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EFFECTS OF AGE AND COLD STORAGE OF TRANSPLANTS ON THE GROWTH AND QUALITY OF BROCCOLI HEADS

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Summary

In the two-factor field experiment conducted in 2002-2004 the effect of transplant age and the time of storage on the yield of broccoli cv. 'Lord F_1'was investigated. Transplants were stored in freon cold room without access to light at +2ºC and a relative air humidity of 80-85%. Both investigated factors had no significant effect on crop acceleration. Plants obtained from 4-week old transplants gained marketable yield significantly higher than plants obtained from 10-week old transplants. Significantly higher yield was obtained from transplants stored in a cooling room as compared to non-stored transplants. No univocal effect of the transplant age on the percentage of hollow stems was demonstrated.

key words: broccoli, storage period, transplant age, yield

INTRODUCTION

The effect of transplant age on the size and quality of the yield of many vegetable species were discussed in detail by Vavrina (1998). In the case of broccoli, due to contradictory data regarding the effect of transplant age on yield and its quality, the above quoted author proposes further investigations on the problem. It is extremely interesting due to the fact that Lamont (1992) demonstrated that the effect of highly varied transplant age on the yield was insignificant. These results are contradictory to the standards so far used in practice, according to which the age of brassicas transplants should not exceed 8 weeks (Schrader 2000). In experiments carried out in the Krakow area, higher broccoli yield was obtained from transplants older than the so-far recommended (Wlazło & Kunicki 2003). If the possibility of using advanced-age transplants was confirmed, this fact would allow for working out methods of precise broccoli cultivation timing. The problem is nowadays important as in recent years a considerable growth of the cultivation area of this vegetable has been noted all over Europe (Kunicki 2004).

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MATERIALS AND METHODS

In the experiments carried out in 2002-2004 a medium late "Lord F_1" cultivar of broccoli was used. The two-factor field experiment was established in randomised blocks with four replications and concerned two factors: (1) transplant age (4, 6, 8 and 10 weeks) and (2) the time of storage in a cold room (0, 1 and 2 weeks). The transplants were planted into field in 67.5 and 40 cm distance. In each experimental plot (9.72 m^2) there were 36 plants of which 24 were measured and assessed. The remaining plants constituted protection stripes. Seeds were sown in April and May (Table 1) to VP 96 type multipots of a single cell volume of 53 cm^3 , filled with peat substrate of 6.5 pH, including a standard content of micro and macro elements. 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.

Nitrogen fertilization was applied before the planting of transplants in the form of nitrochalk and in the second and fourth week after transplant planting (ammonium nitrate). Weeds were controlled by Triflurotox 480 EC herbicide (trifluralin). During the vegetation, whenever necessary, the plants were irrigated. Protection against diseases and pests was in accordance with current recommendations for broccoli.

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

Transplant	2002	2003	2004
	Sowing		
10-week	12.04	11.04	14.04
8-week	27.04	25.04	28.04
6-week	11.05	09.05	11.05
4-week	25.05	23.05	25.05
	Planting		
non-stored	25.06	26.06	27.06
stored for 1 week	03.07	04.07	05.07
stored for 2 weeks	10.07	11.07	11.07

Broccoli heads were harvested two times a week on average, depending on the year of the experiment, from the second 10-days of August to the second 10-days of October, when flower buds reached the diameter of ca. 2 mm and were fully formed and compact. Heads were cut together with a fleshy shoot of ca. 25 cm length. Total and marketable yields were determined, the marketable one included compact main heads with closed flower buds of the colour characteristic for the used cultivar, free of any symptoms of disease or pest activity. The presence of small, delicate leaves was allowed provided they were green, healthy, and did not grow above the head surface more than 3 cm. First, middle and last harvesting times were investigated.

The obtained results were worked out statistically with Tukey's HSD test at $P<0.05$ and presented in the form of mean values from the three years of the experiment.

RESULTS AND DISCUSSION

No significant effect of the investigated factors on the length of the vegetation period from planting time until the particular phases of broccoli head harvest was demonstrated (Table 2). However, regardless of the storage period, vegetation period was slightly shorter for plants obtained from 8 and 10-week old transplants. On the other hand, irrespective of the transplant age, the length of vegetation period to the beginning of harvest was the same for both non-stored and stored transplants. However, in the case of transplants that were not stored in a cold room prior to planting, the period of time from transplant planting to mid and end of harvest was shorter by several days.

Table 2. The length of the vegetation period from the transplant planting to the first, middle and last harvests of broccoli heads depending on transplant age and storage period

Storage period (weeks)	Transplant age (weeks)			
	4	6	8	10
	Beginning of harvest			
0	67	64	62	63
1	68	67	66	64
2	68	61	62	61
	Mid harvest			
0	73	71	68	68
1	73	73	73	71
2	76	75	75	73
	End of harvest			
0	79	76	75	74
1	81	80	78	77
2	86	84	84	84

Transplant age had a significant effect on the total yield of broccoli heads. It was higher for plants cultivated from 4, 6 and 8-week old transplants as compared with plants obtained from 10-week old transplants. On the other hand, taking into account storage period, significantly higher yield was demonstrated in plants cultivated from transplants stored for one and two weeks than in plants cultivated from non-stored transplants (Table 3).

Table 3. Total yield (kg · 10 m^{-2}) of broccoli heads depending on the age of transplants and the storage period

Storage period (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	15.22 a	17.00 abc	17.04 abc	16.76 ab	16.51 A
1	21.55 f	19.95 ef	19.32 def	18.46 bcd	19.83 B
2	20.35 ef	19.89 ef	19.42 def	18.52 bcd	19.54 B
Mean	19.04 B	18.94 AB	18.60 AB	17.91 A	-

Note: Statistical analysis concerns each year separately; different letters within the same column indicate significant differences ($P<0.05$) between the means, capital letters - the effect of investigated factors, small letters - the effect of interaction of the investigated factors

The analysis of the interaction of the investigated factors demonstrated that highest yield was obtained for 4-week old transplants stored in a cold room (18.0 and 19.18 kg per 10 m^2) and 6-8 week transplants stored for 1 or 2 weeks (from 16.93-17.52 kg). Taking into account transplant age only, the highest yield was determined for plants obtained from 4-week old transplants and the lowest one for 10-week old transplants. However, regardless of the age, broccoli yield obtained from stored transplants was significantly higher than from non-stored transplants (Table 4).

Table 4. Marketable yield (kg · 10 m^{-2}) of broccoli heads depending on the age of transplants and the storage period

Storage period (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	14.24 a	14.99 ab	15.24 abc	14.48 a	14.74 A
1	19.18 e	17.52 cde	16.93 bcd	15.73 a-d	17.34 B
2	18.00 e	17.28 cde	17.20 cde	16.25 a-d	17.18 B
Mean	17.14 B	16.60 AB	16.46 AB	15.49 A	-

Note: see Table 3

Both transplant age and storage period had significant effect on broccoli head mass. Heads of greatest mass were obtained from 4-week old transplants stored for 1 and 2 weeks and 6-week old transplants stored for 2 weeks (Table 5). Regardless of the storage period, heads from 4 and 6-week old transplants had greater mass than heads of plants obtained from 8 and 10-week old transplants. Taking into account solely the storage period it was demonstrated that heads of a significantly higher mass were obtained from transplants stored for one and two weeks than from non-stored transplants.

Table 5. The effect of transplant age and the storage period on broccoli head mass (g)

Storage period (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	453 a	483 a	491 a	485 a	478 A
1	630 b	558 ab	541 ab	523 a	563 B
2	615 b	580 b	547 ab	529 a	568 B
Mean	566 B	540 AB	526 A	512 A	--

Note: see Table 3

No evident effect of transplant age on the percentage share of hollow stems was demonstrated. It varied from 30.3% in plants cultivated from 8-week old transplants to 35.8% in plants cultivated from 10-week old transplants (Table 6). Regardless of transplant age, a significantly higher amount of hollow stems was found in plants cultivated from non-stored transplants as well as transplants stored in a cold room for 2-weeks and the lowest in plants cultivated from transplants stored for 1 week.

Table 6. The effect of transplant age and storage period on presence of hollow stems in broccoli head (%)

Storage period (in weeks)	Transplant age (in weeks)				
	4	6	8	10	Mean
0	40.3 b	39.5 bc	29.4 a	37.6 b	36.7 B
1	30.3 a	27.2 a	29.2 a	29.5 a	29.1 A
2	29.0 a	32.2 ab	32.4 ab	40.4 bc	33.5 AB
Mean	33.2 AB	33.0 AB	30.3 A	35.8 B	-

Note: see Table 3

The results of many experiments regarding the transplant age of brassicas as well as other vegetables carried out in various regions of the world demonstrate that storage a transplant for the time longer than the optimum one of its growth usually leads to serious disturbances in further growth and development of plants, resulting in yield decrease (Wien 1997). It is assumed that the age of broccoli and cauliflower transplant in autumn cultivation should not exceed 5 weeks. Otherwise there is considerable risk of the plants' prematurely entering the phase of generative growth which may result in more buttoned heads (Schrader 2000). In case of cauliflower higher yield and fewer buttoned heads were obtained in the case of cultivation from younger transplants (Skąpski 1960-61, Skąpski & Oyer 1964, Wiebe 1981, Wurr & Fellows 1984). Taking into consideration all the above data, the results of the present experiment seem to be very promising, as they indicate the possibility of obtaining marketable yield from 10-week old transplants even after 2-week storage in a cold room (which actually means planting 14-week old transplants). To a certain degree, the present results confirm very spectacular results of Lamont (1992) who demonstrated that marketable yield can be obtained even from 30-week old trans-

plants and it be on the same level as in the case of 6-week old transplants. Thus, it can be said that among brassicas broccoli is an interesting exception. The discussion of the results regarding the effect of transplant storage in a cold room on the yield may pose some difficulties due to the lack of sufficient information on this matter. Jones *et al*. (1991) claim that transplant age had no effect on yield size in spring cultivation. Also Damato *et al*. (1994) demonstrated that transplant age (33-58 days) did not have effect on marketable yield. In the case of plants obtained from older transplants, the percentage of hollow stems was lower whereas in this experiment the effect of transplant age on this feature was not evident. In the experiment of Babik (2000), lowest yield was obtained from the oldest, 50-day old transplants as compared with 20-day old transplants. The decrease of the head mass with transplant age was also demonstrated in Italian experiments (Damato *et al*. 1994). Similar interrelations were demonstrated by Lewandowska (1992) for cauliflower. In the experiment of Wlazło & Kunicki (2003) higher yield was obtained in cultivation from 8-week old transplants than from 4 and 6-week old ones. However, Olson & Locascio (1990) did not demonstrate a significant effect of transplant age (3, 4, 5 and 6 weeks old) on broccoli yield. The present experiment, however, did not demonstrate a significant effect of transplant age on crop acceleration. It needs to be stressed though, that the period of time from transplant planting to first harvest was shorter in the case of plants obtained from older, 8 and 10-week old transplants. On the other hand, regardless of the transplant age, storage period had no significant effect on crop acceleration (first harvest after 63-66 days from transplant planting). In the previous experiment, though, a considerable tendency of this time becoming shorter with the transplant age was demonstrated. In the case of 10-week old transplants, 61 days passed from the time of planting (the beginning of July) to first harvesting and in the case of 4-week old seedlings 87 days (Wlazło & Kunicki 2003). Similar interrelations were demonstrated by Babik (2000) and Jones *et al*. (1991) who found that in the case of older seedlings (above 35 days old) the early crop was significantly higher for broccoli cultivated in autumn crop. On the other hand Damato *et al*. (1994) demonstrated the increase of the period from planting to the first harvest by 17 days in the case of plants obtained from older seedlings.

The results of the experiment can be deemed extremely promising by many broccoli producers. They indicate the possibility of obtaining marketable yield from 8 and 10-week old transplants, on the level comparable with the yield gained from 4-6-week old seedlings even after 2-week storage at 2°C in a cold room, with no access to light. This information is important due to the fact that sometimes conditions for transplant planting in the scheduled time are unsatisfactory in result of factors being beyond the control of the producer (delay of forecrop harvest, draught, intensive rainfalls, field flooding, etc.). In such situations, transplant storage for a relatively long period of time without losing its yield potential can contribute to avoiding economic loss.

CONCLUSIONS

1. Transplant age and storage period in a cold room had no significant effect on crop acceleration.
2. Plants obtained from 4-week old transplants gained marketable yield significantly higher than plants obtained from 10-week old transplants.
3. Significantly higher yield was obtained from transplants stored for 1 and 2 week period in a cold room as compared to non-stored transplants.
4. Highest head mass was demonstrated in plants cultivated from 4-week old transplants which differed considerably from head mass of plants from 8 and 10-week old transplants. Heads of significantly higher mass were obtained from plants cultivated from transplants stored for 1 and 2 weeks than in the case of plants obtained from transplants which were not stored in a cold room.
5. No univocal effect of the transplant age on the percentage share of hollow stem in broccoli heads was demonstrated. Regardless of the transplant age, significantly lowest hollow stem number was found in the case of the transplants stored for one week.

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WPŁYW WIEKU I OKRESU PRZECHOWYWANIA ROZSADY W CHŁODNI NA WZROST I JAKOŚĆ RÓŻ BROKUŁU

Streszczenie

W trzyletnim doświadczeniu badano wpływ wieku rozsady i okresu jej przetrzymywania na plonowanie brokułu odmiany 'Lord F_1'. Rozsadę przechowywano w chłodni bez dostępu światła w temperaturze +2ºC, wilgotności względnej powietrza 80-85%. Stwierdzono, że zarówno wiek rozsady jak i długość okresu jej przechowywania nie miał znaczącego wpływu na przyspieszenie plonowania. Rośliny otrzymane z rozsady 4-tygodniowej wydały plon handlowy istotnie większy niż z rozsady 10-tygodniowej. Stwierdzono istotnie większy plon u roślin uprawianych z rozsady przechowywanej w chłodni w porównaniu z rozsadą nie przechowywaną. Nie stwierdzono jednoznacznego wpływu wieku rozsady na liczbę pustych przestrzeni w łodygach róży.