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The effects of different methods of cultivation and plant spacing on the chemical composition of broccoli heads

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ABSTRACT

The aim of the present experiment was to assess the influence of the method of cultivation and spacing on the market and nutritive quality of 'Lord F_1' broccoli heads. The experiment was conducted at the University of Agriculture in Krakow, Poland, in 2002-2004. The method of broccoli cultivation (direct sowing or transplanting, and spacing: 20, 30, 40 and 50 cm × 67.5 cm) had no clear influence on the dry matter content in the heads. The mean dry matter content in broccoli heads was 9.5%, and reducing sugar was 1.12% of fresh matter. In 2002 and 2004, transplanting resulted in an increase of soluble sugar content as compared to direct sowing. The element content in broccoli was dependent mainly on the vegetation season, but in many cases directly sown plants had more phosphorus, potassium, calcium, and magnesium. With the increase of spacing in rows the content of some elements (P, K, Ca, Mg) in broccoli heads rose in the first year of the experiment.

The mean content of elements found in broccoli heads was as follows (in mg kg^{-1} of dry matter): phosphorus 6001, potassium 23447, calcium 3696, magnesium 1583, and iron 66.7.

INTRODUCTION

In Poland, meteorological conditions enable broccoli cultivation for the fresh market from spring to autumn. The high usefulness of broccoli for freezing has made it possible to extend the scale of production to include processing. New methods of cultivation were developed to supply the market demand in fresh broccoli heads for a longer period of the year and to improve its quality and chemical composition. Yoldas et al. (2008) investigated the effect of nitrogen fertilizers on quality and nutrient content in broccoli heads. The authors showed that potassium, calcium, magnesium, iron, and zinc content increased with the increase of nitrogen in treatments but phosphorus, copper, manganese, boron, and sodium contents were not influenced. Kunicki (2005) recommended the use of a urea form of nitrogen fertilizer to obtain broccoli of a high nutritive value. The author found that in order to obtain raw material with the lowest amount of nitrates and highest levels of ascorbic acid, carotenoids, thiocyanates, phosphorus, magnesium, iron, zinc, and manganese, broccoli heads with short stems should be harvested. The term of harvest also had an influence on broccoli quality. For example, evening harvests should be recommended for producing heads with maximum ascorbic acid content (Kunicki 2005). In Poland, broccoli is cultivated from transplants produced under covers or in seedbeds. Direct sowing cultivation, recommended in the USA, makes it possible to increase plant density, and to produce a greater yield. This method is also cheaper than transplanting, but the latter intensifies the use of growing area (Kunicki 2004). Different broccoli density makes it possible to control the size of heads according to market demands (Kunicki et al. 1999, Rekowska 2002). The aim of the present investigation was to compare the quality of broccoli heads with varying spacing, and using the direct sowing or transplanting methods of cultivation.

MATERIAL AND METHODS

The experiment was carried out in 2002-2004 at the University of Agriculture in Krakow, Poland, on soil with an organic carbon content of 2%, and pH_{KCl} 6.11. The 'Lord F_1' late yielding broccoli hybrid was used in the study. The experiment was established using the randomized blocks method in four replications, based on two factors: (1) method of cultivation: direct sowing or transplanting, (2) plant

spacing: 20, 30, 40 and 50 cm × 67.5 cm (7.4; 5.0; 3.7 and 3.0 plants per m^2). Seeds were sown after 20 May, directly into the soil (three seeds in one place, after emergences seedlings were thinned leaving one seedling per one place) or into cells of multi-pot trays (type VP 96, with one cell volume of 53 cm^3, filled with peat substrate). Transplants were planted in the last third of June. Each experimental plot was composed of 36 plants. Based on the chemical soil analysis (Tab. 1), fertilizers were applied to achieve the following NPK level (in kg ha^{-1}): N – 200, P_2O_5 – 90 and K_2O – 240. Broccoli heads were harvested from August to October, after reaching the required size according to the Polish Norm (1996). The following analyses of the chemical composition of the broccoli heads were carried out: dry matter according to the Pijanowski method (Pijanowski et al. 1964); soluble sugar using the anthrone method; calcium, potassium, magnesium, and iron using the AAS method, and phosphorus using the colorimetric method. The results were analyzed statistically with the ANOVA method and the Tukey test at $p = 0.05$, separately for each year of the experiment.

Table 1. Results of soil analysis in spring 2002-2004

Year	$N\text{-}NH_4$	$N\text{-}NO_3$	P	K	Ca	Mg	NaCl	pH
	(mg dm^{-3})						(g dm^{-3})	
2002	3.50	21.00	50.00	116.90	1077	155.5	0.32	6.57
2003	17.50	94.50	32.50	27.30	2337	171.5	0.35	7.22
2004	8.75	66.50	48.00	34.90	1031	184.0	0.26	8.02

RESULTS AND DISCUSSION

Dry matter content in broccoli heads in the present experiment varied in a range of 8.08-10.56% (Tab. 2). Similar results were discovered by Kmiecik and Budnik (1997). Dry matter content was different depending on the method of cultivation only in 2002. The broccoli heads produced from transplants were characterized by a higher level of dry matter as compared to direct sowing. Significant differences in dry matter content were not found between treatments with different spacing.

The method of cultivation had a significant effect on the soluble sugar content in broccoli heads in 2002 and 2004 (Tab. 3). Transplanted broccoli had a higher level of soluble sugar in heads as compared to directly sown plants. In 2002, a significantly higher level of soluble sugar was found in broccoli from direct sowing grown in a density of 3.0 plants per 1 m^2. In 2003, spacing did not affect the amount of soluble sugar in broccoli heads. Rekowska (2002) also did not find a significant dependence between spacing and soluble sugar level in broccoli heads, which ranged from 0.43 to 2.84% of fresh matter. This range is comparable to those determined in the present experiment (0.43-1.69% of fresh matter).

Table 2. Dry matter content (% of fresh matter) in broccoli heads as dependent on the cultivation method and plant spacing

Year	Cultivation method	Spacing (cm)				
		20	30	40	50	Mean
2002	Direct sowing	8.36 a*	8.08 a	8.24 a	8.66 ab	8.34 A
	Transplanting	9.48 c	9.66 c	9.19 bc	9.23 bc	9.39 B
	Mean	8.93 A	8.87 A	8.72 A	8.95 A	-
2003	Direct sowing	9.43 a	10.56 b	9.98 ab	9.59 ab	9.89 A
	Transplanting	10.09 ab	10.20 ab	10.19 ab	10.30 ab	10.20 A
	Mean	9.76 A	10.38 A	10.08 A	9.94 A	-
2004	Direct sowing	9.28 a	9.52 a	9.56 a	9.46 a	9.45 A
	Transplanting	9.85 a	9.83 a	9.76 a	9.60 a	9.76 A
	Mean	9.57 A	9.67 A	9.67 A	9.53 A	-

*Values marked with the same letter do not differ significantly at p = 0.05, capital letters – the effect of investigated factors, small letters – the effect of interaction of the investigated factors

Table 3. Soluble sugar content (% of fresh matter) in broccoli heads as dependent on the cultivation method and plant spacing

Year	Cultivation method	Spacing (cm)				
		20	30	40	50	Mean
2002	Direct sowing	0.52 a*	0.73 b	0.43 a	0.47 a	0.54 A
	Transplanting	0.95 c	0.81 bc	0.98 c	1.37 d	1.03 B
	Mean	0.74 A	0.77 AB	0.70 A	0.92 B	-
2003	Direct sowing	1.43 a	1.59 a	1.54 a	1.55 a	1.53 A
	Transplanting	1.51 a	1.69 a	1.32 a	1.45 a	1.49 A
	Mean	1.47 A	1.64 A	1.43 A	1.50 A	-
2004	Direct sowing	1.04 b	1.04 b	1.04 b	0.79 a	0.98 A
	Transplanting	1.21 bc	1.04 b	1.09 bc	1.26 c	1.15 B
	Mean	1.12 A	1.04 A	1.06 A	1.03 A	-

*Explanations: see Table 2

The phosphorus content in broccoli heads was dependent only on the cultivation method in 2002 and 2004 (Fig. 1). A greater level of this element was found in the heads of directly sown plants (7413 and 5790 mg kg^{-1} of dry matter, respectively) as compared to the transplanted ones (6430 and 5356 mg kg^{-1} of dry matter, respectively).

In 2002 and 2003, greater potassium content was found in the heads of directly sown broccoli (30660 and 23086 mg kg^{-1} of dry matter). In 2002, broccoli planted in spacing of 50 cm in rows were characterized by the greatest potassium content (Fig. 2). The diminishing of spacing resulted in decreasing levels of potassium content in broccoli heads, but only in the first year of the study. In 2004, no significant connection was found between potassium content and method of cultivation and spacing of broccoli.

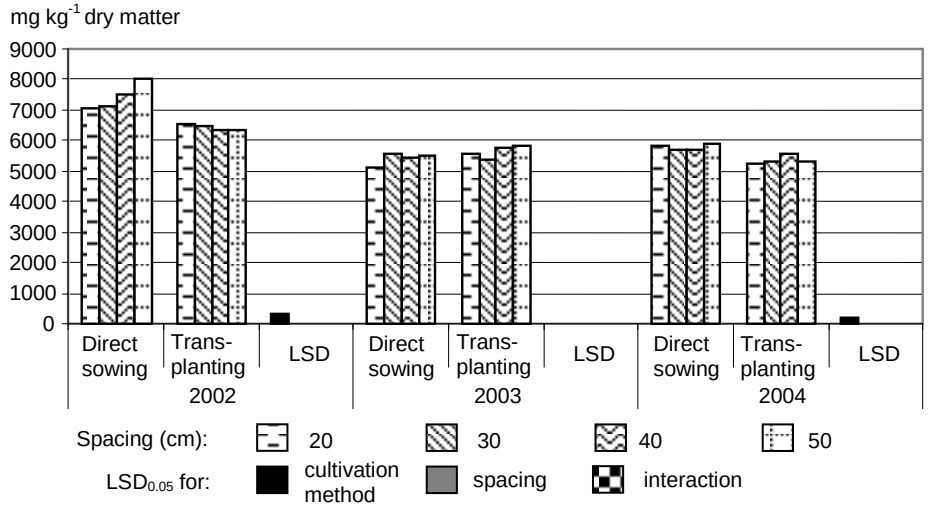

Figure 1. Phosphorus content in broccoli heads as dependent on the cultivation method and plant spacing

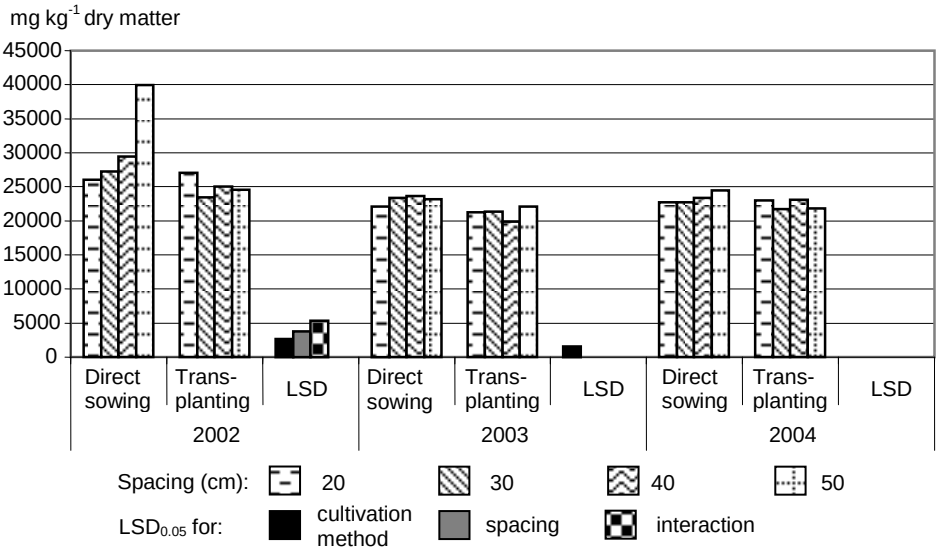

Figure 2. Potassium content in broccoli heads as dependent on the cultivation method and plant spacing

Only in 2002 did the method of cultivation and spacing have a significant effect on calcium content in broccoli heads (Fig. 3). In that year, directly sown plants were characterized by greater calcium content (3626 mg kg^{-1} of dry matter, mean for spacing) as compared to transplanted ones (3212 mg kg^{-1} of dry matter, mean for spacing). Plants cultivated in spacing of 50 cm in rows accumulated a significantly greater amount of calcium (3370 mg kg^{-1} of dry matter, mean for the method of cultivation) in comparison to the other treatments. The interaction of the studied factors had also a significant influence on calcium content in broccoli heads. The greatest content of this element was found in directly sown plants in spacing of 50 cm in rows (3788 mg kg^{-1} of dry matter), and the smallest was in transplanted plants in spacing of 30 cm in rows (2445 mg kg^{-1} of dry matter).

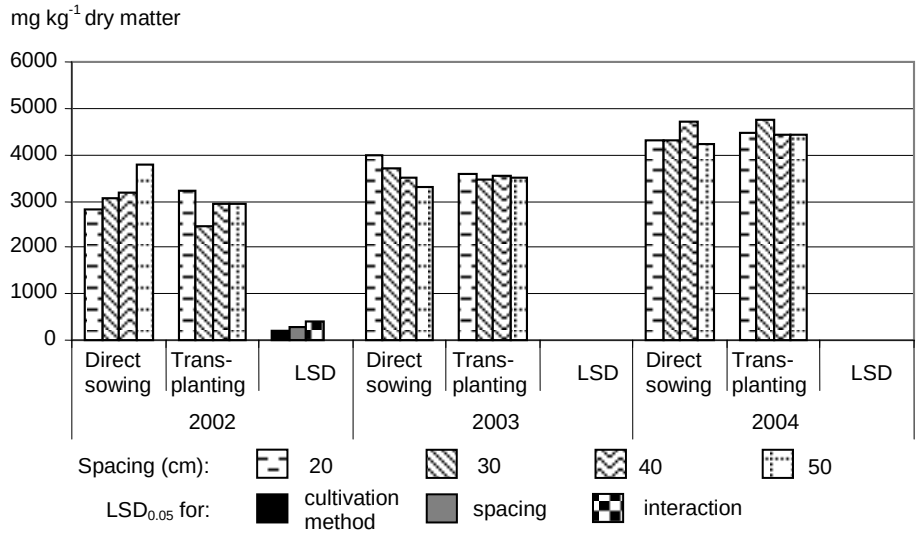

Figure 3. Calcium content in broccoli heads as dependent on the cultivation method and plant spacing

In 2002, the magnesium content in broccoli was significantly dependent on the cultivation method and spacing (Fig. 4). Directly sown plants in spacing of 50 cm had the greatest level of magnesium (2158 mg kg^{-1} of dry matter) as compared to the other treatments. In 2004, only the cultivation method had an influence on magnesium content in broccoli heads. Directly sown plants were characterized by a greater amount of this element (1647 mg kg^{-1} of dry matter, mean for spacing) as compared to transplanted ones (1561 mg kg^{-1} of dry matter, mean for spacing).

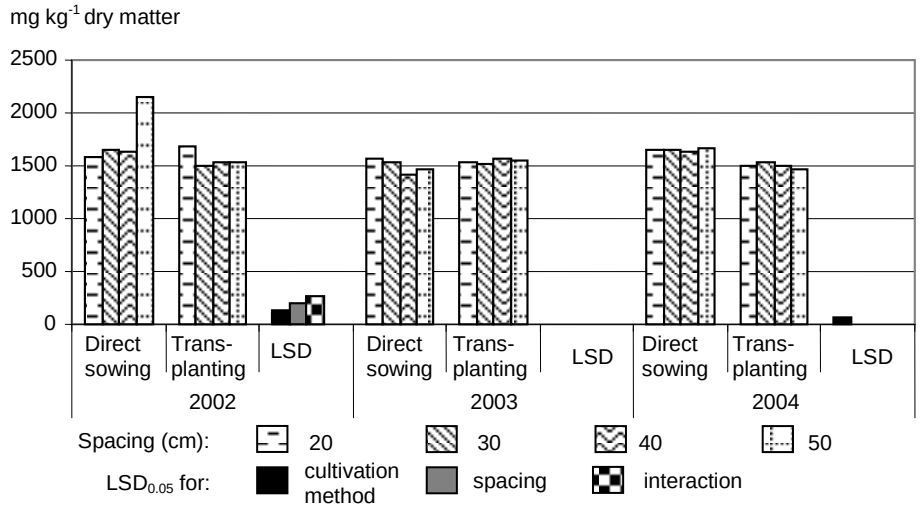

Figure 4. Magnesium content in broccoli heads as dependent on the cultivation method and plant spacing

The iron content in broccoli heads was dependent on the method of production in 2002 and 2003 (Fig. 5). In 2002, directly sown plants had a greater amount of iron (83.4 mg kg^{-1} of dry matter, mean for spacing). In 2003, the transplanted plants were characterized by greater iron accumulation in the heads (73.5 mg kg^{-1} of dry matter, mean for spacing). In 2003, plants cultivated in spacing of 40 cm in rows had the largest content of iron (77.0 mg kg^{-1} of dry matter, mean for the cultivation method).

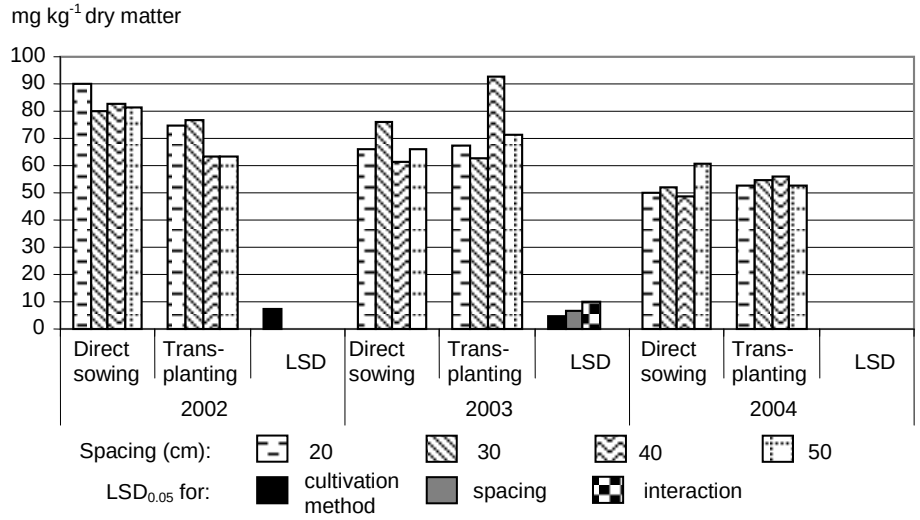

Figure 5. Iron content in broccoli heads as dependent on the cultivation method and plant spacing

Human health depends on diet, and therefore many scientific studies concern the nutritional value of vegetables. Vegetables, especially of *Brassicaceae*, contain active compounds of antimutagenic and antioxidative activity, which prevent civilization-related diseases (Elkner 2000, Eberhardt et al. 2005, Moreno et al. 2006). Broccoli is characterized by a rich mineral composition, which can be modified by the selection of cultivar, fertilization, irrigation, timing of production, or method of cultivation (Elkner 2000, Babik 2006, Aires et al. 2007, Yildirim et al. 2007). Kmiecik et al. (2007) found 289 mg K, 80 mg P, 27.2 mg Ca, 18.1 mg Mg, and 20.87 mg Fe in 100 g of fresh matter of raw broccoli heads. In the present experiment, the content of the tested elements in broccoli was dependent mainly on the year of the study, but in many cases the directly sown plants were richer in phosphorus, potassium, calcium and magnesium than the transplanted ones. With increased spacing in rows, higher content of some elements (P, K, Ca, Mg) was found in broccoli heads in the first year of the study. The mean content of the studied elements found in the broccoli heads was comparable with the results of the other authors (Kunicki and Capecka 2000, 2004, Aires et al. 2007, Kmiecik et al. 2007).

CONCLUSIONS

1. Method of cultivation (direct sowing or transplanting) and differentiated spacing had no direct influence on dry matter content in broccoli heads.
2. Transplanting resulted in an increase of soluble sugar content in broccoli heads in 2002 and 2004.
3. In directly sown plants, a larger content of phosphorus, potassium, calcium and magnesium was observed in the heads.
4. With an increase of spacing in rows the content of phosphorus, potassium, calcium, and magnesium in broccoli heads rose in one of three years of the study.

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WPŁYW METODY UPRAWY I ROZSTAWY ROŚLIN NA ZAWARTOŚĆ WYBRANYCH SKŁADNIKÓW CHEMICZNYCH W RÓŻACH BROKUŁU

Streszczenie: Celem badań było określenie wpływu metody uprawy (siew bezpośredni, uprawa z rozsady) i rozstawy roślin (20, 30, 40 i 50 cm × 67,5 cm) na jakość brokułu 'Lord F_1'. Badania przeprowadzono w Stacji Doświadczalnej Uniwersytetu Rolniczego w Krakowie w latach 2002-2004. Metoda uprawy i zastosowana rozstawa nie miała jednoznacznego wpływu na zawartość suchej masy w różach brokułu. Róże roślin uzyskanych z rozsady cechowała istotnie większa zawartość cukrów rozpuszczalnych, w latach 2002 i 2004. Średnia zawartość suchej masy w różach wyniosła 9,50%, a cukrów rozpuszczalnych 1,12% świeżej masy. Zawartość makro- i mikroelementów była zróżnicowana w latach badań, ale w wybranych przypadkach stwierdzono większą zawartość fosforu, potasu, wapnia i magnezu w różach roślin uprawianych z siewu bezpośredniego. Jednocześnie wraz ze zwiększeniem rozstawy stwierdzono wzrost zawartości fosforu, potasu, wapnia i magnezu w różach, ale tylko w pierwszym roku badań. Średnia zawartość analizowanych wskaźników jakości plonu brokułu była następująca (w mg kg^{-1} suchej masy): fosfor – 6001, potas – 23447, wapń – 3696, magnez – 1583, żelazo – 66,7.

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