

DETERMINATION OF THE GENETIC VARIATION IN THE EFFECT OF TEMPERATURE AND DAYLENGTH ON BOLTING OF *BRASSICA* *CAMPESTRIS* L.

Q. P. VANDERMEER and R. VANDAM

Institute for Horticultural Plant Breeding (IVT), Mansholtlaan 15, 6700 AA Wageningen, the Netherlands

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SUMMARY

Effects of temperature and daylength on the bolting of a number of *B. campestris* accessions were investigated both in the open and in the IVT phytotron. From the results it was concluded that low temperature and genotype are the predominant factors with respect to bolting. Daylength has rather limited influence. One cultivar bolted more than 12 weeks earlier at 10 and 14°C than at 18°C. On the other hand some cultivars did not require vernalization at all.

At 14°C and short daylength, depending on genotype, the period of time between sowing and 50% bolting ranged from 8 to 30 weeks. At this temperature the stimulating effect of long day (24 h), depending again on the genotype, ranged from 0 to 4 weeks. The genotypes most resistant to bolting appeared to be the stubble turnips (*B. campestris* ssp. *rapa*).

In terms of seed(ling) vernalization at 5°C the cold requirement ranged from 0 to more than 3 weeks, depending on the genotype. The required vernalization periods at 5°C can be used as a criterion in screening for resistance to bolting.

INTRODUCTION

The cultivation of Chinese cabbage (*B. campestris* ssp. *pekinensis*) in the Netherlands is severely hampered by bolting, both under glass and in the open. Especially in the open a large variation in bolting behaviour can be observed.

Bolting of Chinese cabbage is strongly influenced by temperature and to a smaller extent by daylength (LORENZ, 1946; ZEE, 1975; ANONYM, 1976; GUTTORMSEN, 1981; ELMERS, 1982; KRUG & KLING, 1982).

Five experiments were performed to determine the genetic variation for bolting in *B. campestris* and to find a method of screening for resistance to bolting.

MATERIAL AND METHODS

Experiment 1. To screen for resistance to bolting under normal growing conditions 57 *B. campestris* accessions, seven stubble turnip cultivars (ssp. *rapa*), 49 Chinese cabbage cultivars (ssp. *pekinensis*), and one paksoi cultivar (ssp. *chinensis*) - were sown

in the open in the middle of March, April, May, June, July and August 1979, with experimental units of 12 plants. The mean temperatures in March, April, May, June, July, August, September and October were ca 5, 8, 12, 15, 16, 15, 13 and 11°C respectively.

Experiment 2. To study the effect of different temperatures (10, 14, and 18°C) various types of *B. campestris* (*B. campestris* ssp. *chinensis*, *pekinensis* and *rapa*) were sown under greenhouse conditions in the IVT phytotron on different dates. Experimental units consisted of 5 to 15 plants.

Experiment 3. To compare more exactly the cold requirement of different genotypes, sowing was done at 10°C in a greenhouse of the phytotron on April 16, 1982, and 10 plants of each genotype were transferred to 22°C after varying periods of time. Because of tipburn and mildew at 22°C plants could not be grown for more than 10 weeks.

Experiment 4. During the winter and spring of 1983 the effect of seedling vernalization was investigated on a number of *B. campestris* genotypes. Sowing in pots was done on January 27. Directly after sowing the pots were placed at 5°C in the dark for zero, one, two, three, four or five weeks respectively. After cold treatment plants were placed in a greenhouse at about 20°C. The experimental units were 17 plants.

Experiment 5. To study the daylength effect 13 accessions were sown at 14°C in a greenhouse of the phytotron on September 28, 1983. Because the daylength effect was supposed to be rather weak, extreme differences in illumination periods were realized. Of each accession 12 plants received natural daylight (decreasing from about 12 hours in September to about 9 hours in December) and 12 plants received continuous light. The latter was achieved by supplementing the natural daylight with one incandescent lamp of 60 Watts per m² at 1 m above the soil surface from half an hour before sunset till half an hour after sunrise.

The observations on bolting were made weekly. A plant was qualified as 'bolting' when flower stalk formation became manifest.

Table 1. Bolting (+) and non-bolting (-) of 57 *Brassica campestris* accessions sown in the open on six different dates.

Category no.	Number of accessions	Number of subspecies			Sowing date					
		<i>rapa</i>	<i>pekinensis</i>	<i>chinensis</i>	March 19	April 12	May 11	June 11	July 11	August 11
1	10	7	3		+	+	-	-	-	-
2	7		7		+	+	+	-	-	-
3	25		25		+	+	+	+	-	-
4	13		12	1	+	+	+	+	+	-
5	2		2		+	+	+	+	+	+

¹ A + was given to an accession when 1 or more of its (12) plants showed bolting.

Table 2. Number of weeks between sowing and 50% bolting of different *Brassica campestris* types at three temperatures under greenhouse conditions.

Sowing data	<i>Brassica campestris</i> ssp.	Cultivar	Origin	10°C	14°C	18°C
August 16, 1979	<i>chinensis</i>	Buk tai	Fair Bank (Australia)	12	12	20
	<i>pekinensis</i>	Granaat	Pannevis (Netherl.)	15	17	—
May 22, 1980	<i>chinensis</i>	Buk Tai	Fair Bank (Australia)	10	11	13
	<i>pekinensis</i>	anonymous	Thailand	8	7	6
March 3, 1981	<i>chinensis</i>	Buk Tai	Fair Bank (Australia)	10	9	14
	<i>rapa</i>	Taronda	Zelder (Netherl.)	20	20	> 32
August 4, 1981	<i>chinensis</i>	Buk Tai	Fair Bank (Australia)	12	14	22
	<i>rapa</i>	Vobra	Mommersteeg (Neth.)	24	30	> 34

RESULTS

Experiment 1. From Table 1 it can be seen that later sowing in the open resulted in less bolting. Very pronounced differences in resistance to bolting occurred between Chinese cabbage cultivars, some being very susceptible (category 5) and some very resistant (category 1). One of the three Chinese cabbage accessions (J S 84 from AVRDC, Taiwan) that were most resistant to bolting was released to Dutch seed firms engaged in the breeding of Chinese cabbage. High resistance to bolting was also found in stubble turnips (*B. campestris* ssp. *rapa*).

Experiment 2. Table 2 shows that in general the periods between sowing and bolting at 10 and 14°C did not differ much, but 18°C resulted in a remarkably longer period.

The Chinese cabbage (ssp. *pekinensis*) accession from Thailand was temperature neutral in this respect whereas stubble turnips again showed a very pronounced cold requirement.

Experiment 3. Table 3 gives the effect on bolting of combined temperature treatments at 10°C and 22°C. Plants standing for some weeks at 10°C and afterwards at 22°C bolted faster than those at a continuous temperature of 22°C. Like in experiment 2, low temperature stimulated bolting. Again the Chinese cabbage cultivar from Thailand and the stubble turnips differed extremely in cold requirement. For the other

Table 3. Number of weeks between sowing and 50% bolting of different *Brassica campestris* types after pre-treatment for varying periods at 10°C and subsequent growing at 22°C.

<i>Brassica campestris</i> ssp.	Cultivar	Origin	Constant 22°C				
			2 weeks 10°C	4 weeks 10°C	6 weeks 10°C	Constant 10°C	
<i>chinensis</i>	Buk Tai	Fair Bank (Austr.)	> 10	9	8	8	10
<i>pekinensis</i>	anonymous	Thailand	5	4	5	6	6
<i>pekinensis</i>	Granaat	Royal Sluis (Neth.)	> 10	9	7	8	10
<i>pekinensis</i>	Nagaoka Early	Takii (Japan)	> 10	10	7	8	10
<i>rapa</i>	Vobra	Mommersteeg (Neth.)	> 10	> 12	> 14	> 16	31

Table 4. Number of weeks between sowing and 50% bolting of different *Brassica campestris* types after pre-treatment for varying periods at 5°C and subsequent growing at 20°C.

<i>Brassica campestris</i> ssp.	Cultivar	Origin	Duration (in weeks) of cold treatment (5°C in the dark)					
			0	1	2	3	4	5
<i>chinensis</i>	Buk Tai	Fair Bank (Austr.)	15	15	10	10	10	10
<i>chinensis</i>	Spoon Pak Soi	Van der Berg (Neth.)	13	13	10	10	11	11
<i>chinensis</i>	Gracious	Know-your Seed (Taiwan)	8	8	7	7	9	10
<i>chinensis</i>	Chiang Chiang	Know-your Seed (Taiwan)	12	12	9	8	9	9
<i>chinensis</i>	Spoon Pak Soi (strain) IVT (Neth.)	IVT (Neth.)	10	9	7	8	9	10
<i>chinensis</i>	Bin Hup (strain)	IVT (Neth.)	10	9	7	8	9	10
<i>pekinensis</i>	WR 60	Takii (Japan)	>16	>16	11	10	10	10
<i>pekinensis</i>	Granaat	Royal Sluis (Neth.)	15	13	9	9	9	10
<i>pekinensis</i>	JS 84	AVRDC (Taiwan)	>16	>16	15	12	11	11
<i>pekinensis</i>	anonymous	—(Thailand)	7	7	6	9	9	9
<i>rapa</i>	Taronda	Zelder (Neth.)	>16	>16	>16	>16	>16 ¹	>16 ¹

¹ At the end of the experiment for *B.c. rapa* only cold treatment for 4 and 5 weeks had resulted in some bolting, namely about 40%.

Table 5. Number of weeks between sowing and 50% bolting of different *Brassica campestris* types in short and long days under autumn- and winterlight conditions at 14°C in a greenhouse.

<i>Brassica campestris</i> ssp.	Cultivar	Origin	Weeks between sowing and 50% bolting	
			Short Day	Long Day
<i>chinensis</i>	Tai Sai	Takita (Japan)	17	17
<i>chinensis</i>	Spoon Pak Soi	Van der Berg (Neth.)	18	14
<i>chinensis</i>	Buk Tai	Fair Bank (Austral.)	18	17
<i>chinensis</i>	Bin Hup (strain)	IVT (Neth.)	12	10
<i>chinensis</i>	Spoon Pak Soi (strain)	IVT (Neth.)	11	10
<i>chinensis</i>	Gracious	Know-your Seed (Taiwan)	10	8
<i>chinensis</i>	Ching Chiang	Know-your Seed (Taiwan)	15	12
<i>pekinensis</i>	anonymous	Thailand	8	7
<i>pekinensis</i>	Winter Knight	Sakata (Japan)	19	18
<i>pekinensis</i>	WR 60	Takii (Japan)	19	17
<i>pekinensis</i>	Granaat	Royal Sluis (Neth.)	17	14
<i>pekinensis</i>	JS 84	AVRDC (Taiwan)	18	18
<i>rapa</i>	Taronda	Zelder (Neth.)	24	24

three accessions two weeks at 10°C were enough for vernalization, whereas four or six weeks at 10°C resulted in the shortest interval between sowing and bolting.

Experiment 4. From Table 4 it can be concluded that for most accessions seedling vernalization clearly shortened the period between sowing and bolting. However in

some cases vernalizing for more than three weeks extended this period because of the slow formation of flower stalks at 5°C ('Gracious' and 'anonymous'). Again pronounced differences in bolting resistance were found.

Experiment 5. Table 5 shows that very long days can stimulate bolting. In general this stimulation was rather limited in comparison with the temperature effect. Three genotypes did not react at all to daylength.

DISCUSSION AND CONCLUSIONS

Temperature and genotypes appeared to be the main factors determining bolting in *Brassica campestris*. Depending on cultivar, daylength appeared to have less, if any, influence. These results agree with the results of ELMERS (1982) and KRUG & KLING (1982).

BREMER (1934) and GUTTORMSEN (1981) found a more pronounced influence of long days. However, in their experiments natural long days were applied and short days were realized by darkening. This approach was relatively inaccurate because, by doing so, the influence of long days was confounded with the influence of much higher light quantities.

Different subspecies and cultivars show a very wide variation in cold requirement. The high resistance to bolting in stubble turnips might be used to adapt Chinese cabbage to cultivation at cool temperatures in high latitudes (45°C and higher) during spring and early summer.

In view of the above results the following method of screening for bolting resistance is proposed for breeding purposes. After sowing in pots the germinating seeds must receive a two-week cold treatment at 5°C. Subsequently, the seedlings are placed in a greenhouse at about 20°C, preferably at long days. Only the plants that are most resistant to bolting will not bolt within 10 weeks at this temperature. For seed production these plants receive an additional vernalization treatment for six weeks at 5°C whereafter they will bolt within eight weeks at 20°C.

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