ファレノプシス栽培における切花の収量･鮮度保持に対するCO2の施用効果

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Effects of CO_2 Enrichment on Yields and Preservability of Cut Flowers in *Phalaenopsis*

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Summary

The effect of CO_2 enrichment on *Phalaenopsis* cut flower production was examined for 30 months throughout five flowering cycles. The plant was cultured in three greenhouses with different CO_2 levels of (A) : control, daily mean of ambient air=438 ppm; (B) : 700 ppm; and (C) : 1000 ppm.

1. The fresh weight of cut flowers, the numbers of inflorescence and flowers per 20 plants varied, depending on the CO_2 concentration for each flowering cycle.

2. The preservability (vase life) of cut flowers always improved under higher CO_2 levels. Organic acid contents of plants were also higher under higher CO_2 levels. The malic acid content in the flowers was higher than in the younger leaf and flower stalk at 1:00 PM and 10:00 PM; and it was also higher in the younger leaf than in the flower stalk at 10:00 PM, but lower at 1:00 PM.

The pH value of plants was always lower at higher ambient CO_2 levels, and lower in the younger leaf and flower stalk at 1:00 PM than at 10:00 PM, wheras at those same times the sugar content at the higher ambient CO_2 levels reached its maximum.

Introduction

Many studies have been done on the effect of CO_2 enrichment on the yield and preservability of vegetable corps (Anon, 1962; Berkel, 1984; Calvert, 1972; Hand, 1982; Imazu et al., 1967), but, there were few such studies on orchids (Fast, 1967; Schmidt and Lauterbach, 1987). The relationship between the preservability of a cut flower and the organic acid and sugar contents in the flower stalk and flower in *Phalaenopsis* were reported by the authors (Endo and Ikusima, 1992).

This paper deals mainly with the effect of CO_2 enrichment on the yield and preservability of *Phalaenopsis* cut flowers, and discusses them in relation to the organic acids and sugars contents in the plant.

Materials and Methods

Sixty plants of white flower hybrid of *Phalaenopsis* (Yukimai) (number of leaves: 3.6; leaf area: 2.45 dm^2; dry weitht: 0.93 g) were grown on a rockwool bed in a greenhouse in natural CO_2 conditions at the Chiba Prefectural Agricultural Experimental Station from the beginning of 1988. The plants were ferti-gated monthly with 2.0 liters of a 1:4000 solution of a commercial orchid liquid fertilizer (Hyponex, Hyponex Japan, Osaka), and 5 mg N, 5 mg P_2O_5, 5 mg K_2O, and micronutrients per plant.

The maximum sunlight was kept between 5 and 7 klx by shading screens on the roof which were rolled up on cloudy days. The temperature was mainatained between 20°C and 30°C by heating and cooling.

Twenty plants each were cultured from April, 1990 to September 1992 in three greenhouses with different CO_2 concentration of (A) : control (daily mean of ambient atmosphere 438 ppm) ; (B) : 700 ppm; and (C) : 1000 ppm. The CO_2 from complete combustion of liquid petroleum gas (LPG) by a CO_2 generator (KCH-20Z, Katsura CO., Ltd.) was used of enrich the greenhouse atmosphere with CO_2 from sunset to sunrise. A fan, suspended under the roof beams, directed the circulation in each greenhouse. The fan revolved at 13-15

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rotations/sec, wind velocity on the leaf surface was 0.01 to 0.8 m per sec. The CO_2 concentration was restored in each greenhouse and was monitored by an infrared gas analyzer (ZFP9: Fuji Electric Co., Ltd., Tokyo).

Inflorescences produced in the autuman of 1990, the spring and autumn of 1991, and the spring and autumn of 1992 were harvested when they were in full bloom. The number of harvested inflorescences per 20 plants and the number of flowers per stalk were counted, and then each inflorescence was weighed.

In the second (March to April 1991) and fourth (March to May 1992) flowering cycle, ten inflorescences with 8 to 10 flowers and weighing 64 to 71 grams were taken from each treatment and put into cylindrical 1-liter vases to investigate their longevity. The limit of preservability was determined by the wilting of the sepals and petals.

At 1:00 PM and 10:00 PM on 18 May 1993, 5 younger leaves and 5 inflorescences were harvested from each of the three CO_2-level environments. Organic acid, sugar contents, and pH were measured using the method of Endo and Ikusima (1989).

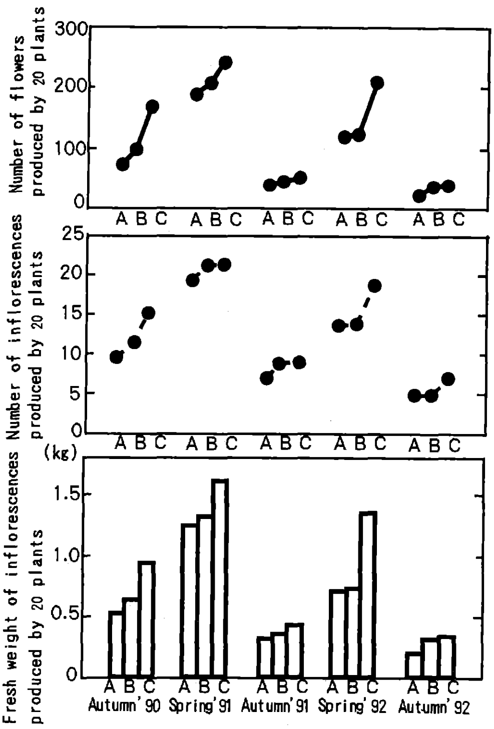

Fig. 1. Effects of CO_2 enrichment on *Phalaenopsis* cut flower cultivation. Data were collected from five flowering cycles from autumn 1990 to autumn 1992. Histograms show fresh weight of cut flowers per 20 plants (bottom). A, control; B, 700 ppm CO_2; C, 1000 ppm CO_2. Solid lines and broken lines show the number of flowers (top) and harvested inflorescences (middle), respectively.

Results

At 700 and 1000 ppm CO_2, the fresh weight of *Phalaenopsis* inflorescences was progrssively heavier with more inflorescences and flowers being produced than it was at ambient CO_2 concentrations. The numeric values of their yield indices were higher in spring than in autumn (Fig. 1). Total fresh weight of inflorescences per 20 plants in the five flowering cycles from autumn of 1990 to autumn of 1992 increased 13% over the control at 700 ppm CO_2 and 58% at 1000 ppm CO_2 (Fig. 1, bottom). The total number of inflorescences per 20 plants harvested during the five flowering seasons increased 11% over the control at 700 ppm CO_2, and 29% at 1000 ppm CO_2. The total number of flowers increased 10% at 700 ppm and 42% at 1000 ppm (Fig. 1, middle and top).

In 1991, the longevity of cut flowers was 62, 66, and 80 days under the CO_2 levels of control, 700 ppm, and 1000 ppm, respectively, whereas they were 44, 60, and 82 days, respectively, in 1992 (Fig. 2).

The organic acid contents and the pH values of leaves, flower stalks, and flowers are shown in Fig. 3. The malic acid contents (Fig. 3, open area) in the younger leaf (left, L), the flower stalk (Fig. 3, center, FS) and the flower (Fig. 3, right, FR) under enriched CO_2 at 1:00 PM (Fig. 3, B) and 10:00 PM (Fig. 3, A) were greater than those under 438 ppm CO_2 levels. The malic acid content in the flower was higher than in the younger leaf and flower stalk under all CO_2 levels. This difference diminished at 10:00 PM, but peaked at 1:00 PM even at the low CO_2 level.

The malic acid content of the younger leaf at 10:00 PM was greater than at 1:00 PM. The differences in malic acid contents in the yonger leaves between 10:00 PM and 1:00 PM were 1.24 mg per gram of fresh weight under control, 0.28 mg per gram under 700 ppm CO_2, and 0.34 mg

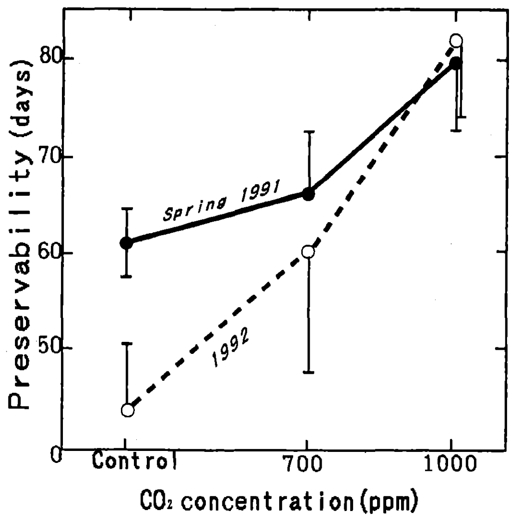

Fig. 2. Preservability of cut flowers of *Phalaenopsis* produced under different levels of CO_2. Based on days from harvesting to wilting of sepal. petals and floral abscission of top flower. Solid line shows preservability of second flowering cycle (Spring 1991), and dotted line shows that of fourth flowering cycle (Spring 1992). Bars indicate standard errors among 10 cut flowers.

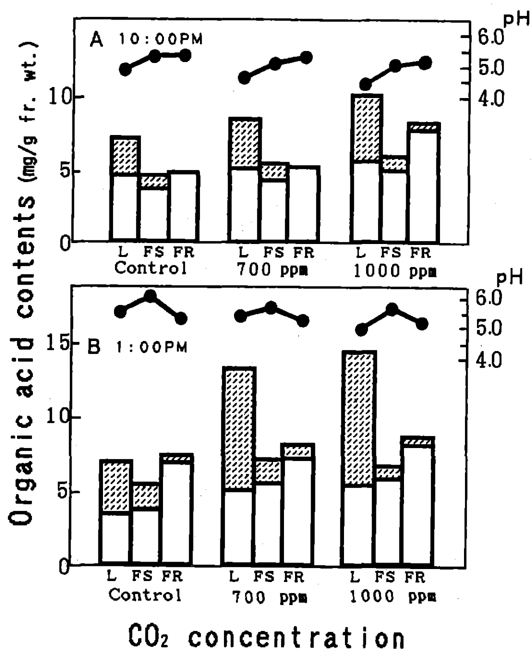

Fig. 3. Content (mg/g fr. wt.) of malic acid (open area), citric acid (dashes) and pH (solid line), in younger leaf (left, **L**), flower stalk (center, **FS**) and flowers (right, **FR**) at 10:00 PM (**A** top) and 1:00 PM (**B** bottom) under different CO_2 levels.

per gram under 1000 ppm CO_2.

Citric acid content (Fig. 3, dotted area) was highest in younger leaves and decreased gradually from flower stalk to flower. These values increased as CO_2 levels increased. The differences in citric acid contents in the younger leaves between 10:00 PM and 1:00 PM were 0.6 mg per gram of fresh weight under control, 5.1 mg under 700 ppm CO_2, and 4.8 mg under 1000 ppm CO_2.

The fluctuation in pH values (Fig. 3, solid line) in leaves, flower stalks, and flowers dropped as the CO_2 levels rose. The difference in pH values at 1:00 PM and 10:00 PM was greatest in the younger leaf and least in the flower.

The contents of fructose (dotted area), glucose (open area), and sucrose (hatched area) in the younger leaf (left, L), flower stalk (center, FS) and flowers (right, F) at each CO_2 level at 10:00 PM (top, A) and 1:00 PM (bottom, B) are shown in Fig. 4. The total sucrose, glucose and fructose contents in each organ rose as the CO_2 concentration increased. The sugar content in the flowers was higher at 1:00 PM than at 10:00 PM, but that relation was reversed in the flower stalk. Sugar content increased in this order: flower, flower stalk, and younger leaf under control of CO_2 all day long. Sugar content in the flower stalk increased with increasing CO_2 levels, reaching a maximum of 28.2 mg per g fresh weight at 1:00 PM under 1000 ppm CO_2.

Discussion

Among Japanese greenhouse growers, such as the muskmelon and rose who adopted CO_2 enrichment, have started to use pure CO_2 gas because it does not pollute the air and poses no risk of damaging the plants.

However, some growers of strawberries and oranges have been generating CO_2 through the combusiton of kerosene which has the added advantage of supplying heat. For double-cropping grapes in plastic-houses, CO_2 enrichment, using LPG fuel in pollution-free burners, has been adopted.

Generating CO_2 from LPG fuels has recently

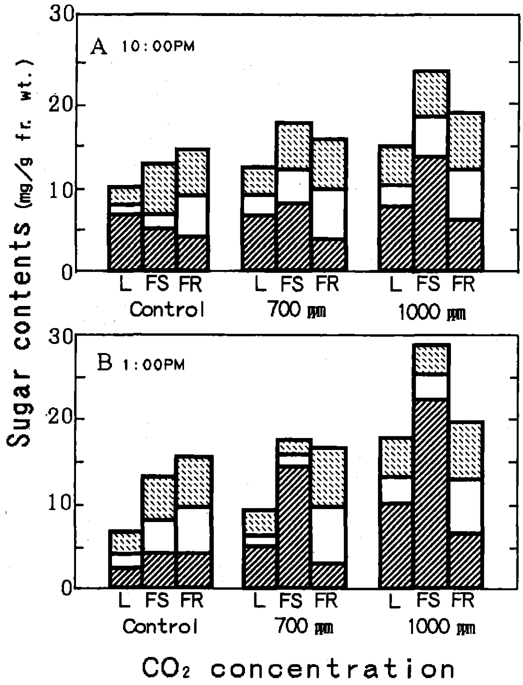

Fig. 4. Content (mg/g fr. wt.) of fructose (dashes), glucose (open area) and sucrose (hatched area) in younger leaf (left, **L**), flower stalk (center, **FS**) and flowers (right, **FR**) at 10:00 PM (**A** top) and 1:00 PM (**B** bottom), following each CO_2 enrichment.

aroused much interest since it is more economical than pure liquid CO_2 (93.3 yen per m^3 and 22.34 K cal of LPG combusiton, compared to 240 yen per m^3 of pure liquid CO_2).

The authors reported enhancing the initial growth of *Doritaenopsis* by CO_2 enrichment, burning LPG at night. *Phalaenopsis* has proven to be tolerant of gaseous air pollutants from LPG.

At CO_2 concentrations of 1000 ppm (Fig. 1 C) from sunset to sunrise, the fresh weight (Fig. 1, bottom), numbers of cut flowers (Fig. 1, middle), and flowers (Fig. 1, top) was highest; and in 700 ppm (Fig. 1, B) these values exceeded the control (Fig. 1, A). This effect of CO_2 enrichment agreed with the results of Schmidt and Lauterbach (1987). The higher the CO_2 concentration, the greater the cut flower yields at five flowering cycles of *Phalaenopsis*.

The CO_2 uptake at night was promoted by CO_2 enrichment. *Phalaenopsis* synthesizes malid acid by CO_2 fixation in the dark (Osmond, 1987). The purpose of our subsequent experiment was to confirm the effect of CO_2 enrichment on *Phalaenopsis* cultivation. We reported that there was a difference in the malic acid content in *Phalaenopsis* leaves between day and night (Endo and Ikusima, 1989). In this study, a further experiment was perfoumed to examine the effect of different CO_2 levels on CO_2 enrichment. As a result, differences in organic acid and sugar contents between light (1:00 PM) and dark conditions (10:00 PM) were reconfirmed.

The total content of citric and malic acids in the plant simultaneously increased at 1:00 PM (Fig. 3, B) to a greater degree than at 10:00 PM (Fig. 3, A). These results agreed with the pH values in all three parts of the plant at 10:00 PM, which were lower than at 1:00 PM (Fig. 3, solid line).

CO_2 uptake by the young leaves of *Phalaenopsis* was higher than in the mature leaves (Ota et al., 1991). However, the maximum level of acidity in the young leaves of *Arachnis* Maggie Oei was only half that of the mature leaves (Goh et al., 1984). Moreover, we reported only a slight difference in malic acid content between 1:00 PM and 10:00 PM in diurnal rhythm (Endo and Ikusima, 1989). We performed the analysis consciously to determine a possible difference in malic acid contents between 1:00 PM and 10:00 PM. Any difference in the malic acid contents would indicate the effects of CO_2 enrichment.

The malic acid content in the yonger leaf in each treatment was higher at 10:00 PM than at 1:00 PM. Moreover, the higher the CO_2 levels, the greater the malic acid content in the younger leaf.

The sugar content in the plant increased with the increase in atmopspheric CO_2 concentration (Fig. 4). *Phalaenopsis,* which are CAM plants, synthesize carbohydrates in the light photosynthetically by using malic acid fixed in the dark. During the day, much CO_2 is available by the deacidification of malic acid in the plant under higher CO_2 levels (Fig. 3-L, 10:00 PM to 1:00 PM). Results demonstrate that the higher the CO_2 levels, the higher the sucrose contents and the greater the plant size.

The preservability of *Phalaenopsis* cut flower was prolonged 10 days at 700 ppm CO_2, and 30 days at 1000 ppm CO_2, (Fig. 2). The total sugar content in the flower stalk at 1:00 PM increased 30% (700 ppm CO_2) and 78% (1000 ppm CO_2) in comparison to the control (Fig 4 B of FS). The translocation of sugars from flower stalk to floret is indicated from the data in Fig. 4 A and B of F. The results agree with our prior theory (Endo and Ikusima, 1992).

CAM plants also produce sugars as photosynthates (Osmond, 1987). In our experiment, sugar content in the leaf was lower than that in the flower stalk and flower, revealing a translocation gradient of total sugar from the leaf to the flower stalk, The longer preservability of flowers produced under higher CO_2 may also be due in part to the contribution of sugar in the flower stalk and flower.

This is a study of the effects of long term CO_2 enrichment on the yields of *Phalaenopsis* cultivated in a greenhouse. Our results might serve to establish the validity of CO_2 enrichment by usnig LPG for grwoth acceleration, an increase in cut flower yields, and the improvement of flower quality in *Phalaenopsis* cultivation.

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Literature Cited

Anon. 1962. Dutch now treat 4,000 acres of lettuce with CO_2. Grower 8 : 194-195.

Berkel, N. van. 1984. Injurious effects of high CO_2 concentrations on cucumber, tomato, chrysanthemum and gerbera. Acta Hort. 162 : 101-112.

Calvert, A. 1972. Effects of day and night temperatures and carbon dioxide enrichment on yield of glasshouse tomato. J. Hort. Sci. 47 : 231-247.

Endo, M. and I. Ikusima. 1989. Diurnal rhythm and characteristics of photosynthesis and respiration in the leaf and root of a *Phalaenopsis* plant. Plant Cell Physiol. 30 : 43-47.

Endo, M. and I. Ikusima. 1992. Changes in concentrations of sugars and organic acid in the long-lasting flowers of *Phalaenopsis*. Plant Cell Physiol. 33 : 7-12.

Fast, G. 1967. Neue Erfahrungen mit *Orchideen-Aussaaten*. Gratenwelt 67 : 287-288.

Goh, C. J., O. Wara-Aswapati and P. N. Avadhani. 1984. Crassulacean acid metabolism in young orchid leaves. New Phytol. 96 : 519-526.

Hand, D. W. 1982. CO_2 enrichment, the benefits and problems, Sci. Hort. 33 : 14-43.

Imazu, T., K. Yabuki and Y. Oda. 1967. Studies on the carbon dioxide enrichment for plant grwoth. II. The effect of CO_2 concentration on growth and fruit set of eggplant (*Solanum melongena* L.). J. Japan. Soc. Hort. Sci. 36 : 275-280.

Osmond, C. B. 1987. Crassulacean acid methabolism: A curiosity in context. Ann. Rev. Plant Physiol. 29 : 379-414.

Ota, K., K. Morioka and Y. Yamamoto. 1991. Effects of leaf age, inflorescence, temperature, light intensity and moisture conditions on CAM photosynthesis in *Phalaenopsis*. J. Japan. Soc. Hort. Sci. 60 : 125-132.

Schmidt, K. and D. Lauterbach. 1987. Topf-Phalaenopsis. Gezielte Blute durch kuhle Kultur. Deutscher Gartenbau 41 : 1324-1327.

ファレノプシス栽培における切花の収量・鮮度保持に対するCO_2の施用効果

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摘　要

ファレノプシス栽培におけるCO_2施用の効果を30ヶ月間5回の開花期にわたり調査した．供試植物を大気中のCO_2濃度が（A）コントロール，（B）700 ppm，（C）1000 ppmの3棟の温室で栽培した．20株当たりの切花重，切花本数および花数は各開花期ともCO_2濃度が高い条件で生産されたもののほうが多かった．切花の鮮度保持日数はCO_2濃度が高いほうが長かった．有機酸含量はCO_2濃度が高いほうが多かった．13時と22時のリンゴ酸含量はいずれも花で最上位葉と花茎より多かった．22時のリンゴ酸含量は最上位葉が花茎より多かったが，13時では少なかった．植物体のpHはCO_2濃度の高いほうが，いずれの部位でも常に低かった．最上位葉と花茎のpHは13時が22時より低かった．糖類含量はCO_2濃度が高いほうが13時，22時ともに多かった．以上のように，ファレノプシス栽培におけるCO_2の施用によって切花の収量は増加するとともに，鮮度保持期間も長くなることが認められた．