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Seasonal timing of floral initiation in strawberry: Effects of cultivar and geographic location

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ABSTRACT

It was previously shown that nitrogen fertilization immediately after commencement of SD exposure enhanced the floral induction effect of SD in June-bearing strawberries (Sønsteby et al., 2009). In order to optimize the timing of such fertilization under field conditions, seasonal timing of floral initiation in the strawberry cultivars 'Frida', 'Polka', 'Korona' and Florence' was studied in the field at five contrasting latitudinal and altitudinal geographic locations in Norway and, for comparison, under controlled environment conditions with 12 h photoperiod and temperatures ranging from 9 to 18 °C. Serial collections and dissections of crowns from the various locations revealed that floral initiation was successively delayed with increasing latitude and altitude of the location, and with decreasing temperature under controlled environment conditions. Both in the field and in the phytotron, floral initiation was earliest in 'Frida' closely followed by 'Polka' and in due course by 'Korona' and finally 'Florence' which was particularly slow to respond. Floral initiation in the phytotron was progressively advanced with increasing temperature and was optimal at 15–18 °C. Flowering time in the field was mainly determined by thermal relations in the spring and early summer, and accordingly, it was strongly delayed with increasing latitude and altitude of the location. In addition, late floral initiation in autumn also delayed flowering in the spring. Based on these observations, optimal timing of autumn fertilization for the various locations and cultivars are suggested.

1. Introduction

Floral initiation in June-bearing strawberry cultivars (*Fragaria x ananassa* Duch.) is controlled by the interaction of photoperiod and temperature (Guttridge, 1985; Heide, 1977). Being quantitative short day (SD) plants, June-bearing strawberries initiate flowers under SD conditions at temperatures up to ca. 25 °C, while at higher temperatures flowering is increasingly inhibited also under SD conditions (Verheul et al., 2007). However, in some cultivars floral initiation can take place even in 24-h long days (LD) if the temperature is below about 15 °C (Heide, 1977; Ito and Saito, 1962), while in other cultivars such as 'Elsanta' and 'Korona', this LD/low temperature flowering pathway is missing (Sønsteby and Heide, 2006; Verheul et al., 2007). Because of these versatile responses, floral initiation is closely controlled by seasonal changes in photoperiod and temperature, although the timing may vary among cultivars (e.g. Sønsteby and Heide, 2008).

Seasonal changes in photoperiod and temperature are functions of latitude and/or altitude. The critical photoperiods and temperatures for triggering of floral initiation will therefore be reached at different times in various geographic locations. It has recently been demonstrated that proper timing of nitrogen (N) fertilization at an early stage of SD floral induction can enhance and promote flowering in strawberry (Lieten, 2002; Sønsteby et al., 2009). On the other hand, the same fertilization applied before commencement of the SD condition had the opposite effect and delayed and reduced flowering. Correct timing of fertilization in the autumn relative to the commencement of natural SD may thus be crucial for successful application of such findings to commercial production conditions. This would require knowledge about the precise seasonal timing of floral initiation in the various cultivars under natural field conditions in a given location. This has prompted us to determine the precise seasonal timing of floral initiation in some strawberry cultivars of contrasting earliness by serial samplings and dissections of crowns from plants grown under field conditions at a range of selected locations in Norway. For comparison, the time of floral initiation relative to the commencement of SD at a range of temperatures was also determined by the same technique in plants grown under controlled environment conditions. The results are presented in the following.

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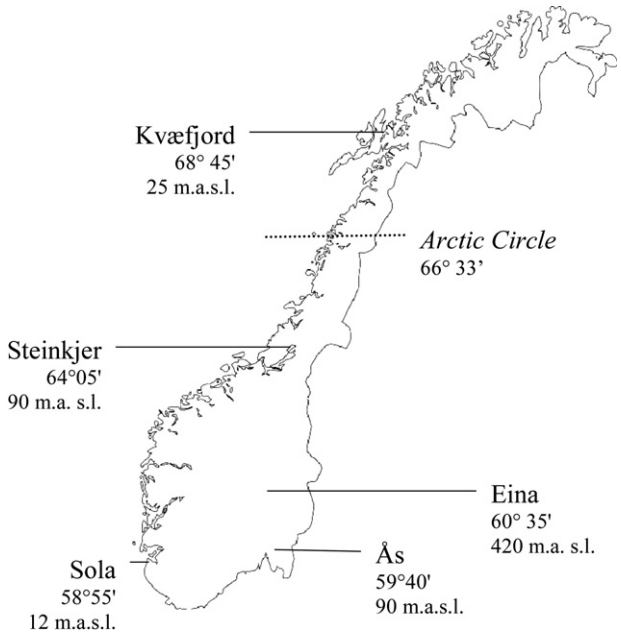

Fig. 1. Map showing the geographic positions of the five experimental locations.

2. Materials and methods

2.1. Field experiments

Phytosanitary certified plants of the cultivars 'Florence', 'Frida', 'Korona' and 'Polka' rooted in plug trays were purchased from a certified commercial nursery in late June 2008 and 2009, and planted in the field at five geographic locations in Norway with varying latitude, altitude and distance from the coast as shown in Fig. 1. Courses of daily mean temperatures at the nearest meteorological station for these locations during late summer and autumn and the following spring and early summer for the two seasons are shown in Fig. 2. The experiment was repeated in 2009 with the cultivars 'Korona' and 'Florence' only, ('Florence' being omitted at Kvæfjord). During propagation and until planted in the field, the plants were maintained under non-inductive conditions (min. 20 °C and natural long summer days of 17–19 h). The plants were planted on raised beds with black polyethylene mulch in double rows, at a spacing of 25 cm × 40 cm × 160 cm, corresponding to 50,000 plants ha^{-1}. Each plot comprised three randomized blocks, each with 65 plants of each cultivar. The plots were fertilized according to conventional practice, and the plants irrigated after planting and later as required. Starting on August 12, crowns were sampled at weekly intervals until October 7. An additional sample of the slow-responding cultivar 'Florence' (and of 'Korona' at the northernmost location) was collected on November 4. At each sampling, 5 crowns from each replicate (*i.e.* 15 crowns of each cultivar) were sampled and stored on glass vials in 70% ethanol in a cold store at 5 °C until dissected under a stereo microscope for determination of flowering stage according to the following six-stage scale (cf. Heide, 1977):

Stage 1 = Vegetative apex with only leaf primordia
Stage 2 = Sepal primordia visible in terminal flower
Stage 3 = Petal primordia visible in terminal flower
Stage 4 = Stamen primordia visible in terminal flower
Stage 5 = First carpel primordia visible in terminal flower
Stage 6 = All flower parts differentiated.

The physical appearances of the stages are shown in Fig. 3.

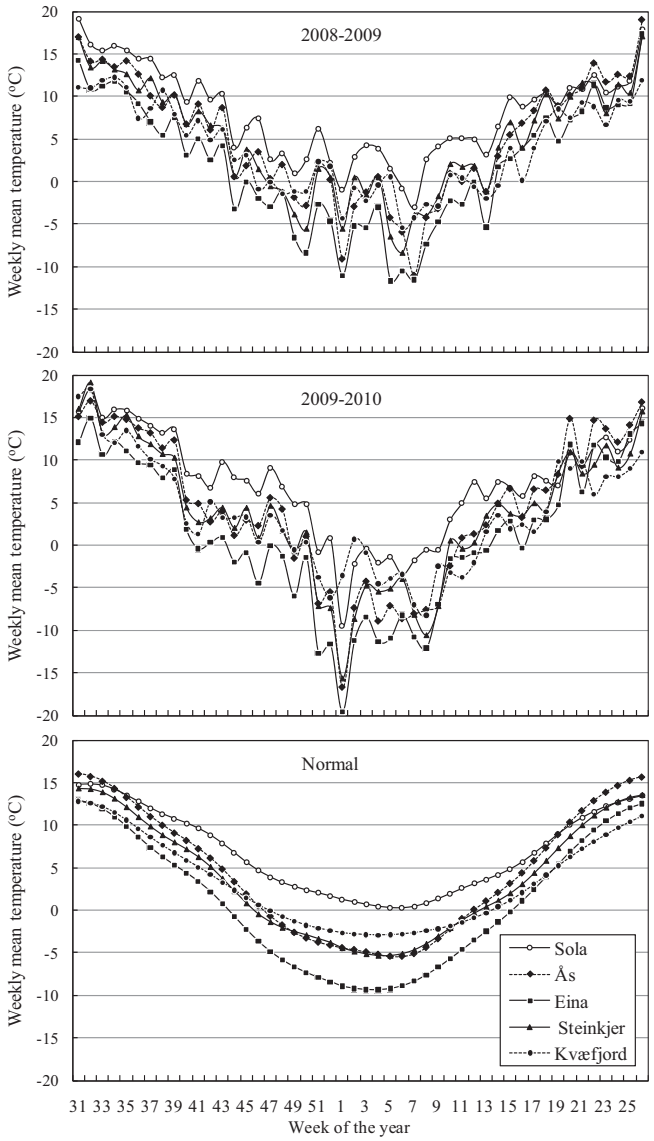

Fig. 2. Weekly mean temperature courses during the 2008/2009 season (panel A) and 2009/2010 season (panel B) and the corresponding normal temperatures for the five experimental locations (panel C).

An additional sample of 3 × 10 plants of each cultivar was left over the winter for determination of time and amount of flowering in the following spring.

2.2. Phytotron experiment

Runner plants of the same cultivars were collected in the field in early July and rooted directly in 10 cm plastic pots filled with a peat-based potting compost fertilized with 300 g $80\,l^{-1}$ of Osmocote controlled-release fertilizer (14% N, 4.2% P, 11.6% K plus micronutrients, release rate 3–4 months) from Scotts UK Ltd, Nottingham, UK. During rooting and raising the plants were maintained at 21 °C and continuous light. On August 10, 2008 and 2009, the plants were moved into daylight compartments of the Ås phytotron and grown on at temperatures of 9, 12, 15 and 18 °C and a photoperiod of 12 h (10 h daylight plus 2 h low-intensity incandescent light) under conditions as described by Sønsteby and Heide (2008). At this stage the plants had an average of 5.0 ± 0.1 developed leaves. In order to mimic conditions in the field, all runners were left intact during the