Determination of a Pre-Vernalization Phase in Carrot (*Daucus carota* L.) cv. Flakkee[1]

G. Galmarini, R. Borgo*, R. Tizio***

ABSTRACT

The present study was conducted to determine the presence of a prevernalization phase in carrot (*Daucus carota* L. cv. Flakkee), before vernalization at low temperatures. Carrot plants and seedlings in the following phenological stages: 9 to 10, 7 to 8, 5 to 6, 3 to 4, 1 to 2 leaves and in cotyledon stage, grown under long-day conditions (14 h, 280 Umol $s^{-1}m^{-2}$) and temperatures ranging from 25°± 1°C day and 20°± 1°C night, were simultaneously exposed at low temperatures (7° ± 1°C day and 5° ± 1°C night) and short days (10 h, 280 Umol s^{-1} m^{-2}) during 55 days. In addition, germinating and dried seeds were also treated. Later, the plants were exposed to long days (16 h) and 25° ± 1°C day and 20° ± 1°C nights. Only those plants which were at the stage of 9 to 10 leaves at the beginning of the cold treatment bolted and flowered normally. This indicates that cv. Flakkee has a pre-vernalization phase which lasts until the 9 to 10-leaf stage is reached.

COMPENDIO

El presente trabajo fue realizado con el fin de determinar la existencia de una fase de prevernalización en *Daucus carota* L. cv. Flakkee. Se utilizaron plantas de zanahoria en los siguientes estados fenológicos: 9 a 10 hojas, 7 a 8 hojas, 5 a 6 hojas, 3 a 4 hojas, 1 a 2 hojas y en estado cotiledonar, que crecieron en condiciones de días largos (14 h, 280 Umol s^{-1} m^{-2}) en temperaturas de 25°C ± 1°C en la luz y 20°±1°C en la oscuridad, y fueron expuestas simultáneamente a condiciones con bajas temperaturas (7° ± 1°C en la luz y 5° ± 1°C en la oscuridad) y días cortos (10 h, 280 Umol s^{-1} m^{-2}) durante 55 días. De igual manera fueron tratadas las semillas secas en estado avanzado de germinación. Posteriormente todo el material se sometió al tratamiento de días largos (16 h) bajo el mismo régimen térmico de 25°C en la luz y 20°C en la oscuridad. Sólo las plantas correspondientes al estado de 9 a 10 hojas entallaron y florecieron al inicio del tratamiento en frío. Estos hechos indican que el cv. Flakkee posee una fase de prevernalización que culmina con la emisión de la novena a décima hojas.

INTRODUCTION

Carrots, vegetative rosette plants, have been classified as day-neutral plants with a vernalization requirement necessary for flower initiation (2, 4, 12, 13). Atherton *et al.* (1) suggested that carrots are short-day (SD)-long-day (LD) plants, with cold requirements to flower.

In Argentina, carrots of European origin have a biennial behavior; that is, seed sown in "La Consulta" (Mendoza, 33°44'S) in April remain in the rosette stage during spring and summer. The shoot is vernalized the next winter and flowering occurs during the spring of the second year. Other groups of carrots, the "Criolla-type" population, have a high percentage of bolting during the same sowing year, even when the carrots are sown in the late winter or early spring. Lona and Crnko (8) suggested that European carrots have a long pre-vernalization phase, which might be absent in the "Criolla-type" population.

The minimum vernalization treatment required for carrot flower initiation and carrot seedstalk development in cultivars like Chantenay, French Forcing, Nantes and Imperator varies between periods of 15 to 60 days at temperatures ranging from 4°C to 15°C (9). Several authors agree that carrots must reach a certain stage of development before low temperatures can be effective in promoting flowering (3, 6, 8, 14). On the other hand, Kumaki (7) was able to vernalize carrot seeds. He exposed them to temperatures of 2°C to 3°C during three months. No reports have been published on vernalization requirements in cv. Flakkee.

The aim of our work was to determine the existence of a prevernalization phase in cv. Flakkee measured in chronological age and number of leaves under controlled conditions. This will contribute to the adjustment of sowing dates for seed production, especially for the "seed-to-seed" method.

---

1 Received for publication 20 April 1990.
This research was supported by a financial grant no. 5050925/85 of *Consejo Nacional de Investigaciones Científicas y Técnicas* (CONICET), Arg.

* Research scientist, *Estación Experimental La Consulta*, INTA, Mendoza, Arg.

** Laboratorio de Fisiología Vegetal, Facultad de Ciencias Agrarias, Universidad Nacional de Cuyo (5505), Chacras de Coria, Mendoza, Arg.

MATERIAL AND METHODS

Carrot seeds of cv. Flakkee were periodically sown in flats containing a mixture of peat, soil and sand (1:1:1). When the seedlings reached the second leaf stage, they were individually potted in 950 cm^3 containers. Plants were grown in a Sherer Growth Chamber Model Cel 512-37 (Sherer-Gillette Co.), at temperatures of 25°C ± 1°C/day and 20°C ± 1°C/night, under long photoperiods (14 h, PAR:280 Umol s^{-1} m^{-2} provided by cool white fluorescent tubes and incandescent lamps. Thereafter, 20 plants from each of the following phenological stages: 1 to 2, 3 to 4, 5 to 6, 7 to 8, 9 to 10 leaves and at the cotyledonary stage were simultaneously exposed to low temperatures (7°C ± 1°C/day and 5°C ± 1°C/night) under short-day conditions (10 h, PAR: 280 Umol s^{-1} m^{-2}) for the next 55 days (Table 1). These conditions were selected to simulate winter conditions.

Seeds were germinated by sowing them on humid filter paper at 25°C in Petri dishes. Four days later, they were potted in 950 cm^3 containers. Dried seed were also sown directly in individual pots. Both treatments were exposed to the same cold conditions as described above.

After cold treatment, the plants were placed under long photoperiods (16 h, PAR:280 Umol s^{-1} m^{-2}) at 25°C ± 1°C/day and 20°C ± 1°C/night to promote flowering.

Plants were periodically watered with half-strength Hoagland's nutrient solution (5). Leaf development, bolting and flowering were recorded twice weekly. Plants were considered bolted or flowered when the first elongated internode and/or the first primordium of umbel could be seen macroscopically. A completely randomized experimental design, including 8 treatments replicated twenty times, was used (Table 1).

Table 1. Time (in days) between sowing date and the beginning of cold treatment in carrot cv. Flakkee.

Treatment	Number of leaves	Days after sowing
1 Dried seeds		0
2 Germinating seeds		4
3 Cotyledonary leaves		20
4	1-2	33
5	3-4	49
6	5-6	63
7	7-8	84
8	9-10	102

RESULTS

Only those plants that were at the stage of 9 to 10 leaves at the beginning of the cold treatment (treatment 8) bolted and flowered. Other treatments remained as vegetative rosette plants (Table 2). At the end of the experiment, there was a 67 percent of the plants in treatment 8 flowered, while none in the other treatments did.

Table 2. Effect of cold treatment on leaf number, bolting and flowering in carrot plants cv. Flakkee with different number of developed leaves.

Treatment	Leaf number before cold treatment*	Leaf number after cold treatment*	Days after cold treatment to reach 50%		Bolting and flowering at the end (%)	
			bolting	flowering	bolting	flowering
1	Dried seeds	Ger. seeds	NB	NF	0	0
2	Ger. seeds	1.5	NB	NF	0	0
3	EC	2.3	NB	NF	0	0
4	2	3.9	NB	NF	0	0
5	3.5	6.6	NB	NF	0	0
6	6	7.1	NB	NF	0	0
7	7.3	9	NB	NF	0	0
8	9.3	10.9	112	155	67	67

References: Ger. seeds: Germinating seeds, EC: Expanded cotyledons, NB: No bolting, NF: No flowering, *: Mean values.

During the cold treatment, there was a moderate development of new leaves. It was comparatively greater in treatment 4 than in the other phenological stages (Table 2). Moderate seed-stalk elongation was observed in flowered plants.

DISCUSSION

This study shows that cv. Flakkee has a pre-vernalization phase, which lasts until the plants have at least 9 to 10 leaves (about 14 weeks form sowing, under the experimental conditions tested). These results do not agree with those from Kumaki (7), who was able to vernalize carrots at seed stage. Cultivar differences may account for this fact.

Further studies are needed to determine the critical temperatures and exposition time necessary to vernalize cv. Flakkee.

These results could assist in selecting areas and sowing dates for seed production with more accuracy, when the "seed to seed" method is required.

LITERATURE CITED

1. ATHERTON, J.G.; BASHER, E.A.; BREWSTER, J.L. 1984. The effects of photoperiod on flowering in carrot. Journal of Horticultural Science 59:213-215.

2. DICKSON, M.H.; PETERSON, C.E. 1960. The influence of gibberellin on the flowering of carrots. Canadian Journal of Plant Science 40:468-473

3. HARRINGTON, J.F.; RAPPAPORT, L. 1957. Effect of gibberellic acid on seedstalk development and flowering of vegetable seed crops. **In** American Society of Horticultural Science Annual Meeting. Stanford, Calif., Standford University.

4. HILLER, L.K.; KELLY, W.C. 1979. The effect of post-vernalization temperature on seedstalk elongation and flowering in carrots. Journal of the American Society for Horticultural Science 104:253-257.

5. HOAGLAND, D.R. 1948. Lectures on the inorganic nutrition of plants. Waltham, Mass. Chronica Botanica. 177 p.

6. JUNGES, W. 1959. Abhangigkeit des schossens bienner gemusepflanzen von ihrem alter und von der dauer der eiwnwirkung niederer temperaturen. Archiv. Gortenbau VII Band. Heft 7:485-504.

7. KUMAKI, Y. 1956. Vernalization experiments in carrots. Journal of the Horticultural Association of Japan 25:163-166.

8. LONA, J.L.; CRNKO, J. 1967. Floración prematura en zanahoria en las condiciones de La Consulta en relación a la producción de semilla. Mendoza, Arg., INTA, Centro Regional Andino, E.E.A. La Consulta. p. 4.

9. QUAGLIOTTI, L. 1967. Effect of different temperatures on stalk development, flowering habit and sex expression in the carrot (*Daucus carota* L.). Euphytica 16:83-103

10. SAKR, E.S.; THOMPSON, H.C. 1942. Effect of temperatures and photoperiod on seedstalk development in carrots. Proceedings of the American Society for Horticultural Science 41:343-346

11. VINCE-PRUE, D. 1975. Photoperiodism in plants. London, McGraw-Hill.

12. WITTWER, S.H.; BUKOVAC, M.J. 1957. Gibberellin effects on temperature and photoperiod requirements for flowering in some plants. Science 126:30-31.