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Breeding for early root thickening of radish (Raphanus sativus L. var. radicula Pers.) under poor light conditions. 1. Performance of F_1 half-sib families at different temperatures in late autumn

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Summary

As root thickening of radish cultivars under glass in late autumn and winter proceeds slowly, it was investigated if the growth rate of radish roots can be improved by selection. For this purpose half-sib families were produced from early thickening plants which had been selected out of 4 cultivars in late autumn. These families were sown out in autumn at 10, 14, 17 and 20 °C.

At higher temperature leaf production increased. The optimal temperature for root thickening was 14 °C.

From the results with the half-sib families it appeared that earliness can be improved by family selection, and that selection can be carried out most efficiently at about 14 °C.

Introduction

In the Netherlands there is increasing interest in growing radish in glasshouses in late autumn and winter. Under these conditions, however, the early Dutch radish cultivars mostly produce harvestable plants only after about 2 to 3 months, whereas in spring and summer this period lasts 3 to 6 weeks. Hence a breeding program was started to investigate the possibilities to shorten the growing period in autumn and winter by selection. For this purpose in late autumn out of a number of early Dutch radish cultivars plants were selected and propagated of which the roots thickened very early. The growth and earliness in autumn of these progenies were compared at a range of temperatures with those of the parent cultivars. The results are given in this paper.

Material and methods

The experiment described involved half-sib families from mother plants which had

been selected in a late autumn trial with early Dutch radish cultivars. In this trial at higher temperatures (17-26 °C) little root thickening and relatively much leaf production occurred (Nieuwhof, 1976). At these temperatures in some cultivars, however, a small number of plants started root thickening at a distinctly earlier date than most other plants. In December 1974, 30 of these early plants were selected, and flowered together in 1975 in an isolation room. Pollination of the plants was done by honey-bees. Seeds of 20 plants were harvested separately, the other 10 plants died prematurely.

The 20 F_1 half-sib families – 2 originating from 'Cherry Belle', 7 from 'Robijn', 5 from 'Rota' and 6 from 'Triplo' mother plants – and the 4 parent cultivars were sown on 2 October 1975 in temperature-controlled glasshouses of the IVT phytotron at 10, 14, 17 and 20 °C, in randomized blocks, with 3 replicates at each temperature, and on plots of 1 row with a length of 1 m, and a distance of 12 cm between rows and of about 2 cm between plants.

Records were made of the date of emergence, the size of the cotyledons (on 24 October; scale 2 to 9: 2 = $<$ 2.5, 3 = 2.5 - 3.5, 4 = 3.5 - 4.5, 5 = 4.5 - 6, 6 = 6 - 8, 7 = 8 - 11, 8 = 11 - 15, 9 = $>$ 15 cm²) and the length of leaves (on 3 November). Just before harvesting (on 10 November) of all plots root diameter was scored on a scale from 1 to 9 (1 = no root thickening, 2 = root Ø $<$ 4 mm, 3 = 4 - 8, 4 = 8 - 12, . . . , 9 = $>$ 28 mm).

As leaves at 14, 17 and 20 °C became heavily attacked by downy mildew, at these temperatures the plots had to be harvested prematurely from 11 to 14 November. Plots at 10 °C were harvested from 8 to 10 December. At harvest roots were scored again according to the scale mentioned above. After harvest at all temperatures fresh leaf and root weight of 5 families and 1 parent cultivar were determined.

Table 1. Effect of temperature on emergence, size of cotyledons and leaves (averages of 20 families and 4 parent cultivars) and on weight of leaves and roots (averages of 5 families and 1 parent cultivar).

	10 °C	14 °C	17 °C	20 °C
Days from sowing to emergence	8	5	5	3
Size of cotyledons[1] on 24 October	4.9	5.9	5.9	6.1
Length of leaves (cm) on 3 November	5.8	14.3	15.2	20.5
Root diameter[1] on 10 November	5.1	6.5	5.6	3.9
Weight (g) per plant at harvest[2]				
leaves	3.8	4.3	5.1	6.7
roots	6.1	3.5	2.5	0.9
Distribution (%) of plants over classes for root diameter (mm) at harvest[2]				
<12	6	29	45	76
12–16	12	33	29	14
16–20	43	23	17	6
20–24	31	11	6	3
>24	8	4	2	1

[1] Scale, see 'Material and methods'.
[2] Harvest at 10 °C on 8–10 December, and at 14, 17 and 20 °C on 11–13 November.

Table 2. Average root diameter at harvest of 4 parent cultivars and 20 half-sib families at 10, 14, 17 and 20 °C. Scale of root diameter: see 'Material and methods'.

		10 °C	14 °C	17 °C	20 °C	Average
Parent cultivars						
Cherry Belle		5.2	4.0	3.6	2.7	3.9
Robijn		6.3	5.2	4.9	3.3	4.9
Rota		7.0	5.2	5.1	3.6	5.2
Triplo		6.1	4.8	4.2	3.2	4.6
Half-sib families						
Cherry Belle	75127	6.1	5.1	4.9	3.2	4.8
Cherry Belle	75125	6.1	5.2	4.6	3.4	4.9
Robijn	75118	6.6	4.5	4.1	2.8	4.5
Robijn	75114	6.5	4.9	4.8	2.9	4.8
Robijn	75113	6.3	5.2	4.8	3.0	4.8
Robijn	75117	6.4	5.2	4.3	3.6	4.9
Robijn	75111	6.6	5.4	4.6	3.7	5.1
Robijn	75115	6.3	5.5	5.1	3.9	5.2
Robijn	75116	6.4	5.9	5.3	4.0	5.4
Rota	75108	6.0	4.7	4.3	3.0	4.5
Rota	75106	6.3	5.1	4.2	3.3	4.7
Rota	75109	6.4	5.0	4.8	3.2	4.8
Rota	75107	6.4	5.5	5.0	4.5	5.3
Rota	75110	6.7	6.0	5.5	4.2	5.6
Triplo	75124	6.2	4.6	3.9	2.8	4.4
Triplo	75123	5.9	4.6	4.1	3.6	4.5
Triplo	75122	6.1	4.9	4.4	3.7	4.8
Triplo	75120	6.4	5.1	4.5	3.4	4.9
Triplo	75119	6.3	5.5	4.7	3.6	5.0
Triplo	75121	6.2	5.6	4.9	3.4	5.0
Average half-sib families		6.3	5.2	4.6	3.5	
Coefficient of variation		3.7	6.2	8.1	13.4	
F half-sib families		2.4**	4.7**	3.8**	2.9*	
h^2_{BV} on family means		0.65	0.83	0.79	0.72	

* $P < 0.05$; ** $P < 0.01$.

Results

Effect of temperature on growth and development

Table 1 gives some average results at the 4 temperatures. At higher temperatures seedlings emerged earlier and larger cotyledons and leaves were formed.

The optimum temperature for root thickening was 14 °C. At this temperature a limited number of plants was already harvestable in mid November. Those at 10 °C could be harvested in the beginning of December. At 20 °C root thickening was very slow.

Table 3. Calculated and observed average root diameters of 4 groups of half sib families at 10, 14, 17 and 20 °C and the number of families with a larger (+) and a smaller (—) average root diameter than the calculated average, Scale of root diameter: see 'Material and methods'.

Number of families	Parent cultivar	10 °C		14 °C		17 °C		20 °C	
		calculated	observed	calculated	observed	calculated	observed	calculated	observed
2	Cherry Belle	5.7	6.1	4.5	5.2	4.1	4.8	3.0	3.3
7	Robijn	6.3	6.4	5.1	5.2	4.7	4.7	3.3	3.4
5	Rota	6.6	6.3	5.1	5.3	4.8	4.8	3.4	3.6
6	Triplo	6.2	6.2	4.9	5.1	4.4	4.4	3.3	3.4
Average		6.3	6.3	5.0	5.2	4.6	4.6	3.3	3.5
Number of families with larger (+) and smaller (—) root ø than calculated average		14+/6—		14+/6—		12+/8—		13+/7—	

Performance of parent cultivars and families

Growth of the parent cultivars did not differ essentially from that of these cultivars in a previous experiment (Nieuwhof, 1976). 'Rota' showed the fastest root growth and 'Cherry Belle' the slowest (Table 2).

Between families significant differences were assessed for size of the cotyledons, leaf length and earliness of root formation. These differences became less distinct at higher temperatures (decreasing F values for half-sibs).

Significant differences between families in average root diameter at harvest were also found (Table 2). The earliest families originated from mother plants selected out of the 2 earliest cultivars 'Rota' and 'Robijn'.

The heritability of the breeding value (h^2_{BV}) of this character on the basis of family means has been estimated, assuming that the families were half-sibs by the common male parent. As can be seen from Table 2, h^2_{BV}'s were larger at 14 and 17 °C than at 10 and 20 °C, but differences were rather small.

There was no clear influence of temperature on the order of the families for average root diameter at harvest. Only No 75118 formed an exception, coming second for root size at 10 °C, and practically lasts at higher temperatures.

Selection response

From the average root diameter of the 4 parent cultivars the average root diameter of the 4 corresponding groups of families can be calculated, assuming a proportional at random fertilization of the selected plants, an additive inheritance of root diameter and no effect of selection. Table 3 gives the calculated and the observed averages of the 4 groups of families and also the number of families with a larger and smaller root diameter than the calculated averages. It is evident that the differences between the calculated and observed averages for root diameter were small. These differences appeared to be largest for families with mother plants originating from the late cultivar 'Cherry Belle' and smallest for those originating from 'Robijn'. There was no distinct effect of temperature on the difference between calculated and observed diameters. About two-thirds of the families showed a positive deviation from the calculated root diameter. Some families were also somewhat earlier than the earliest of the 4 parent cultivars, viz 'Rota', except at 10 °C.

Conclusions

It is evident that by selection of radish plants with very early root thickening in November and December families can be obtained with a shorter growing period under poor light conditions than the parent cultivars. As h^2_{BV} was largest at 14 °C selection is best carried out at about this temperature. The high h^2_{BV}'s found imply that with this material half sib family selection is a promising procedure to improve earliness further.

Reference

Nieuwhof, M., 1976. The effect of temperature on growth and development of cultivars of radish under winter conditions. *Scientia Hort.* 5: 111-118.