Effects of Air and CO_2 Application within Strawberry Plant Canopy on Dry Matter Production and Fruit Yield during Summer and Autumn Culture

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Background

Strawberries can be divided into **June-bearing** and **ever-bearing** types depending on the environmental conditions that determine flower bud differentiation. In Japan, the harvest yield and distribution of strawberry fruits in summer and autumn are low, and the cultivation of ever-bearing strawberries is limited to areas with cool summers, such as Hokkaido and Tohoku region. Problems include reduced photosynthetic ability due to high temperatures and heavy fruit load. A cultivation technique that suppresses the reduction in photosynthesis and does not decrease plant vigor during the cultivation period is the local application of CO_2 using liquefied carbon dioxide. Application of this technique during ever-bearing strawberry cultivation increased yield. Further improvement of the efficiency of CO_2 application and reduction of application amount will likely become necessary in the future. Therefore, in this study, we investigated whether blowing air treatment before CO_2 application within the strawberry plant canopy could improve CO_2 absorption efficiency and increase dry matter production.

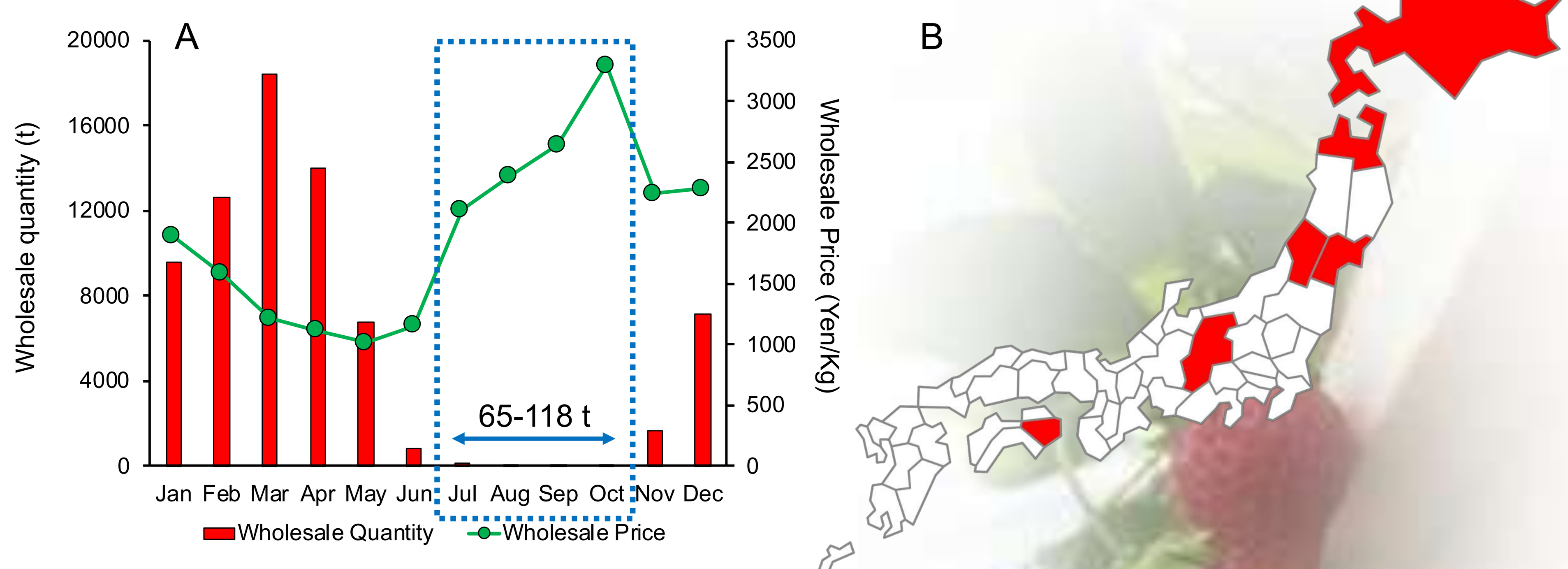

Fig. 1. Wholesale quantity and price in main Japanese fruit and vegetable markets (A). Major production areas (red color) of ever-bearing strawberries in Japan (B).

➡ It is necessary to establish a cultivation techniques that enables the production of ever-bearing strawberries even in the warm regions of Japan.

Materials and Methods

The cultivar 'Suzuakane' was used at the Faculty of Agriculture, Ibaraki University. The following treatments were used: blowing air into the plant canopy before CO_2 application (**Air/CO_2**), blowing air without CO_2 (**Air**),, applying CO_2 without blowing (**CO_2**), and control (not blowing air and applying CO_2 (**C**),). We investigated the CO_2 concentration, dry matter production, yield characteristics, individual leaf photosynthesis characteristics, projected leaf area, cumulative light interception, light use efficiency, and fruit quality. On 14 April 2022, six frigo bare root plants were planted in a polystyrene container (35.5 cm × 75.0 cm × 14.5 cm deep; 24 L) filled with black peat moss (BVB soil substrate; Toyotane, Aichi, Japan). Frigo bare root plants were planted 30 cm apart, with 10 cm between rows. The average CO_2 concentrations every 15 min during CO_2 application in the plant canopy of C, Air, CO_2), and Air/CO_2 were 411, 414, 729, and 736 μmol·mol−1, respectively.

'Suzuakane' strawberry
https://hokusan-kk.com/item/

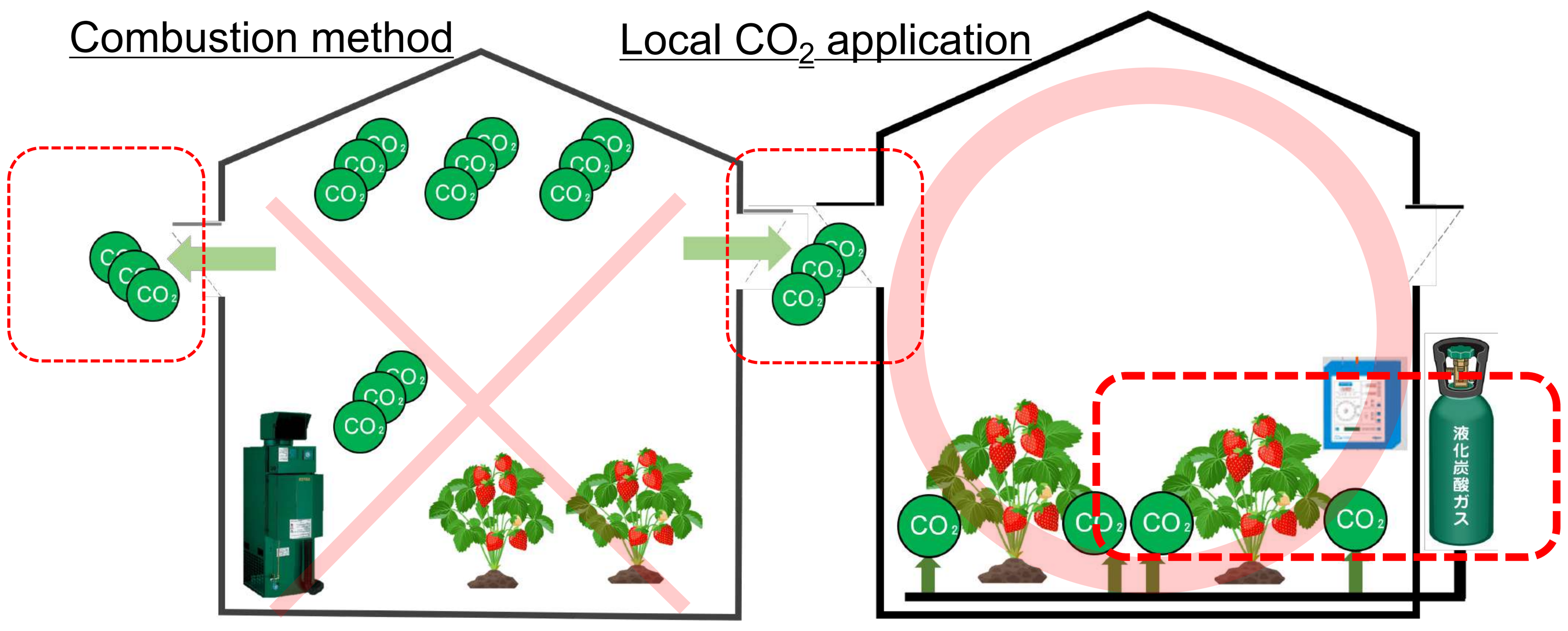

Fig. 2. Images of Combustion and Local CO_2 application for strawberry cultivation.

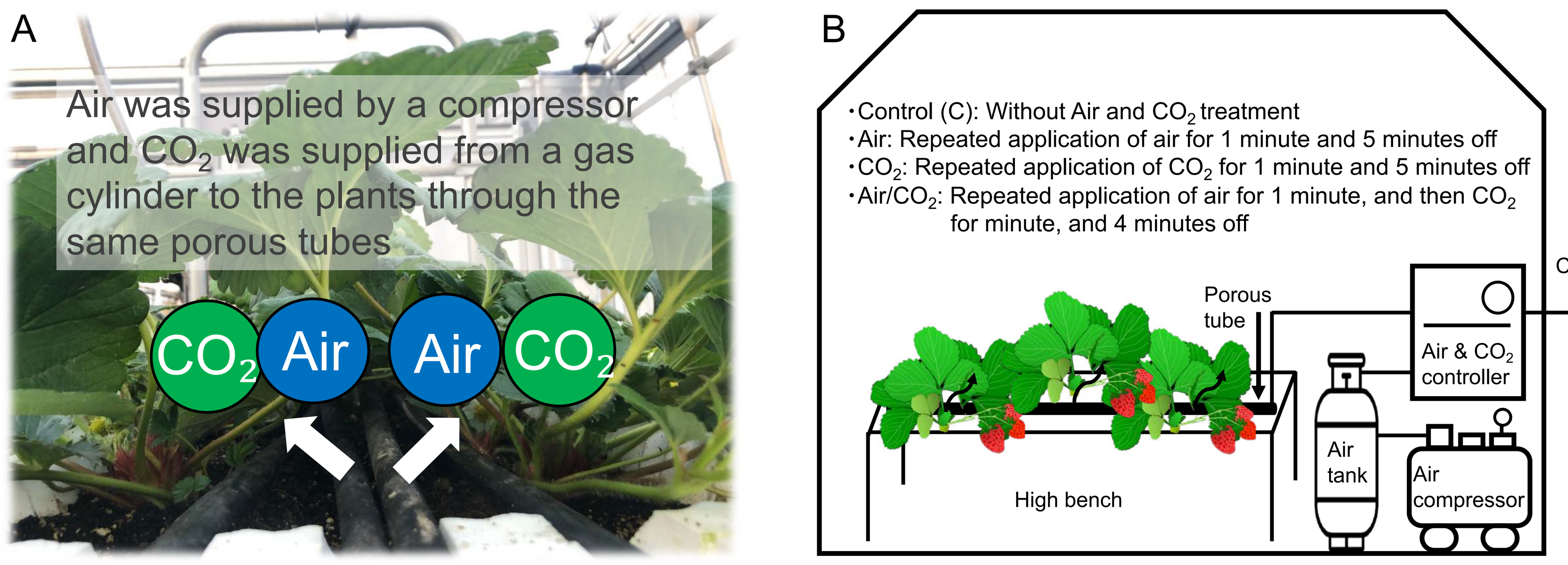

Fig. 3. A picture of within strawberry plant canopy, porous tube was set within the canopy (A). Schematic diagram of the local air and CO_2 application system. Treatment was conducted from sunrise to 6 hours before sunset (B).

Results

Table 1. Effect of air and CO_2 application within a strawberry plant canopy on fruit yield.

Treatment	Fruit yield (g/plant)				
	July	August	September	October	Total
C	90.6 b^z	84.8 b	50.2 b	32.7	258.3 c
Air	106.5 ab	90.7 ab	56.7 b	25.4	279.3 bc
CO_2	125.9 ab	110.3 a	69.2 b	28.6	334.0 b
Air/CO_2	135.2 a	100.4 ab	103.9 a	32.5	372.0 a

^{z} Different letters represent significantly different values. ($p < 0.05$; One-way ANOVA followed by Tukey-Kramer test n=5–11).

Table 2. Changes in total dry weight and in dry weights of each plant part.

Date	Treatment	Leaf (g DW)	Crown (g DW)	Root (g DW)	Peduncle (g DW)	Fruit (g DW)	Total (g DW)
11 Jul.	–	12.2	1.88	6.62	5.01	ND	25.7
31 Aug.	C	21.5 b^z	2.20	2.47 b	2.11	14.3 bc	42.6 c
	Air	22.5 b	2.44	4.16 a	2.83	14.1 c	46.0 bc
	CO_2	22.1 b	2.26	2.73 ab	2.99	21.7 a	51.8 ab
	Air/CO_2	25.0 a	2.52	3.72 ab	3.21	18.5 ab	52.9 a
31 Oct.	C	38.5 b	4.49	5.93	2.40 b	23.4 d	74.7 c
	Air	39.1 b	4.85	5.72	2.61 ab	29.2 c	81.5 b
	CO_2	42.8 a	5.63	5.96	3.48 a	36.7 b	94.5 a
	Air/CO_2	40.6 b	4.43	4.85	3.37 a	41.0 a	94.5 a

^{z} Different letters represent significantly different values ($p < 0.05$; One-way ANOVA followed by Tukey-Kramer test n=9–22).

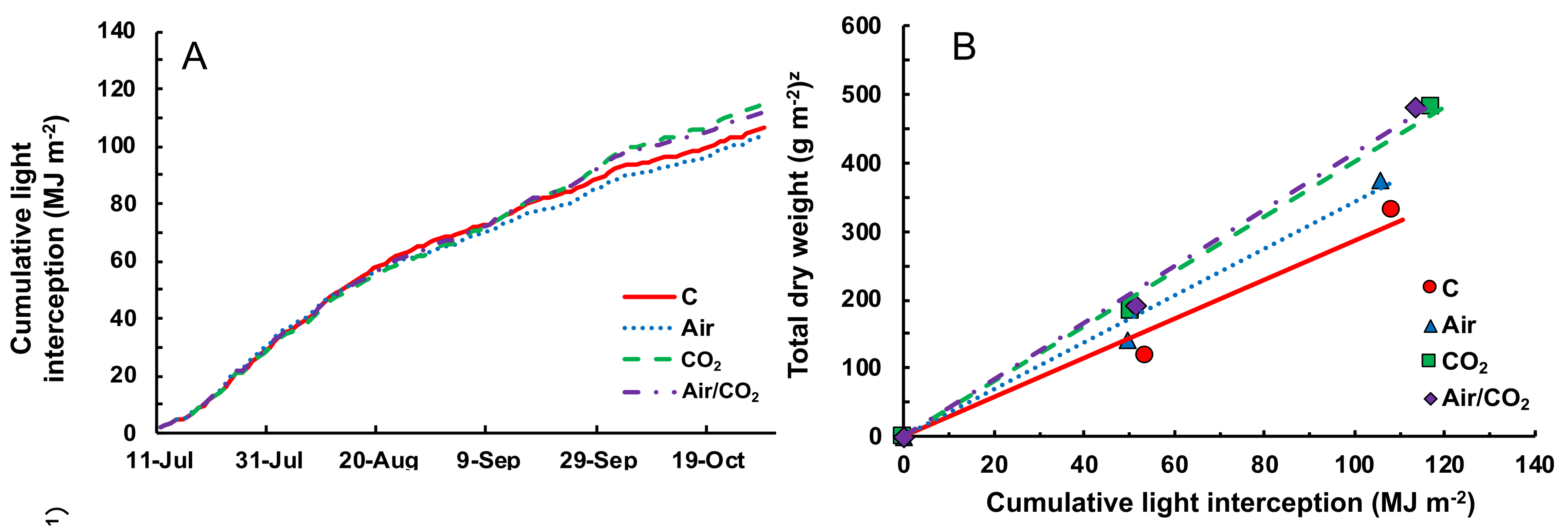

Fig. 4. Changes in cumulative light interception (A). Comparison of light use efficiency in four treatments (B). The slopes of the regression lines, namely, light use efficiency (95% confidence intervals), of C, Air, CO_2 and Air/CO_2 are 2.87 (2.40−3.34), 3.42 (3.06−3.78), 4.03 (3.79−4.27), and 4.14 (3.87−4.41), respectively. z: Increase in dry weight after starting treatment.

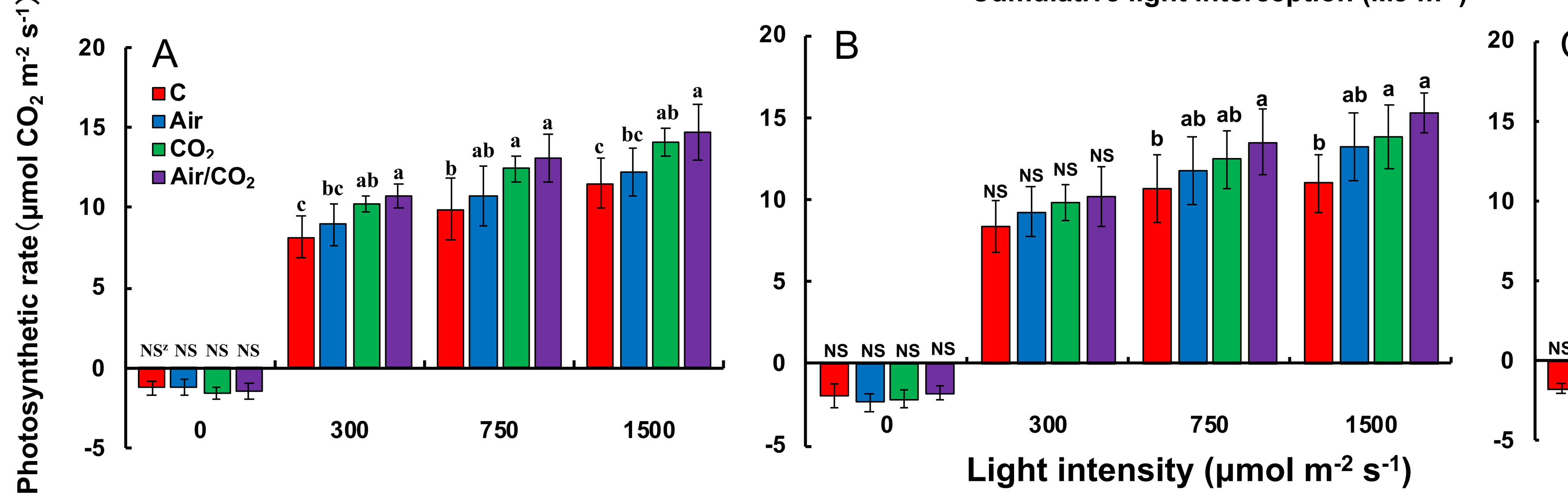

Fig. 5. Photosynthetic rate at different light intensities on July (A), August (B), and September (C) in 4 treatments.
^{z}: Different letters represent significantly different values ($P < 0.05$; Tukey-Kramer test; NS; not significance; n=5−7).

Discussion and Conclusion

Total fruit yield of application of CO_2 after air application (**Air/CO_2**) was the highest followed by **CO_2**, **Air**, and C (Table 1). The local application of only **CO_2** or **Air** and, **Air/ CO_2** treatment within the plant canopy considerably increased the dry matter production. This is probably because the application of CO_2 and air expanded the leaf area (Data not shown), increased cumulative light interception (Fig. 4A), and improved light use efficiency (Fig. 4B). In addition, the photosynthetic rate of **Air**, **CO_2** and **Air/ CO_2** treatments was higher than that of the **C** (Fig. 5) because of higher stomatal conductance (Data not shown). This suggests that local application of liquefied CO_2 after air application can effectively **increase fruit yield**, and that air treatment will **improve plant vigor**, further increasing strawberry production in summer and autumn.

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