

**SOME EFFECTS OF THE PHOTOPERIOD ON GROWTH
AND PITHINESS OF RADISHES**

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INTRODUCTION

There is much difference in the sensitivity of radish varieties to getting pithy. Sensitive types are used as well as resistant ones.

When sown early in the open (about March), varieties with a certain degree of resistance to pithiness are preferred. But when sown very early (e.g. January) under glass, professional men are not afraid to use very sensitive types, provided that they grow quickly.

It may be that this is justified by the tendency to harvest radishes grown under glass at an earlier stage of development than open air radishes. However, it also might be presumed that the difference in day length has some effect. It is well known that the flowering of radishes is mainly controlled by the length of day (1, 2, 3). If pithiness of the roots always preceded flowering, this could imply a day length influence on pithiness as well.

Therefore, as part of a programme to get a better basis for selection work, a study of growth and pithiness under different lengths of day was made.

MATERIALS AND METHODS

In the present experiments two varieties of A. R. ZWAAN & SONS were used: Cherry Belle, very resistant to pithiness, and Nr. 6205, a typical early variety that ripens quickly and easily becomes pithy. This is illustrated in Fig. 1, which shows the course of the percentage of pithy roots of both varieties in comparison with six varieties of ordinary sensitivity, in a field experiment.

The two varieties were sown on January 17, 1956, in rows in flat asbestos boxes fixed on small wheeled tables, called trucks. The seedlings were transplanted on February 8 and 9; each seedling in a pot of 8 cm diameter.

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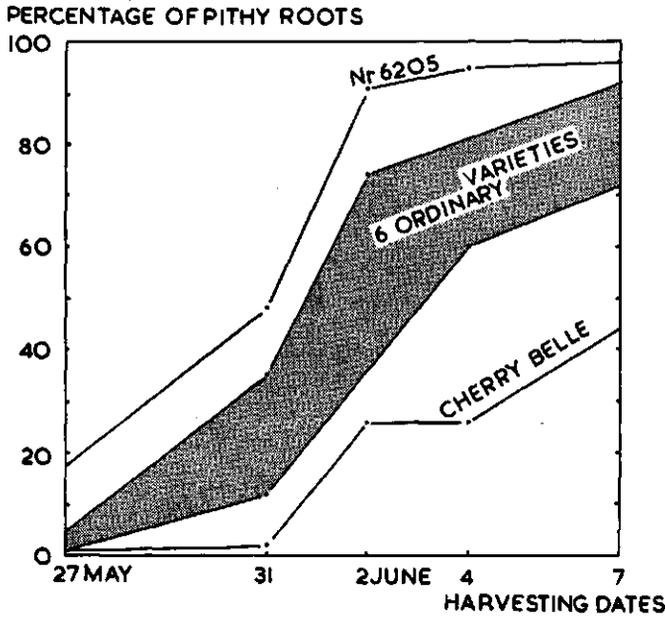


FIG. 1. COURSE OF THE PERCENTAGES OF PITHY ROOTS OF CHERRY BELLE, NR. 6205 AND SIX VARIETIES OF AN AVERAGE SENSITIVITY, IN A RANDOMIZED BLOCK EXPERIMENT (55 A). THE VARIETIES WERE SOWN AT APRIL 21, 1955

The experiments were carried out in the phytotron of our institute, and the day length treatment started on January 30. Every day, from 8 a.m. till 4 p.m., the plants were in a glasshouse kept at a constant temperature of 17°C, the maximum deviation from the mean temperature being about 1°C. At 4 p.m. all trucks were moved from the glasshouse to air-conditioned compartments kept at the same constant temperature, but here the maximum deviation from the mean temperature was about ½°C. In addition to the 8 hours of natural day light the plants received here 0, 2, 4, 6, 11, or 16 hours of artificial light. The following morning at 8 a.m. the trucks were returned to the glasshouse.

The artificial light in the air-conditioned compartments was provided by Philips fluorescent tubes, type white nr. 33. The radiant energy between 4000 and 7200 Å was about 6000 m W/m² at plant height.

Thus six different day lengths (8, 10, 12, 14, 19 and 24 hours) were given, all at 17°C. Each treatment was given to two trucks, each truck containing both varieties.

There were five successive harvests (February 27, and March 1, 5, 8, and 12), at each of which 12 plants of Cherry Belle and 10 plants of Nr. 6205 were pulled per truck.

Plants were classified for bolting and signs of pithiness or woodiness. The weights of the root and foliage were recorded for each individual plant, and, at the first three harvests, all leaves of each harvested plant were phototyped.

BOLTING AND PITHINESS AT DIFFERENT LENGTHS OF DAY

The proportion of plants bolting and/or pithy of each treatment were expressed as average percentages. They are shown in Table 1.

TABLE 1. BOLTING AND PITHY PLANTS EXPRESSED IN PERCENTAGES OF TOTAL NUMBER OF PLANTS PER TREATMENT

Variety	Length of day	Percentage of bolting plants in harvest no.					Percentage of pithy roots in harvest no.				
		1	2	3	4	5	1	2	3	4	5
Cherry Belle	8 hours	0	0	0	0	4	0	0	4	8	25
	10 "	0	8	0	0	4	0	0	13	21	42
	12 "	0	0	0	0	0	0	0	8	13	63
	14 "	0	0	0	4	4	0	0	17	17	33
	19 "	25	29	21	54	67	0	0	8	21	38
	24 "	54	58	65	79	96	0	0	39	38	50
Nr. 6205	8 hours	0	0	0	0	10	0	5	10	70	80
	10 "	0	0	0	0	15	0	10	40	70	90
	12 "	0	0	16	0	15	0	20	53	85	95
	14 "	0	5	20	35	45	0	5	30	50	80
	19 "	10	50	30	95	80	0	5	35	45	80
	24 "	30	70	80	100	95	0	10	60	45	90

Apart from a few irregularities which can be ascribed to the heterozygous nature of this heterogamous plant, bolting shows a fair response to day length. Both varieties show an increasing percentage of bolters at the longer day lengths from the first harvest, with the highest percentages at 24 hours. At 14 hours Nr. 6205 starts bolting in the second harvest, whereas Cherry Belle does not do so until the fourth harvest. At the shorter day lengths bolting of both varieties seems to start in the fifth harvest.

Pithiness does not show any direct relation to the length of day. At some day lengths pithiness is more severe, but it is not proportional to the length of the daily photo-period.

As every individual plant was inspected for bolting, pithiness, and woodiness, it can be ascertained whether bolting is associated with either of the other two characters. The results have been classified in Table 2.

In the successive harvests the ratio not pithy / pithy roots of Cherry Belle is 19: 0, 21: 0, 15: 5, 24: 9 and 28: 14; of Nr. 6205 it is 8: 0, 23: 1, 20: 9, 25: 21 and 11: 41.

As most plants have bolted without being pithy, this is additional evidence to that of Table 1 that pithiness is not a preliminary of flowering in radishes.

Woodiness does not necessarily precede bolting either. Of Cherry Belle 102 bolters were not woody against 33 that were woody. For Nr. 6205 this ratio is 102: 57. There is a slight increase of woody roots in the successive harvests.

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TABLE 2. DISTRIBUTION OF THE NUMBERS OF BOLTED PLANTS AMONG FOUR CLASSES: "NOT PITHY NOT WOODY", "NOT PITHY WOODY", "PITHY NOT WOODY", AND "PITHY WOODY"

Harvest nr.	Pithy	Woody	Cherry Belle	Nr. 6205
1	-	-	15	4
	-	+	4	4
	+	-	0	0
	+	+	0	0
2	-	-	17	12
	-	+	4	11
	+	-	0	1
	+	+	0	0
3	-	-	10	11
	-	+	5	9
	+	-	5	8
	+	+	0	1
4	-	-	15	10
	-	+	9	15
	+	-	9	18
	+	+	0	3
5	-	-	17	9
	-	+	11	2
	+	-	14	29
	+	+	0	12

GROWTH RATE AT DIFFERENT LENGTHS OF DAY

At the first three harvests the leaves of every plant were phototyped, so that their size and number could be studied later on. Together with the root and foliage weights these data can give a fairly good idea of the type of growth of the plants up to the third harvest.

Table 3 gives average root weights, average foliage weights and average numbers of leaves per plant.

Evidently the growth rate of the plants increases with daylengths from 8 to 12 hours. Looking at the averages of the three harvests the root weights at 12 hours are greater than at 10 hours; at 10 hours they are also greater than at 8 hours, but here the difference is smaller. At 14 and 19 hours they drop about to the level of 8 and 10 hours, with this restriction that the root weight of Cherry Belle is somewhat higher at 14 hours.

The root weights at 24 hours are considerably higher, but the average of the three harvests does not reach the level of that at 12 hours. In the first harvest the average root weights at 24 hours were at least at the level of those at 12 hours, but their increase in the following harvests becomes less and less; for Nr. 6205 the root weight at 24 hours is lower than that at 12 hours in the second harvest, whereas for both varieties they are lower in the third harvest.

Probably it is the interaction with the condition that leads to bolting that gives a reduction in the growth rate at the three longer day lengths. It is remarkable that this

TABLE 3. GROWTH RATE OF ROOTS AND FOLIAGE UP TO THE THIRD HARVEST

Length of day		Cherry Belle in harvest nr.				Nr. 6205 in harvest nr.			
		1	2	3	Av.	1	2	3	Av.
8 hours	Average root weight (g)	1.05	1.97	3.21	2.08	1.86	2.01	4.25	2.71
	Av. foliage weight (g) . .	2.17	2.36	3.00	2.51	1.83	2.34	3.75	2.64
	Average leaf number . .	4.8	4.8	5.8	5.1	5.0	5.2	6.9	5.7
10 hours	Average root weight (g)	1.58	2.07	3.37	2.34	1.61	2.89	4.43	2.98
	Av. foliage weight (g) . .	2.26	2.60	3.11	2.66	2.34	2.25	3.01	2.53
	Average leaf number . .	5.1	5.1	5.3	5.2	5.1	5.0	5.8	5.3
12 hours	Average root weight (g)	1.91	2.36	4.53	2.93	2.74	3.76	5.76	4.09
	Av. foliage weight (g) . .	2.75	3.27	3.73	3.25	2.47	3.23	3.97	3.56
	Average leaf number . .	4.8	5.4	5.4	5.2	4.7	5.3	5.6	5.2
14 hours	Average root weight (g)	1.53	2.39	4.01	2.64	1.64	2.49	3.67	2.60
	Av. foliage weight (g) . .	2.45	2.87	3.52	2.95	2.33	2.83	3.70	2.95
	Average leaf number . .	4.4	5.0	5.4	4.9	5.1	5.1	5.6	5.3
19 hours	Average root weight (g)	1.54	1.75	3.36	2.22	1.74	2.52	4.12	2.79
	Av. foliage weight (g) . .	2.62	3.57	4.31	3.50	3.09	4.13	4.71	3.96
	Average leaf number . .	5.0	5.0	5.6	5.2	5.1	5.1	5.3	5.2
24 hours	Average root weight (g)	1.99	2.59	3.98	2.85	2.83	3.51	5.22	3.85
	Av. foliage weight (g) . .	3.45	4.09	5.47	4.34	3.69	5.90	7.67	5.75
	Average leaf number . .	5.0	5.3	5.5	5.3	5.0	5.4	5.7	5.4
Average	Average root weight (g)	1.60	2.19	3.74	2.51	2.07	2.86	4.44	3.17
	Av. foliage weight (g) . .	2.62	3.12	3.86	3.20	2.63	3.45	4.47	3.54
	Average leaf number . .	4.9	5.1	5.5	5.2	5.0	5.2	5.6	5.3

effect is also visible at 14 hours, when bolting only occurs in later harvests. But the opinion that the growth rate is reduced by the induction of the bolting condition, is corroborated by the fact that the root weight of Cherry Belle at 14 hours is reduced less than that of Nr. 6205 at the same day length. As Table 1 shows, with day lengths of 14 hours, Nr. 6205 begins to bolt at an earlier harvest than Cherry Belle.

In days of 8, 10 and 12 hours the foliage weight has a tendency to increase with the increase in the length of day. At the day length of 14 hours the foliage weight of both varieties drops below the level of that at 12 hours: at 19 and 24 hours it is much higher. This is partly caused by the development of flower stalks at 19 and 24 hours.

Table 3 shows that the number of leaves is essentially the same at all day lengths, and Figures 2 and 3 show that the size of the leaves is gradually increasing with the increase of day length. This is in agreement with the results of WEAVER and HIMMEL (4) with the radish variety White Icicle. So it is the increase in the size of the leaves (not in the number of leaves) under the influence of day length that causes a higher foliage weight. The greater size of the leaves evidently causes a higher growth rate of the roots in cases where this is not reduced by the induction of the bolting condition.

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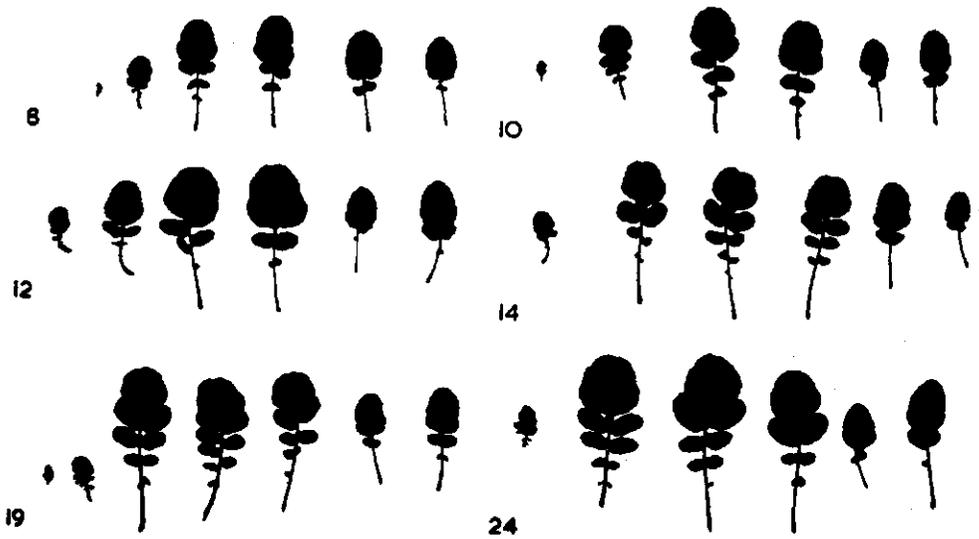


FIG. 2. CHERRY BELLE AT SIX DAY LENGTHS. PHOTOTYPED LEAVES OF ONE PLANT PER DAY LENGTH, IN EACH CASE REPRESENTING AS MUCH AS POSSIBLE THE AVERAGE SIZE. DAY LENGTHS ARE INDICATED BY THE NUMBERS 8, 10, 12, 14, 19, 24.

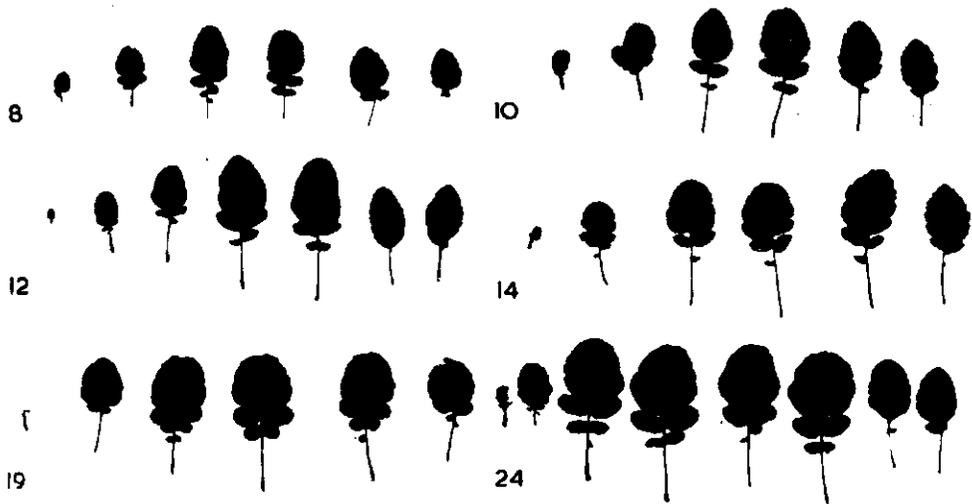


FIG. 3. NR. 6205 AT SIX DAY LENGTHS. PHOTOTYPED LEAVES AS IN FIG. 2.

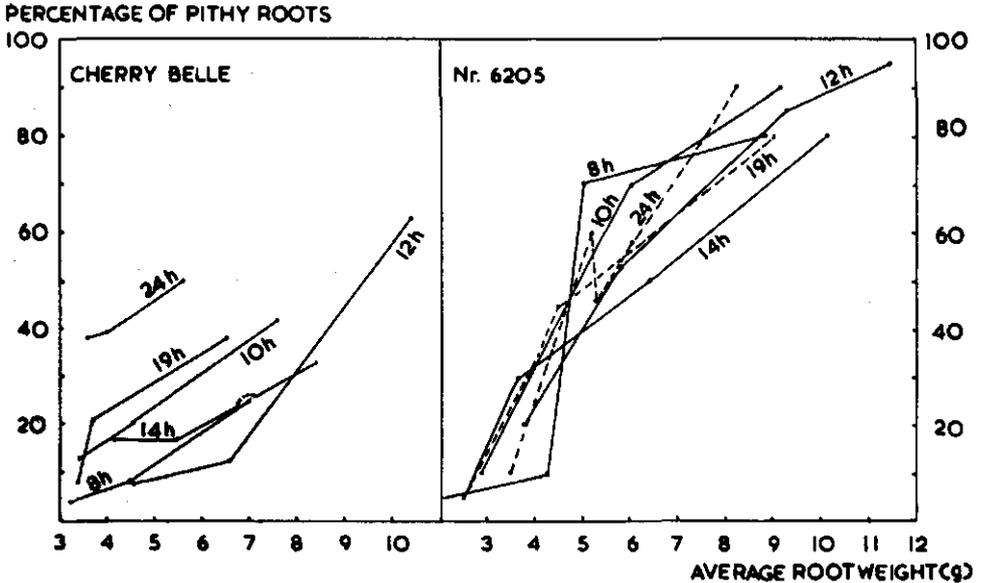


FIG. 4. RELATION BETWEEN PERCENTAGE OF PITHY ROOTS AND AVERAGE ROOT WEIGHT AT THE DIFFERENT LENGTHS OF DAY

GROWTH RATE AND PITHINESS OF THE ROOTS

General experience has shown that the chance of becoming pithy increases with the size of the radishes. As we have seen that the growth rate of the roots tends to become greater with increasing day length (in the absence of bolting), it may be useful to look for a possible relation between the size of the roots and the percentage of pithiness. Therefore in Fig. 4 the percentage of pithy roots (Table 1) has been plotted against the average root weight (Table 3).

With Nr. 6205 we see a strong relation between the average root weight and the percentage of pithy roots. This percentage rises with average root weight. Evidently the differences in pithiness expressed in Table 1 can largely be explained on the basis of different root sizes.

With Cherry Belle the situation seems to be more complicated. For the day lengths of 8 to 19 hours the same relationship may hold, though it is not shown as clearly as with Nr. 6205. But the curve of the day length of 24 hours seems to indicate too high a percentage of pithiness for the average root weight that is attained. A possible explanation is suggested by the fact that at the day length of 24 hours Cherry Belle had an exceptionally high proportion of very small roots. The distribution of these small roots in the last three harvests was as follows (Table 4).

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TABLE 4. DISTRIBUTION OF CHERRY BELLE ROOTS AT THE DAY LENGTH OF 24 HOURS

	Size	Number of roots in harvest nr				Average root weights in grammes
		3	4	5	Sum	
Not pithy	Large	5	7	3	15	7.6
	Small	10	12	9	31	1.9
Pithy	Large	4	2	8	14	8.7
	Small	4	3	4	11	3.4

Of the non-pithy roots there were 31 very small, mostly early bolters, but some lagging behind for some other reason. The high proportion of these very small roots, which were not observed in such quantity in any of the other cases, certainly has exerted a depressing influence on the average root weight.

For comparison the percentages of small roots at all the day lengths in the last three harvests have been reproduced in Table 5, for both varieties.

TABLE 5. NUMBER OF SMALL ROOTS IN THE THIRD, FOURTH, AND FIFTH HARVEST, EXPRESSED AS A PERCENTAGE OF TOTAL NUMBER OF ROOTS

Day length (hours)	Cherry Belle			Nr. 6205		
	Small roots	Proportion of small roots bolting	Proportion of small roots pithy	Small roots	Proportion of small roots bolting	Proportion of small roots pithy
8	15%	—	18%	8%	—	—
10	13%	—	—	2%	—	100%
12	13%	—	—	9%	20%	60%
14	18%	8%	23%	13%	50%	—
19	31%	82%	5%	20%	92%	—
24	61%	86%	34%	23%	100%	29%

Evidently, in most cases, small roots were the result of early bolting.

SUMMARY

1. The influence of six different day lengths at 17°C on growth and pithiness of two radish varieties was studied.
2. In accordance with earlier investigations bolting gave a clear response to day length. At day lengths of 19 and 24 hours the plants bolted very quickly, at 14 hours more slowly, and at 8, 10 and 12 hours very slowly.
3. There was no direct influence of day length on the degree of pithiness. To some degree there was an indirect influence via the growth rate of the roots as the chance of getting pithy increased with the increase in size of the roots.
4. The number of leaves was essentially the same at all day lengths, but their size increased with longer day length. This evidently was the cause of a higher growth rate of the roots at longer days, in those cases where the bolting condition of the plants had not yet been induced. At the day lengths of 14, 19 and 24 hours the induction of the bolting condition reduced the growth rate of the roots very appreciably.

SAMENVATTING

Invloed van de daglengte op de groei en voosheid van radijs

1. De invloed van zes verschillende daglengten bij 17°C op de groei en de voosheid van twee radijsrassen werd nagegaan.
2. In overeenstemming met vroegere onderzoeken reageerde het schieten van de planten duidelijk op de daglengte. Bij een daglengte van 19 en 24 uren schoten de planten zeer vlug, bij 14 uren langzamer en bij 8, 10 en 12 uren zeer langzaam.
3. De daglengte had geen directe invloed op de mate van voosheid. Tot op zekere hoogte was een indirecte invloed te herkennen via de groeisnelheid van de knollen, daar de kans op voosheid toeneemt naarmate de knollen groter zijn.
4. Het aantal bladeren per plant was bij alle daglengten ongeveer gelijk, maar de bladeren waren groter naarmate de daglengte groter was. Dit was kennelijk de oorzaak van een snellere knolgroei bij langere daglengte, welke optrad in die gevallen waarin de planten nog niet tot doorschieten waren geïnduceerd. Bij een daglengte van 14, 19 en 24 uren, waar de planten al vroeg tot schieten waren geïnduceerd, had namelijk duidelijk een reductie van de knolgroei plaats gevonden.

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¹⁾ Zolang de voorraad strekt kunnen deze publikaties franco worden toegezonden, na ontvangst van het vermelde bedrag op giro no. 425340 van het Instituut voor de Veredeling van Tuinbouwgewassen, S. L. Mansholtlaan 15 te Wageningen onder vermelding van wat verlangd wordt; ook bestaat de mogelijkheid deze publikaties uit de bibliotheek van het I.V.T. te lenen.

²⁾ Eerder verschenen publikaties zijn vermeld achterin in de Mededelingen nos 1 t/m 70.