EFFECTS OF TRANSPLANT CONDITIONING ON 'CHANDLER' STRAWBERRY PERFORMANCE IN A WINTER GREENHOUSE PRODUCTION SYSTEM

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ABSTRACT. Plug plants of 'Chandler' strawberry were transplanted into horizontal nutrient film techniques (NFT) gutters and pots. Plants produced from runner tips and transferred into a 1-L containers in September developed greater numbers of branch crowns and produced more fruit in winter than plants maintained in 0.08-L cells. Plug plants derived from large and small tips produced similar yields. Chilling (10 °C) plug plants during the night for 20 days had no effect on the fruiting pattern or total yield. Plants in the NFT gutters produced up to 900 g of fruit per plant.

In North America, strawberry cultivation in greenhouses or under high tunnels is still limited. However, interest in soilless strawberry culture systems designed to produce fruit specifically out-of-season is increasing rapidly (Takeda, 1993). The period between November and January is the time when strawberries are not readily available and the price for fresh strawberries the highest (USDA, 1995). In the United States, the impending loss of methyl bromide as a soil fumigant in 2006 has underscored the need for economically acceptable alternative methods of growing strawberry plants for fruit production and vegetative propagation material. In the mid-Atlantic coast region there is impetus to help smaller growers extend their fruit and vegetable marketing into the off-season by using protected culture systems with an emphasis on short-term crops. These systems are also intended to assist particularly the small or limited-income farmers in the areas that have been severely impacted by recent cuts in government support programs or who can no longer make a profit in traditional commodity.

In the eastern United States, growers can use controlled environment agriculture to produce strawberries during winter months when fresh berries can demand high prices (USDA, 1995). Takeda et al. (1993, 1997) have reported that greenhouse production of 'Camarosa' strawberry yielded 1.2 kg/plant over a 6-month harvest period between December and May in narrow nutrient film technique (NFT) channel gutters. Strawberries have been produced in vertical systems to use the vertical space in the greenhouse better (Durner, 1999; Takeda, 1999a, 1999b; Takeda et al., 1993). However, as with any vertical, high density system, irradiance levels in the middle and lower sections of the tower were suboptimal, resulting in a significant delay in growth of plants and a reduction in fruit production. During the winter months in the mid-Atlantic coast region (about 39° N latitude), the irradiance reaching the plants at the bottom of six-pot tower system were less than 20% of levels measured at the top (Takeda, 1999b).

Cold-stored, dormant transplants in plasticulture, NFT, and soilless systems do not fruit satisfactory (Kempler et al., 1991). Alternative transplant sources are fresh-dug, bare-root plants from nurseries in Canada. However, the plants are only available during mid-September to mid-October, which is too late for planting in the mid-Atlantic coast region. Also, field produced

transplants may not be free of soilborne pathogens which can proliferate in a hydroponic system. Research was initiated to develop a runner tip production strategy using mother plants growing in a greenhouse soilless culture system. The objectives of this study were to determine the effects of a) the size of runner tips, b) cool night temperatures, c) the time of plugging runner tips, and d) container size on flowering and fruiting of 'Chandler' plants in an out-of-season production environment.

MATERIALS AND METHODS

Mother plant establishment. In vitro-grown 'Chandler' plantlets were set in flats in a heated greenhouse at Beltsville, Md., in mid-January 1999 with a 16-h photoperiod under high pressure sodium (HPS) lamps. In late March, when sufficient roots had developed, plantlets were teased out of the substrate, transplanted into 1-L pots, and transferred to a greenhouse in Kearneysville, W.Va. Potted plants were grown on heated mats (22 ± 2 °C) for another month until roots were protruding from the bottom of the pots. Plants, along with the rooting substrate, were then placed 30 cm apart in slightly inclined NFT gutters filled with horticultural perlite (Carolina Perlite Co., Gold Hill, N.C.) The details of the nutrient solution composition and delivery method have been described previously (Takeda, 1999; Takeda et al., 1997). Day and night temperatures in the greenhouse with a NFT gutter system were 25 ± 5 °C during the day and 18 ± 6 °C during the night. The photoperiod was extended to 16 h with HPS lamps.

Runner tip harvest and plug plant production. Two harvest methods were used to collect runner tips for producing plug plants. In Method 1, mature single runner tips were harvested on 18 June and 20 July and stuck immediately in 48-cell packs (0.08-L) for rooting under mist. In Method 2, the runners were left intact and allowed to elongate and develop daughter plants until 20 July, when the daughter plants were harvested and sorted by size classes, ranging from 1 to 10 g. Tips weighing about 1 g (very small) and 5 g (large) were stuck into 48-cell packs (Study 1).

The June-propagated plants from Method 1 were either retained in 48 cell-packs or transplanted in early September into 1-L pots filled with 2/3 horticultural perlite and 1/3 coconut coir (Verti-Gro, Inc., Lady Lake, Fla.) (Study 2). For 20 d in September, one set of July-propagated container plants were moved each day in late afternoon into an unlit growth chamber maintained at 10 °C for about 14-h night cooling treatment. The control plants were left in the greenhouse and received night temperatures of 16 to 20 °C during the same period (Study 3). In addition, runner tips harvested from field-grown plants of 'Chandler' strawberry were obtained in early September from a nursery in Canada (about 43° N latitude) and were rooted under mist. The performance of plug plants, generated from field produced runner tips, was compared in a pot culture system (Study 4) with runner tips harvested in July by Method 1.

Greenhouse fruit production. On 14 Oct., all container plants were transplanted into NFT gutters or pots in a greenhouse with day and night temperatures maintained at 20 ± 3 °C and 14 ± 3 °C, respectively. The HPS lamps provided about 5.4 $M \cdot m^{-2} \cdot d^{-1}$ PAR over ambient solar energy. In Study 1 and 2 plants were set 30 cm apart in 15-cm-wide and 15-cm-deep gutters, which were filled with horticultural perlite and fertigated four to seven times a day. In Studies 3 and 4, three plants of each treatment were transplanted into 11-L pot filled with media consisting of one part each of peat, perlite, and coconut coir and fertigated daily for 10 min. The experiment was a randomized block design: the pot system consisted of four replications of single-pot plots and the gutter system consisted of four replications of six-plant plots. Branch crown numbers and crown diameter at the substrate level were determined in January and May 2000. Ripe fruit in each plot were harvested twice weekly until mid-May 2000. All data were analyzed using the general linear model procedure of the Statistical Analysis System and treatment means were separated by Duncan's new multiple range test ($p = 0.05$).

RESULTS

Study 1. The size of runner tips (1 vs. 5 g) used to produce plug plants (Method 2) had no effect on the initial bloom date (about 23 Nov.). Plants derived from large runner tips (5 g) produced slightly more fruit early (December and January) and again in April. By January, plants generated from large and small runner tips had similar crown development (21 mm diameter and 2.2 branch crowns per plant).

Study 2. Plug plants transplanted into 1-L containers flowered 2 weeks earlier (6 vs. 20 Nov.), had more branch crowns (4.2 vs. 1.8), and were larger (31 vs. 20 mm crown diameter) than plug plants left in 0.08-L containers. However, since the flowers were removed until 12 Nov., both plants produced the same amount of fruit (0.13 kg/plant) in December and January. After January, the plants transferred into 1-L containers produced more fruit than those retained in 0.08-L cell packs. Over the whole season those from 1-L pots produced more crowns (7.5) and more fruit (900 g/plant) compared to 5.3 crowns and 630 g per plants for those from 0.08-L cell packs.

Study 3. The 14 h cool-night temperature treatment for 2 weeks in September had no effect on initial bloom date, fruiting cycle, or total yield. Plants in both treatments produced about 0.7 kg of fruit per plant for the season. Crown development was not effected by exposures to cool temperatures at night. Both the control and treated plants enlarged their crown diameter to about 23 mm by January.

Study 4. The propagation date of runner tips for rooting affected the performance of 'Chandler' strawberry in the greenhouse. Plants plugged in July began flowering on 28 Nov. and produced more fruit in December and January than those plugged in September that began flowering on 20 Dec. Plant crown sizes in January were as follows: 1.7 branch crowns and 19 mm crown diameter versus 3.9 branch crowns and 33 mm crown diameter for July- and September-plugged plants, respectively. Spring fruit production was significantly greater in plants that were propagated in September. By mid-May, the plants propagated in September with field-grown runner tips and grown in pots had produced 782 g of fruit per plant while July-propagated plants yielded only 613 g of fruit per plant. Mean productivity in NFT was slightly less (570 g) than in pots but treatment did not differ due to problems with spider mite infestation.

DISCUSSION AND CONCLUSIONS

Early fruit production in 'Chandler' strawberry can be increased by earlier propagation date (July vs. September), larger container volume for rooting tips (1.0 vs. 0.08 L), but not by the size of the daughter plants (very small vs. large) or exposure to cool nights in September. The larger runner tips may have been restricted by the small cell volume (0.08 L) and as a consequence showed no greater yield than the small runner tips. Propagation in larger cell volume could have led to greater eventual production by the large tips. These results suggest that the onetime harvest of runners of different maturity (small to large) would be acceptable for production of plug plants. Onetime harvesting of runner tips generates three times the number of runner tips with less labor input than for the multiple, weekly harvesting of runner tips (Takeda et al., 2000).

Plug plants of 'Chandler' strawberry produced 600 to 700 g of fruit in winter without a chilling treatment. Plug plants from July and September propagation dates produced less fruit than those plants that were propagated in June. The lower yield of plants propagated in July was likely because they were held for two months in restricted rooting conditions beyond the 4 weeks needed for producing plug plants. The earliest and highest yields were obtained from plants rooted in June in 0.08-L, 48-cell pack containers and later transferred to 1-L pots. These plants flowered in early November and produced their peak spring crop a month earlier in March. Additional studies are needed to determine the effect of plant source as well as propagation time.

Plant productivity and development can be affected by environmental conditions and plant manipulation imposed on container plants before their establishment in the greenhouse. In a study of waiting-bed plant performance for winter production in Spain, Lopez-Galarza et al. (1997), reported that

in 'Chandler' strawberry there was a linear increase in production with crown number. Our results suggest that the seasonal productivity of 'Chandler' strawberry is not correlated with its branch crown number at the onset (January) or the end (May) of fruiting season.

Generally, short-day cultivars such as 'Chandler' have produced more fruit in the winter to spring greenhouse production system (Takeda, 1999). However, to realize higher cropping potential in November and December, everbearing types should be considered. Hamann and Poling (1997) reported that day-neutral 'Selva' plants that were propagated in May and exposed to as little as 2 weeks of cool temperatures during the night beginning in late June produced more than 200 g of fruit from August to October. Recently, Shaw and Larson (2000) reported that their new day-neutral 'Diamante' and 'Aromas' strawberries produced 2 kg/plant in a field-plot study at Watsonville, Calif. Also, waiting-bed production techniques (Leiten, 1993) may be used to achieve higher yields in early winter.

Controlled environment production systems can be used to produce strawberries during winter in the eastern United States. Previously, we demonstrated that 'Camarosa' strawberry could produce as much as 1.2 kg of fruit from January to May (Takeda, 1999). However, more research is needed to identify additional cultivars with high reproductive potential and disease resistance in the greenhouse environment, mitigate insect, mite, and fungal problems with biological control measures and different environmental parameters, and develop strategies to accelerate flowering and fruiting cycle to increase plant yields during the Thanksgiving Day to Valentine's Day period. If markets for strawberries during winter remain strong and greenhouse management systems can be improved, growers in the mid-Atlantic region will have opportunities to capture a portion of the high-value fresh strawberry markets in the eastern United States during the holidays.

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