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# Winter Greenhouse Strawberry Production Using Conditioned Plug Plants

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***Abstract.*** **Two- to three-week-old 'Sweet Charlie' strawberry (*Fragaria ×ananassa* Duch.) plug plants were conditioned [seven 9-hour short days without chilling (21 °C day/21 °C night) followed by seven 9-hour short days with chilling during the nyctoperiod (21 °C/12 °C night)] in September, then planted in a vertical hydroponic system for winter greenhouse production. Conditioned plugs produced significantly more fruit than did nonconditioned control plugs in January and February, but the difference was nonsignificant in March and April. Fruit yield increased linearly with height in the column (≈40 g/plant for every 30-cm increase in column height), probably because of increasing light level. When productivity is considered on an area basis (kg·m$^{-2}$) and the column height effect on yield is accounted for, productivity over a 4.5-month period was 4.8 kg·m$^{-2}$ for controls and 7.8 kg·m$^{-2}$ for conditioned plugs. Conditioned plug plants offer the potential for increasing strawberry productivity and therefore the profitability of a winter greenhouse production system.**

Florida and California provide the bulk of fresh strawberries on the market in the United States from January through late October. From November through early January, a market window exists, as availability of fresh strawberries is at a minimum (U.S. Dept. of Agriculture, 1995). Commercial greenhouse production of strawberry is common in Europe and Japan. Selection and preparation of plant material prior to forcing is critical for adequate production and economic viability (Leiten, 1991, 1993; Mochizuki, 1995).

Greenhouse production of strawberries in the United States is limited to a few small hydroponic operations and the long-term profitability is still unknown. The greatest impediments to success include the high costs of production coupled with limited productivity due to: 1) the complex nature of the flowering response in strawberry, 2) planting stock variability in both type (dormant, fresh dug, or plugs) and vigor, 3) variability of environmental treatment before forcing, and 4) the lack of a horticulturally and economically appropriate system for production.

Strawberry plug plants (Poling and Parker, 1990) are becoming popular in the United States as transplants for field production in the annual hill system (Poling, 1993). Photoperiod and temperature conditioning of plugs induces precocity and enhances yield in the Florida winter production system (Bish et al., 1997; Durner and Poling, 1999). This paper reports enhanced winter production of strawberries in a greenhouse by applying conditioning treatments to plug plants.

## Materials and Methods

Two- to three-week-old 'Sweet Charlie' strawberry plug plants in 50-cell tray packs were obtained from Walker Brothers Nursery, Pittsgrove, N.J., on 27 Aug. 1997. Plugs were conditioned, then planted in a vertical hydroponic system on 30 Sept. 1997. Nonconditioned plugs were planted as controls. Conditioning treatment was seven 9-h short days without chilling (21 °C day/21 °C night) followed by seven 9-h short days with chilling during the nyctoperiod (21 °C day/12 °C night). Photoperiod treatment was provided using lightproof growth boxes constructed of insulating board. Chilling treatment was provided in a lightproof cold room. Plants were moved to the greenhouse daily to avoid a possible photosynthetic effect. The experimental design was a randomized complete block with four blocks. Blocking was by height in the production column, with four blocks per column.

The hydroponic system was constructed of 18-cm plastic drainage pipe. Four holes (4.5 cm in diameter) were drilled equidistant around the circumference of the pipe and staggered and spaced every 15.75 cm up the pipe, for a total of eight sets of four holes each per column. Columns were 1.75 m tall, spaced 1 m apart in the greenhouse. Two emitters per column provided trickle irrigation. One emitter was placed at the apex and the other halfway down the column. The substrate was coarse perlite. Fertigation was supplied via dual Dosmatic Plus DP30 injectors (Dosmatic USA, Carrollton, Texas), controlled by a Nelson Irrigation Controller (L.R. Nelson Corp., Peoria, Ill.). Columns were fertigated twice daily (20 min each time) with Hydrosol (Scotts-Sierra, Marysville, Ohio) supplemented with calcium nitrate and magnesium sulfate. The fertigation solution was not recycled. Bumblebees (Koppert Biological Systems, Inc., Ann Arbor, Mich.) were introduced to the greenhouse when plants began to flower. A Johnson 1332 generator (Johnson Gas Appliance Co., Cedar Rapids, Iowa) was used to maintain $CO_2$ levels of 1000 μL·L$^{-1}$ from 12:30 until 8:00 AM. Natural daylength in the greenhouse was supplemented with ET-SU-400/100-HPS/MH 1000-W lights (Energy Technics, York, Pa.) from 1:00 to 8:00 AM to provide a photoperiod of 16 h. One lighting fixture was centered over every four columns. Light intensities were not measured. Temperature in the greenhouse was 17 °C day/12 °C night.

Fruit were harvested fully ripe and nonmarketable fruit were culled. Yield data for marketable fruit were summarized by month (December–April) and total yield was calculated. Data were subjected to an analysis of variance (ANOVA) and comparisons between the control and conditioned plugs were made via Fisher's protected least significant difference (LSD).

## Results and Discussion

Conditioned plugs produced significantly more fruit than did control plugs in January and February (Table 1), but the difference was nonsignificant in March and April. By March, all plants had been under the same environmental conditions for 3 months, and the conditioning effect had apparently dissipated. Though conditioned and control plugs were productive over an extended period, the bulk of the harvest was not realized in time for the targeted winter holiday market. Earlier productivity is a major goal of continuing research. With production extending well into spring, conditioning treatments might increase production for spring holidays as well. Remarkably, plants were still flowering and fruit-

Table 1. Winter productivity for 'Sweet Charlie' strawberry plugs in a vertical hydroponic system.

| Treatment | Month | | | | | Total |
|---|---|---|---|---|---|---|
| | Dec. | Jan. | Feb. | Mar. | Apr. | |
| | | | *Yield (g/plant)* | | | |
| Control | 18.7 a[z] | 84.4 b | 12.2 b | 56.1 a | 54.1 a | 225.5 b |
| Conditioned | 15.9 a | 125.3 a | 60.5 a | 98.4 a | 68.0 a | 367.9 a |
| | | | *Fruit per plant* | | | |
| Control | 0.9 a | 6.1 a | 1.3 b | 4.6 a | 6.3 a | 19.2 b |
| Conditioned | 0.8 a | 7.5 a | 4.8 a | 8.3 a | 7.0 a | 28.3 a |

[z]Mean separation within columns via *t* test, $P = 0.05$.

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ing on 1 July 1998 (May and June yield not recorded).

Fruit yield increased linearly with height in the column [yield/plant (g) = 154.5 + 1.4 × column height (cm), $r^2 = 0.13$], probably because of increasing light level. Yield increased ≈40 g/plant for every 30-cm increase in height in the column. The response to height position in the column was not influenced by conditioning treatment, as no height × treatment interaction was detected by the ANOVA.

Average fruit size (12.0 g) was small, and was not influenced by treatment, and was consistent over time. Fruit were not size-graded; thus, average berry weight can be misleading. Many primary fruit weighed 25 to 40 g. Fruit quality was very good; fruit were aromatic, sweet, and flavorful.

When productivity is considered on an area basis ($kg \cdot m^{-2}$) and the column height effect on yield is accounted for, productivity over a 4.5-month period was 4.8 $kg \cdot m^{-2}$ for controls and 7.8 $kg \cdot m^{-2}$ for conditioned plugs. This yield is very good when compared with European (Lieten, 1991, 1993) and Japanese (Mochizuki, 1995) yields.

Conditioning significantly enhanced production. Conditioned plug plants offer the potential for increasing strawberry productivity and, therefore, the profitability of a winter greenhouse production system. Future work will involve cultivar selection and refinement of the conditioning treatment and planting date to induce earlier production. The economics of such a system will have to be considered to determine its commercial feasibility.

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