

An integrated environmental control system and supplemental lighting increase strawberry production in subtropical regions

Strawberries (*Fragaria* × *ananassa* Duch.) are popular fruits consumed worldwide, and the demand for high-quality strawberries has been increasing in tropical and subtropical regions. This study aimed to elucidate the effects of environmental control and daytime LED supplemental lighting on strawberry production in a subtropical climate. Two strawberry cultivars, namely 'Yotsuboshi' and 'Benihoppe,' were grown by forcing culture in three greenhouses: (1) conventional greenhouse, with side vents open and no other environmental controls; (2) controlled environment (CE) greenhouse, equipped with an integrated environmental control system to cool air and growing medium; and (3) CE and LED greenhouse (CE&LED), equipped with an integrated environmental control system and LED supplemental lighting during the day.

Daily mean air and growing medium temperatures are lower in CE and CE&LED than in the conventional due to the combination of nighttime cooling, ventilation, shading, fogging, and medium cooling systems (Table 1). Even in the subtropical region, the temperature in greenhouses could be kept cooler by integrated environmental control. On Ishigaki Island, where the experiment was conducted, photosynthetic photon flux density (PPFD) increases in CE&LED in winter regardless of weather conditions (Fig. 1a, b). However, after April, when daily solar radiation exceeds 20 MJ m⁻², PPFD does not differ among greenhouses on sunny days (Fig. 1c). Conversely, even after April, PPFD increases with LED supplemental lighting during cloudy days (Fig. 1d). The integrated environmental control allows CE to produce yields comparable to the mean yield in Japan (Fig. 2). Environmental control also improves the percentage of marketable fruits weighing 6 g or more. Yield in CE&LED has significantly increased compared to CE. The number of fruits harvested and soluble solid content (SSC) in fruit increase when environmental control and LED supplemental lighting are used together (Table 2).

By introducing the integrated environmental control system, strawberry yield and quality improve in hot and humid environments such as subtropical regions. In addition, the combination of environmental control and supplemental daytime LED lighting is an effective technique for improving yield and fruit quality. On the other hand, since the effect is limited in environments where solar radiation exceeds 20 MJ m⁻², it is necessary to consider local weather conditions when introducing LED lighting.

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Table 1. Daily mean air temperatures and mean growth medium temperatures by month

Greenhouse	Nov	Dec	Jan	Feb	Mar	Apr	May
<i>Daily mean air temperature</i>							
Conventional	23.1	21.5	20.0	19.3	23.1	25.5	25.3
CE	19.9	18.4	17.7	17.8	21.2	23.2	22.6
CE & LED	21.1	19.1	18.8	18.9	21.5	22.8	22.5
<i>Mean growth medium temperature</i>							
Conventional	23.2	21.8	21.2	19.9	23.9	26.8	26.5
CE	17.2	16.7	16.3	16.6	17.8	18.9	18.7
CE & LED	18.2	17.3	17.1	17.4	18.8	19.8	19.8

Air temperature was measured at a height of 1.5 m in the center of the greenhouse, and medium temperature was measured at a depth of 5 cm between plants.

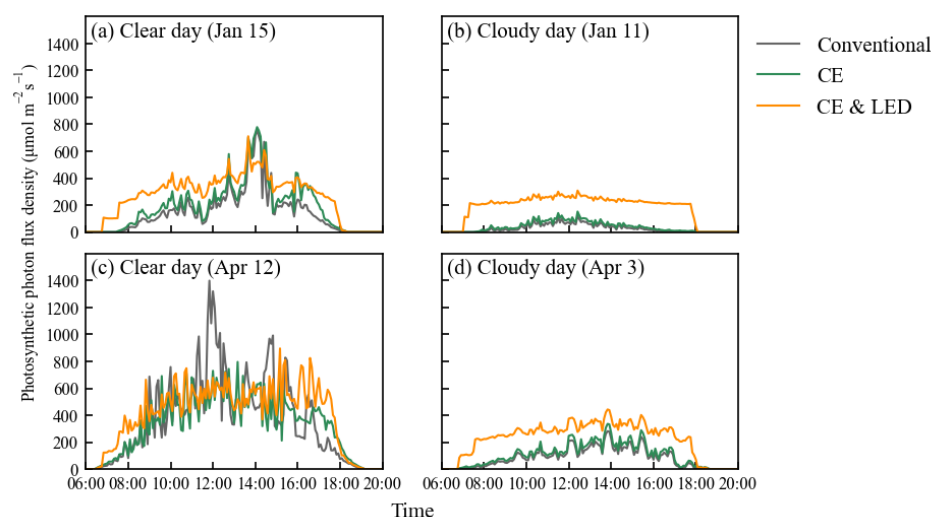
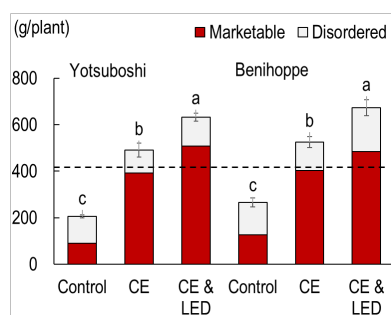
**Fig. 1. Daily photosynthetic photon flux density in the conventional, controlled environment (CE), and LED (CE&LED) greenhouses on sunny and cloudy days**

Fig. 2. Total and marketable yield
Marketable fruits weighing 6 g or more. Different letters indicate significant differences at the 5% level. The dashed line indicates Japanese average (410 g/plant).

Table 2. Number of fruits, fruit weight, and soluble solid content (SSC)

	Number of fruits (fruits/plant)	Fruit weight (g)	SSC
<i>Greenhouse</i>			
Conventional	34.9 c	10.6 b	7.4 c
CE	45.3 b	13.6 a	7.7 b
CE & LED	56.2 a	14.1 a	8.0 a
<i>Cultivar</i>			
Yotsuboshi	47.3 NS	12.5 NS	7.7 NS
Benihoppe	43.7	14.5	7.7

Different letters indicate significant differences at the 5% level.

Reference: Nakayama and Nakazawa. (2023) *Scientia Horticulture* 321: 112349. © Elsevier B.V. 2023
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