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Bolting control by low temperatures in root chicory (*Cichorium intybus* var. *sativum*)

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Abstract

The effects of a vernalization treatment on bolting of root chicory were investigated and compared in four varieties. Experiments where plants were initially cultivated in controlled growth rooms, before transplanting in the field in late April or in early May, strongly suggested that low temperatures were responsible for the high percentages of bolting and flowering recorded in early-sown plants in the field. Effectiveness of a treatment at a constant 4 °C in inducing bolting depended on its duration, on the variety, and on plant age when vernalization started. Greatest sensitivity to cold occurred soon in plant's life, during seed imbibition. Fluctuating temperatures (16 h at 4 °C followed by 8 h at 15 °C) were also able to cause bolting. Vernalization effectiveness was affected by climatic variations after vernalization and the transfer of the plants in the field. The results are discussed in relation to information coming from studies on radicchio and Witloof chicories.

Keywords: Bolting; *Cichorium intybus* L.; Flowering; Low temperatures; Root chicory; Vernalization

1. Introduction

Industrial root chicory (*Cichorium intybus* var. *sativum*), a crop originally grown in north-western Europe only, was used exclusively for coffee-like beverages (roasting chicory) up to the 1980s (Desprez et al., 1999). During the last decades, however, there was an increasing interest for the plant due to the inulin it produces and stores in its tap-root and to the hydrolysis product of inulin, namely fructose. Inulin, the main reserve carbohydrate of *Asteraceae*, is used in the food industry not only as a source of dietary fibres (Flamm et al., 2001), but also as a functional food ingredient since it affects biochemical and physiological processes resulting in better health and reduction in the risk of many diseases in rats and human beings (Roberfroid and Delzenne, 1998; Kaur and Gupta, 2002). Several non-food applications are

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also known (for a review, see Stevens et al., 2001). Inulin started to be exploited on an industrial scale in the early 1980s in Belgium where the fructan chicory acreage averaged 16,000 ha in 2002 (about 65% of the world total production, FAO source). Today, the culture is rapidly spreading in many countries in the world, including Portugal (Azores, Januário et al., 1996), USA (Western Nebraska, Wilson et al., 1998), Italy (Monti et al., 2002), Australia and Chile.

Cultivated chicories are biennial plants (Gianquinto and Pimpini, 1995) requiring vernalization and thus a cold season to bolt and flower but, for industry purposes, root chicory is grown as an annual plant to avoid bolting. Bolted plants are indeed sources of problems for growers and for the industry: (1) they produce unwanted seeds resulting in weed chicory in fields of the following year crop; (2) they have a lower yield due to the development of the inflorescential structure which competes with the root for carbohydrates and consumes the root reserves, and (3) their root becomes fibrous, due to the lignification of the stalk, and is thus very hard and uneasy to process. Up to a few years ago, chicories were sown in the field in May to prevent vernalization by low spring temperatures. However, to increase the duration of the growing period in the field and insure a maximal yield in autumn (40–48 T/ha), sowings are made now very early in spring (end of March–early April in Belgium) and frequently, germinating seeds and seedlings endure low temperatures which lead plants to bolt in the same year. As a consequence, a costly manual rooting out of the bolted plants is required.

Breeders were developing new varieties more resistant to bolting, but this resistance must remain easy to break to allow seed production for the next year and for breeding programs aiming to produce hybrids through sexual reproduction and crossings. This opposite requirement, i.e. preventing flowering for inulin production and stimulating flowering for seed production, would be more easily met if the environmental parameters controlling bolting and floral induction of industrial root chicory were understood. In fact, they are known empirically and information is coming also from field experiments performed on radicchio (*C. intybus* var. *silvestre/foliosum*) (Pimpini and Gianquinto, 1988; Gianquinto and Pimpini, 1995; Gianquinto, 1997; Wiebe, 1990, 1997) and from in vitro studies using root explants of Witloof (*C. intybus* var. *foliosum*) (Paulet, 1985 and references therein; Demeulemeester and De Proft, 2000).

The only factor essential to flowering that is common to all studies is the post-vernalization requirement for long days (Paulet, 1985; Badila et al., 1985; Demeulemeester et al., 1995; Gianquinto, 1997). In contrast, depending on the variety, the low temperature requirement appeared to be either absolute or facultative (Joseph and Paulet, 1975; Gianquinto and Pimpini, 1995; Gianquinto, 1997; Wiebe, 1997) and work by Michniewicz and Kamienska (1964) indicated that the vernalization requirement could be replaced by kinetin, a cytokinin. The duration and the intensity of an effective vernalization treatment also depend on the variety, extending from 3 to 16 weeks at temperatures ranging from 0 to 12 °C, with 5–10 °C being the optimum (Wiebe, 1997; Gianquinto, 1997). The stage of sensitivity to cold is a matter of debate since some studies indicate that seed vernalization is possible (Wiebe, 1990, 1997) while other works suggest that the stage of sensitivity to low temperatures is delayed and that sensitivity increases with plant age (Pimpini and Gianquinto, 1988; Gianquinto, 1997; Demeulemeester and De Proft, 1999).

Thus, the requirements for floral initiation of *C. intybus* are far from being fully understood (Demeulemeester and De Proft, 1999) and a better knowledge of the factors regulating flowering in root chicory, in particular, is urgently needed. It is with this perspective in mind that we performed several experiments in controlled rooms and in the field. Our aim was to define how flowering of root chicory is affected by (a) the sowing date in the field, (b) the duration of a vernalization treatment, (c) the physiological stage reached by the plant at the time of the cold treatment, and (d) a regime of temperatures fluctuating during a 24-h cycle.

2. Materials and methods

2.1. Plant material

The experiments were performed using four root chicory (*C. intybus* var. *sativum*) varieties: 'Tilda' (SES Europe S.A., Belgium) and 'Fredonia' (SAREA,