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Effects of light quality and quantity on flower initiation of *Fragaria chiloensis* L. CHI-24-1 grown under 24 h day-length

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ABSTRACT

Flower initiation of a wild strawberry strain, *Fragaria chiloensis* CHI-24-1, is induced by 24 h day-length including a far-red (approximately 700–740 nm wavelength) light component. The photo-induction response differed from the response of long day plants in that no flower initiation occurred without continuous exposure to the far-red light component, even if grown under 24 h day-length. To characterize the flower initiation habit and photo-control mechanism of the CHI-24-1 plants under 24 h day-length, the effects of light wavelength and photon flux density on flower initiation were examined under various 24 h day-length treatments. As the results, flower initiation habits of the CHI-24-1 were made clear under 24 h day-length. (1) Both far-red and visible light were effective to induce flower initiation. (2) A threshold photon flux density to induce flower initiation existed in each monochromatic LED board. (3) Threshold photon flux densities differed according to the light wavelength. (4) Flower initiation occurred if the photon flux densities of the monochromatic LED board exceeded the threshold photon flux densities. These flower initiation habits of the CHI-24-1 were different from the flower initiation habits of long day plants. Additionally, the Pfr form of phytochrome seems to have sole control of flower initiation, as the action spectrum had its greatest peak at approximately 712 nm, with a smaller one in the blue region.

1. Introduction

Day-length (DL) is an important environmental factor that controls flower initiation in higher plants. According to their photoperiodic response, three basic groups have been identified: short day (SD), long day (LD), and day-neutral plants (Garner and Allard, 1920; Garner and Allard, 1923). Herein, the category of "day-neutral plants" is designated with different expression. However, a wild octoploid strawberry strain, *Fragaria chiloensis* L. CHI-24-1 (Rosaceae), is not classifiable into these groups, as its flower initiation is induced under SD and LD but not under intermediate DL (Yanagi et al., 2006a). This strain is apparently an ambiphotoperiodic plant (Thomas and Vince-Prue, 1997). Few papers have described studies examining the photo-induction mechanisms of flower initiation in ambiphotoperiodic plants.

The flower initiation habit of CHI-24-1 plants under LD conditions is unique because flower initiation is strongly induced when grown for at least 25 days under sunlight and nightly illumination by far-red (FR) light (Yanagi et al., 2006b). However, no flower initiation occurs without continuous exposure to a FR light component, even if grown under 24 h DL. The flower initiation of CHI-24-1 plants under 24 h DL was apparently controlled precisely by FR light, although few LD plants showed such photo-control of flower initiation. In addition, when CHI-24-1 plants are grown under 20–23 h DL conditions, flower initiation is induced at the asexually propagating stolon and in daughter plants that maintain a stolon attached to the parent plant, but not at the main shoot on the parent plants (Yanagi et al., 2006a,b). The flower initiation of the main shoot is only induced under 24 h DL with the FR light component. A similar phenomenon was found in an octoploid strawberry cultivar named 'Sparkle'. The cultivar was classified as a SD plant (Austin et al., 1961; Moore and Hough, 1962), but when grown under a 24 h DL condition, flower initiation occurred in asexually propagated plants that maintained a stolon attached to the parent plant (Collins and Barker, 1964; Collins, 1966). In addition, the phenotype of flower initiation under 24 h DL was inherited by approximately 50% of F_1 hybrids between CHI-24-1 and an SD type of octoploid strawberry cultivar (Yanagi et al., 2005). These reports indicate that the flower initiation gene(s) controlling flower initiation under 24 h DL exist in certain wild and cultivated strawberry plants. Nevertheless, few reports have described a similar phenomenon in other higher plants.

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In CHI-24-1, the photo-induction mechanism of flower initiation under 24 h DL seemed to have some relation to the photoreceptor that converts light into an endogenous flower initiation inducing signal because the effectiveness for inducing flower initiation under 24 h DL differed according to the light wavelength. The light wavelength dependence of flower initiation was apparently derived from the light absorption characteristics of the photoreceptor. Therefore, the photoreceptor might be identified if an action spectrum of flower initiation under 24 h DL is elucidated using action spectroscopy (Schäfer et al., 1983).

Flower initiation is induced in LD plants when the day and night cycles are synchronized with their circadian rhythm (Suarez-Lopez et al., 2001; Yanovsky and Kay, 2002; Thomas, 2006). Moreover, phytochrome and cryptochrome play roles in perceiving light and controlling both circadian rhythm setting and flower initiation gene expression. Some studies have demonstrated that red light but not FR light can induce flower initiation in LD plants, based on the results of action spectra obtained using the experiment of night interruption and continuous lighting (Borthwick et al., 1948; Parker et al., 1950; Schneider et al., 1967; Ishiguri et al., 1975). However, the flower initiation of the CHI-24-1 plants under 24 h DL was apparently controlled by a single photoreceptor of phytochrome, because it was strongly induced by FR light. Consequently, the flower initiation habit under LD conditions might be different between CHI-24-1 and LD plants. To characterize the flower initiation habit and photo-induction mechanism of flower initiation under 24 h DL, the effects of monochromatic light and its photon flux density on flower initiation of the CHI-24-1 plants were examined under various 24 h DL treatments. Also, to understand the physiological aspect of flower initiation in the CHI-24-1 is important key to identify the gene(s) which controlled it. If the gene will be identified, it might be important in the field of strawberry production and industry.

2. Materials and methods

2.1. Plant material

Asexually propagated clones of CHI-24-1 were transplanted one-by-one into 200-ml plastic pots filled with sandy soil mixed with compost (2:1) and 2 g of slow release chemical fertilizer (N:P:K = 8:8:8). The plants were grown outside or in a greenhouse under non-inductive DLs (from 12 h to 16 h) with daily mean temperatures higher than 20 °C to avoid flower initiation. Plants grown for more than 2 months were used for experiments. After being arranged to have one stem, four expanded young leaves and no stolon, the plants were grown under various 24 h DL conditions at 22 °C for 25 days.

Fig. 2. Flower bud of *F. chiloensis* CHI-24-1.

2.2. The 24 h DL conditions

To establish the various 24 h DL conditions, plant growth fluorescent lamp (PGFL, approximately 100 μmol/m^2/s, and including 10% FR light; Panasonic Inc.) and monochromatic light emitting diodes (LEDs, Epitex Inc.) of 15 types were used respectively, for white and monochromatic light sources (Fig. 1). We developed the 15 types of the monochromatic LED board (MLB) and their lighting systems (Okamoto et al., 1996). The peak wavelengths (half-value widths of the emission spectra) in the MLBs were 405 nm (19 nm), 417 nm (20 nm), 451 nm (20 nm), 469 nm (22 nm), 517 nm (30 nm), 546 nm (34 nm), 595 nm (22 nm), 627 nm (16 nm), 651 nm (24 nm), 671 nm (24 nm), 692 nm (26 nm), 712 (28 nm), 733 nm (32 nm), 750 nm (24 nm) and 774 nm (28 nm) (Fig. 1). Each MLB is denoted herein by its peak wavelength.

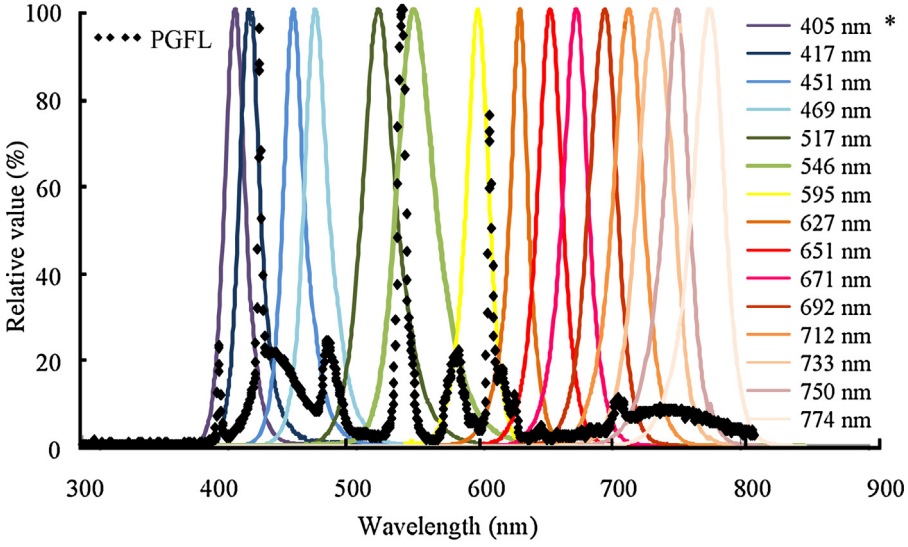

Fig. 1. Emission spectra of the plant growth fluorescent lamps (PGFL) and monochromatic LED board (MLB) used in the experiments. *Peak wavelength of each MLB.