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A System for Producing Large Quantities of Greenhouse-grown Strawberry Plantlets for Plug Production

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SUMMARY. **A greenhouse hydroponic system, which uses suspended plastic troughs, was found to be an efficient system for the production of high quality strawberry (*Fragaria ×ananassa*) plantlets. In this system micropropagated mother plants of 'Oso Grande' and 'Sweet Charlie' produced an average of 84 and 80 daughters per mother plant, respectively, in 1996, at a plant density of 3 mother plants/ft² (32 mother plants/m²). Nearly 100% of the plantlets harvested from the system were successfully rooted in plug trays, and showed no symptoms of leaf or crown diseases.**

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Commercial strawberry cultivars must be propagated vegetatively because their seeds are not true to type. The standard strawberry transplant used in Florida and other major winter production areas of the world is produced by planting a field nursery in the spring. The nursery plants produce daughter plants on stolons in response to long daylengths and high temperatures. In early fall the daughter plants from the nursery field are dug, soil is removed from the roots, and the plants are held at 32 to 36 °F (0 to 2 °C) for 1 to 2 weeks until they are planted in a fruit production field. High early season fruit production in Florida requires that three or more functional leaves remain on the plant after digging and during the establishment period (Albregts and Howard, 1985).

A disadvantage of this type of leafy, bareroot transplant is that extensive overhead irrigation is required for successful establishment on black plastic covered raised beds (Stanley et al., 1991). During planting in early October, Florida growers typically operate their sprinkler irrigation systems 7 h·d^{-1} for 7 to 10 d to ensure plant establishment. This practice uses large amounts of water, which can cause nutrient leaching and create an environment conducive to the development and spread of diseases. In comparison, plug or tray transplants require very little water for establishment (G.J. Hochmuth, unpublished data). A factor that currently limits the production of plugs in the United States is an economical source of high quality plantlets. Cuttings for plug production are presently taken from field nurseries. Material from this source is tedious to collect and is likely to contain pathogens (Stapleton et al., 2000). Large quantities of pathogen-free plants can be produced through micropropagation (Boxus et al., 1977), but this plant material is expensive, especially if used directly for plug production. However, if plantlets derived from micropropagated mother plants are used for plug production, costs should be more reasonable. The objective of this study was to evaluate a soilless greenhouse system for the ability to generate large quantities of viable, disease-free strawberry plantlets from micropropagated mother plants. The productivity of foundation stock (i.e., first-year daughters from micropropagated plants) and plants not derived from micropropagation was also evaluated in this system.

Materials and methods

The system consisted of white plastic troughs, 4 inches (10 cm) wide and 4 inches deep, suspended horizontally 4 ft (1.2 m) above the greenhouse floor (Fig. 1). The troughs were filled with a mixture of 4 vermiculite : 1 perlite (by volume) . Drip tubing with a 12 inch (30.5 cm) emitter spacing and with each emitter having a flow rate of 0.33 gal/h (1.25 L·h^{-1}) at 8 lb/inch² (55 kPa) (Netafim, Orlando, Fla.) was placed on top of the soilless substrate, followed by 1-mil [0.001 inch (0.03 mm) thick] white-on-black plastic mulch to deter algae growth.

This system was built and evaluated in a glass greenhouse at the University of Florida, Gainesville. Air temperatures in the greenhouse during the evaluation period were maintained at 90 °F day/77 °F night (32 °C day/25 °C night), and 30% shade cloth was used, which resulted in a light intensity of 3500 fc (700 μmol·m^{-2}·s^{-1}) during full sun. The photoperiod was extended to 16 h with high-pressure sodium halide lamps [1139 fc (150 μmol·m^{-2}·s^{-1})].

Micropropagated and foundation plants of 'Sweet Charlie' and 'Oso Grande' were obtained from Nourse

Fig. 1. Greenhouse hydroponic system used to produce plantlets for strawberry plug production.

Farms, Inc. (South Deerfield, Mass.), and plants of 'Sweet Charlie' and 'Oso Grande' not derived from micropropagation were obtained from a field nursery at the Gulf Coast Research and Education Center, Dover, Fla. On 3 Mar. 1995 and 1996, plants were planted on both sides of the drip tube with a 4 inch (10 cm) space between plants. Troughs were spaced 12 inches apart, center to center. Plots contained 10 plants each and were arranged in a randomized complete-block design, with each treatment replicated five times.

Plants were fertigated for 10 min, three times a day. The electrical conductivity (EC) of the fertilizer solution was decreased in 1996 (Table 1) because leaf tipburn was observed in 1995. The tipburn was attributed to localized calcium deficiency, which could have been caused by the high osmotic potential of the nutrient solution (Doolan et al., 1983).

Runners (stolons) produced by the mother plants hung over the troughs and grew down toward the greenhouse floor. These runners were harvested after 8 and 16 weeks from the start of the experiment, and the number of daughter plantlets were recorded. Up to 50 plantlets from each plot were then rooted under mist irrigation (12 s of mist every 6 min) for 1 week in 1.15-inch^3 (18.8-cm^3) flats (Todd 100; Speedling, Inc., Sun City, Fla.). The rooting medium consisted of 4 vermiculite : 1 perlite (by volume). The percentage of surviving daughter plants was recorded after two weeks in the rooting flats. Data from each year was analyzed separately by analysis of variance using the SAS GLM procedure (SAS Institute, 1989).

Results and discussion

More plants were produced in 1996 than in 1995, probably due to the difference in concentration of nutrients in the fertigation solution. The EC of the nutrient solution was 1720 μmhos/cm (μS·cm^{-1}) in 1995 and 700 μmhos/cm in 1996.

Micropropagated plants (MP) consistently produced more daughters than daughters of micropropagated plants (DM) or standard propagated plants not derived from micropropagation (SP) (Table 2). The increased runnering ability of MP versus SP plants is well known, and was documented in the early 1980s by Swartz et al. (1981) and Marcotrigiano et al. (1984).

Daughter plant survival across cultivars, years, and mother plant type was virtually 100%, and no disease symptoms were observed on any of the rooted plants (data not shown). Plug transplants derived from MP, DM, and SP mother plants have been highly productive, in terms of fruit yields, when planted in a Florida winter production system (Bish et al., 1997).

In 1996 'Oso Grande' MP mother plants produced an average of 84 daughters per mother plant (total of both harvests), and 'Sweet Charlie' MP mother plants produced an average of 80 daughters per mother plant. These daughter plant yields were impressive, but could potentially be higher. Runners in this study were not harvested after early July, but commercially runners could be harvested until the end of July. This would still allow enough time to produce mature plug plants for an early October planting date in Florida fruit production fields.

Runners in the suspended trough system were easier to harvest than run-

Table 1. Nutrient concentrations in fertigation solutions used in a greenhouse hydroponic system to produce strawberry plantlets for plug production.

	Concn [ppm (mg·L^{-1})]	
Element[z]	1995	1996
N	120	30
P	40	10
K	120	30
Ca	120	30
Mg	40	10
S	64	16
B	0.8	0.2
Cu	0.2	0.05
Fe	4.8	1.2
Mn	0.4	0.1
Mo	0.04	0.01
Zn	0.4	0.1
	EC[x] = 1,720 μmhos/cm pH = 5.7	EC = 700 μmhos/cm pH = 5.7

[z]Nutrients derived from calcium nitrate, potassium nitrate, potassium phosphate, magnesium sulfate, boric acid, di-sodium copper, sodium EDTA ferric, di-sodium manganese, sodium EDTA molybdate, and sodium EDTA zinc.
[y]EC = electrical conductivity; μmhos/cm = μS·cm^{-1}.

Table 2. Strawberry daughter plant production from mother plants grown in a greenhouse hydroponic system.

Harvest[z]	Cultivar	Mother plant type[y]	Daughters (no.) 1995	1996
1	Oso Grande	MP	14.1 a[x]	15.3 a
		DM	9.4 b	12.8 b
		SP	6.6 c	7.2 c
	Sweet Charlie	MP	9.4 b	15.7 a
		DM	6.8 c	7.2 c
		SP	2.6 d	3.9 d
2	Oso Grande	MP	35.9 a	68.7 a
		DM	29.7 b	47.0 d
		SP	26.8 c	37.2 f
	Sweet Charlie	MP	30.4 b	64.2 b
		DM	27.2 c	57.6 c
		SP	25.7 c	41.5 e

[z]Harvests 1 and 2 occurred 8 and 16 weeks, respectively, after planting mother plants.
[y]MP = micropropagated plant; DM = daughter of micropropagated plant; SP = standard propagated plant (not derived from micropropagation).
[x]Mean separation within columns and harvests by Duncan's multiple range test at $P \leq 0.05$.

ners from a field nursery. No stooping was required with the suspended trough system. Another advantage of the suspended trough system was that less harvesting was needed to obtain the desired number of plantlets. Runners were left on mother plants until they were several feet in length and contain numerous plantlets. Mother plants in field nurseries need to be harvested regularly to prevent plantlets from rooting into the soil.

By using the suspended trough system in a glass or plastic house, plants were kept dry, which has the potential to minimize the development and spread of many diseases, including those caused by *Botrytis cinerea*, *Colletotrichum* sp., and *Xanthomonas fragariae*. Also, insect vectors could be excluded, reducing the likelihood that plants will become infected with viral or phytoplasmal pathogens.

In 1996, 'Oso Grande' MP plants produced 40% more daughters than 'Oso Grande' DM plants, whereas 'Sweet Charlie' MP plants produced 27% more daughters than 'Sweet Charlie' DM plants. With such increased productivity over DM plants, MP plants would seem to be the best type of mother plant to use in this system. The initial cost of mother plants, however, should be considered. MP plants are currently five times as expensive as DM plants ($0.85 versus $0.175 per plant) (T. Nourse, personal communication). The use of SP plants in this system is not recommended because of their low daughter plant yield, and potential to contain viruses and other systemic pathogens.

In conclusion, it appears that the suspended trough system described above is an excellent system for the generation of daughter plants for commercial plug production. Assuming three DM mother plants/ft^2 and an average yield of 80 daughters per mother, less than 10 acres (4 ha) of greenhouse space would be required to supply the 100 million plantlets needed by the Florida strawberry industry each year.

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