related with typical for that period low content of carbohydrates that are the main source of energy in nitrate reduction process and, in further perspective, to the process of incorporating nitrogen into amino acids. In the experiment of Wlazło and Kunicki (2003) no significant differences in nitrate contents in the heads were demonstrated in the first year of the experiment, which varied from 252 mg $NaNO_3$ kg^{-1} f.m. in 4-week transplants to 344 mg in 10-week transplants. However, in the second year of the experiment, significantly less nitrates (262 mg $NaNO_3$ kg^{-1} f.m.) were found in the heads of the plants obtained from 10-week transplants.

CONCLUSIONS

- Depending on the storage time in the cooling room, higher content of the studied compound was found in the heads of the plants obtained from non stored transplants and transplants stored for one week than from transplants stored for two week.
- Transplant age and the storage time had no significant effect on L-ascorbic acid content in the heads of broccoli.
- The effect of the transplant age on the contents of phosphorus, calcium, magnesium, sodium and iron was found as well as the effect of transplant storage on calcium, zinc and manganese contents in broccoli heads.
- Transplant age had no significant effect on nitrate content in broccoli heads. On the other hand, nitrate content was higher in the plants cultivated from transplants stored for one and two weeks than in the plants cultivated from non-stored transplant.

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WPŁYW WIEKU ROZSADY I OKRESU JEJ PRZETRZYMYWANIA W CHŁODNI NA SKŁAD CHEMICZNY RÓŻ BROKUŁU

Streszczenie: W przeprowadzonym w Akademii Rolniczej w Krakowie trzyletnim doświadczeniu, badano wpływ wieku rozsady i okresu jej przetrzymywania w chłodni na jakość handlową i odżywczą róż brokułu odmiany 'Lord F_1'. Rozsadę przechowywano w chłodni bez dostępu światła w temperaturze +2ºC i wilgotności względnej powietrza wynoszącej 80-85%. Nie stwierdzono istotnego wpływu wieku rozsady na zawartość suchej masy, natomiast wyższym poziomem tego składnika charakteryzowały się róże roślin uprawianych z rozsady nie przetrzymywanej i przetrzymywanej przez jeden tydzień w chłodni (11,49 i 11,17%), niż z rozsady przetrzymywanej przez dwa tygodnie (10,36%). Wykazano, że oba badane czynniki nie miały istotnego wpływu na zawartość kwasu L-askorbinowego w różach brokułu. Stwierdzono istotny wpływ wieku rozsady na zawartość w różach brokułu pierwiastków, takich jak: fosfor, wapń, magnez, sód i żelazo. Z kolei biorąc pod uwagę okres przetrzymywania rozsady w chłodni, wykazano jego wpływ na poziom zawartości wapnia, cynku i manganu. Wiek rozsady nie wpłynął istotnie na zawartość azotanów w róży, natomiast więcej azotanów stwierdzono w różach roślin, których rozsadę przetrzymywano zarówno przez jeden, jak i dwa tygodnie.

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