Vegetable Section

Proc. Fla. State Hort. Soc. 128:166–169. 2015.

Investigating Technologies for Florida-produced Strawberry Plug Transplants

Emmanuel A. Torres-Quezada*[1,2], Lincoln Zotarelli*[2], Vance M. Whitaker[1,2], Rebeca L. Darnell[2], and Kelly T. Morgan[3]

[1]*University of Florida, IFAS, Gulf Coast Research and Education Center, 14625 CR 672, Wimauma, FL 33598*

[2]*University of Florida, IFAS, Horticultural Sciences Department, P.O. Box 110690, Gainesville, FL 32611-0690*

[3]*University of Florida, IFAS, Southwest Florida Research Education Center, 2685 SR 29 North Immokalee, FL 34142*

Additional index words. *Fragaria* x *ananassa*, time in nursery, strawberry cultivars

Most strawberry (*Fragaria* x *ananassa*) production in Florida is based on bare-root transplants (BR), which are relatively inexpensive and provide acceptable yield. However, overhead irrigation is required for establishment during the first 10 days after transplanting. Strawberry plug transplants (SP) are an alternative to BR transplants with reduced or no requirement for overhead irrigation during establishment; however, the cost is greater compared to BR due to labor and shipment costs. This experiment evaluated the effect of time in nursery on Florida-produced SP for three cultivars, 'Strawberry Festival', 'Florida Radiance', and Sensation™ 'Florida127'. Strawberry plugs were grown for four and six weeks in a passive-ventilated high tunnel during August and September 2014 and transplanted to the field in early October. The performance of SPs was compared to BR of each cultivar from a commercial nursery. For Sensation™ 'Florida127' and 'Florida Radiance', BR resulted in higher early yield with 2.51 and 1.72 MT·ha^{-1}, respectively, at 12 weeks after transplanting (WAT). In the case of 'Strawberry Festival', there was no difference between BR and 4-week-old SP transplants, with an average yield of 1.26 MT·ha^{-1} at 12 WAT. For total cumulative yield at 22 WAT, there were no differences between BR and 4-week-old SP transplant treatments for Sensation™ 'Florida127' or 'Strawberry Festival'. 'Florida Radiance' resulted in 13% higher yield when transplanted as 4- or 6-week-old SP compared to BR, with an average yield of 32.23 MT·ha^{-1}.

California and Florida are the two leading producers of cultivated strawberries (*Fragaria* x *ananassa*) in the United States (U.S. Department of Agriculture, 2012). Florida production in the winter months represents about 16% of the national total production (Mossler, 2010). Although strawberry is the most valuable crop per unit land area in Florida, the industry has faced increasing market competition, particularly from Mexico. Increased imports have contributed to the decrease in the seasonal average price, which fell from US $1.87 to US $1.10 per pound between 2010 and 2012 (U.S. Department of Agriculture, 2012). In order to achieve profitability in a more competitive market, it is necessary to take advantage of specific time periods that are most likely to coincide with high market prices. The highest strawberry prices occur between late November and early December, when neither Mexico nor Florida have yet reached full production (Tanino and Wang, 2008; Wu et al., 2012). This makes early season yield an important target for Florida growers (Bish and Cantliffe, 2002; Gilreath et al., 2006).

High quality transplants are essential for early fruit yield. There are two main production systems in Florida for strawberries. The most commonly-used is bare-root (BR) transplants (Bish et al., 1997b; Bish et al, 2002). Even though BR transplants are very affordable, in order to be established, large quantities of overhead irrigation water are required during plant establishment (Bish et al., 1997a). Between 10 and 14 d of overhead sprinkler irrigation (approximately 8 hours per day) are used to reduce temperature around the strawberry crown (Bish et al., 1997a; Bish et al., 2002; Bish and Cantliffe, 2002). This irrigation practice accounts for one-third of the total water needed during the strawberry season (Hochmuth et al., 2006a), increasing leaf wetness, water splashing, and ultimately contributing to disease spread and nutrient leaching out of the rooting zone (Bish et al., 1997a; Hochmuth et al., 2006b; Southwest Florida Water Management District, 2000).

An alternative production method for strawberry is plug transplants (SP). The active root system of SP and the high moisture retention of the medium allows the plants to establish with little, if any, overhead water (Crawford et al., 2000; Durner et al., 2002), potentially reducing water usage for establishment by 600,000 gallons per acre (gal/acre). However, one of the limitations of this system is the cost compared to BR which is almost double (Bish and Cantliffe, 2002; Hochmuth et al., 2006b). In Florida, most of the strawberry production is based on BR transplants from temperate regions (southern Canada, northern California,

*Corresponding author. Email: etorres1618@gmail.com; lzota@ufl.edu

and the mountains of North Carolina and Tennessee). With the added cost of shipping, handling and extra labor required to produce plugs, few growers are willing to spend an extra US $2600 per acre to use this technology. The development of production techniques for SP transplants in Florida could make SP transplants economically feasible while reducing water needed for establishment. The primary objective of this project was to evaluate the effect of time in nursery (four weeks vs. six weeks from runner tips) on early and total yield for Florida-produced strawberry plugs for three cultivars, compared to BR transplants.

Materials and Methods

Field trials were conducted during the 2014–15 strawberry season at the University of Florida-IFAS Gulf Coast Research and Education Center, in Wimauma, FL (lat. 27°75'N, long. 82°22'E). 'Strawberry Festival', Sensation™ 'Florida127' (hereafter referred to as 'Florida127') and 'Florida Radiance' mother plants were planted in 1-gallon pots using potting mix (Farfard-2 mix; Farfard, Agawam, MA) as growing media in a 6250 ft^2 high tunnel (Tunnel Tech, Tillsonburg, ON). Irrigation was adjusted according to the crop requirements. Emitters had a flow of approximately 125 mL/min (John Deere, San Diego, CA). Irrigation cycles delivered 375 mL/cycle per plant, three to four times per day. Mother plants received 1 lb/acre of nitrogen (N) per day, using a solution containing nutrient levels of 2.3% N, 1% phosphorus, 6.5% potassium, 2% calcium, 0.4% magnesium, 0.02% boron, 0.04% manganese, and 0.02% zinc. In mid-August and early September, runners from the three cultivars were harvested and transplanted into 50-cell plug trays, using the same potting mix described above. Runners were irrigated three times per day using micro-jets with a flow rate of approximately 930 mL/min with irrigation cycles of 10 min (Netafim, Israel). Fertilization started 10 days after plugging. Plugs received 0.5 lb/acre of N in a daily application until ready for field transplanting. Runners were grown for either four or six weeks according to the treatment.

Treatments consisted of three strawberry cultivars and three transplant types. The transplant types tested were BR transplants (control) (Crown Nursery, Inc., Red Bluff, CA), 4-week-old SP transplants and 6-week-old SP transplants. During the nursery stage in 2014, BR transplants received approximately 211 h of chilling (determined as hours at temperatures between 1 °C and 7 °C) (Lassen Canyon Nursery, 2015). Treatments were arranged in a randomized complete-block design with four replications. Each treatment plot was 13.5-ft long, with 20 plants per plot.

The soil at the experimental site is classified as a Myakka fine sand, siliceous hyperthermic Oxyaquic Alorthod with < 1.5% organic matter and a pH of 6.6. Before planting, the soil was tilled twice to an approximate depth of 8 inches. In late August, pressed beds were formed that were 27 inches wide at the base, 24 inches wide at the top, and 10 inches high, spaced 4-ft apart on center. During pressing, beds were fumigated with 1,3-dichloropropene (63.4%) + chloropicrin (34.7%) at a rate of 250 lb/acre (Telone® C-35; Dow AgroScience; Indianapolis, IN). Immediately after fumigation, beds were covered with high-density black polyethylene mulch film (1-mil thickness; Intergro Co., Clearwater, FL). At the same time, one drip tape line (0.5 $L \cdot h^{-1}$ per emitter, 12 inches between emitters; Rivulis, Gvat, Israel) was applied to the top center of the bed, directly under the polyethylene film. BR and SP treatments with three to five leaves were transplanted at the field on 6 Oct. 2014.

Transplants were set in double rows 15 inches apart. Overhead irrigation was only applied for 8 hours/day for the first 10 days to establish the BR transplants. The fertilization program was followed current recommendations for strawberry production in the state of Florida (Santos et al., 2014). Plots received 150 lb/acre of N of the same fertilizer formula described above. Daily fertilizer applications started two weeks after transplanting (WAT) through the drip lines using a hydraulic injector (Dosatron, Clearwater, FL) to pump concentrated stock solution into the irrigation water, using a dilution rate of 1:50 (v/v).

Plots were harvested twice a week starting 8 WAT (6 Dec 2014). Early marketable yield was defined as the cumulative marketable weight of the first five harvests (10 to 12 WAT), whereas total marketable yield consisted of the cumulative weight of 22 harvests during the season. Fruit were harvested on Mondays and Thursdays of each week between 6 Dec. 2014 and 2 Mar. 2015. A marketable fruit was defined as a fruit of at least 10 g, without visible blemishes, and at least 75% external red color. Average fruit weight was determined by dividing the marketable fruit weight of each treatment by its corresponding fruit number. Crown number per treatments was collected using five randomly selected plants per plot at 12 WAT.

Data were analyzed using analysis of variance within weeks after transplanting. Cultivars and transplant type were analyzed for interactions and main factors using the general linear model ($P < 0.05$). In case of significance, treatment values were separated using Fisher's protected least significant difference test (Statistix Analytical Software, version 9, Tallahassee, FL).

Results and Discussion

Strawberry yield and fruit number were evaluated at 12, 16, and 22 WAT. There was an interaction between cultivar and week of harvest and between transplant type and week of harvest for early and total yield and early fruit number. Therefore, each harvest was analyzed separately for the variables mentioned above. All treatments were first harvested on 6 Dec. (9 WAT), where plant type treatments showed similar trends within cultivars (Fig. 1). 'Strawberry Radiance' and 'Florida127' BR showed slightly higher yield than SP transplants at the first 3 weeks of harvest. Between 13 and 14 WAT (week 4 and 5 of harvest), all SP treatments showed an increase in yield compared to the BR treatments (Fig. 1). After 14 WAT, yield trends were similar among treatments, with a steady increase until 19 WAT. After this period, yield started to steadily decrease in all treatments (Fig. 1).

When comparing cumulative yields at 12, 16, and 22 WAT, there was an interaction between cultivars and plant type. At 12 WAT, 'Florida127' and 'Florida Radiance' BR resulted in higher early yield compared to SP transplants with 2.51 and 1.72 $MT \cdot ha^{-1}$, respectively (Table 1). In the case of 'Strawberry Festival', there was no difference between BR and 4 week-old SP transplants, while 6-week-old SP transplants resulted in the lowest cumulative yield with 0.23 $MT \cdot ha^{-1}$ (Table 1). At 16 WAT, 'Florida Radiance' 6-week-old SP transplants resulted in 33% higher cumulative yield than the BR control (Table 1). There were no differences in strawberry yield between BR and 4-week-old SP for 'Florida127' and 'Florida Radiance' at 16 WAT. For 'Strawberry Festival' at 16 WAT, the 4- and 6-week-old SP transplants resulted in 8% higher yield than BR transplants. For total cumulative yield at 22 WAT, there were no differences between BR and 4-week-old SP transplant treatments for 'Florida127' and 'Strawberry Festival' with 30.64 and 23.74 $MT \cdot ha^{-1}$, respectively. 'Florida Radiance'

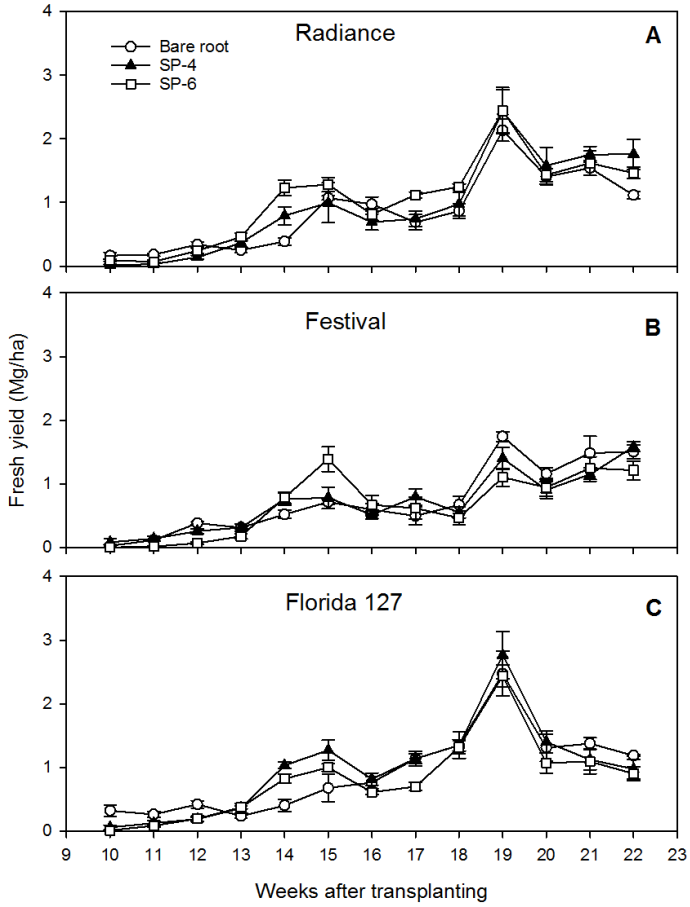

Fig. 1. Weekly harvests for A) 'Florida Radiance', B) 'Strawberry Festival' and C) 'Florida127' bare-root, 4-week-old and 6-week-old strawberry plug transplants from 6 Dec. 2014 (10 WAT) to 2 Mar. 2015 (22 WAT) at Balm, FL. Bars represent ± standard error of the mean. BR = Bare-root transplants, SP = Strawberry plug transplants. WAT = Weeks after transplanting. 1 MT·ha^{-1} = 0.4461 ton/acre.

resulted in 10% and 21% higher yield when transplanted as 4 week-old (30.70 MT·ha^{-1}) or 6 week-old (33.76 MT·ha^{-1}) SP transplants compared to BR (Table 1).

There was no interaction between transplant type and cultivar for 12, 16, and 22 WAT for fruit number. Cultivars performed differently for total fruit number at 12, 16, and 22 WAT. At 12 WAT, there was no difference between 'Florida Radiance' and 'Strawberry Festival' for fruit number with an average of 318,085 fruit per hectare, while 'Florida 127' had the lowest fruit number with 253,620 fruit per hectare. 'Florida Radiance' had the highest fruit number at 16 and 22 WAT with a total of 1,319,920 fruit per hectare. There was no difference between 'Strawberry Festival' and 'Florida127' at 16 and 22 WAT.

The number of crowns per plant was similar among cultivars with an average of 3.6 crowns per plant. However, there was an effect of transplant type on crown number. BR transplants averaged 2.8 crowns per plant, while 4- and 6-week-old SP transplants averaged 3.8 and 4.5 crowns per plant, respectively. The 4- and 6-week-old SP transplants had 31% more crowns per plant than BR. The lower number of crowns in BR treatments could be related to the temperatures to which BR transplants were subjected prior to establishment at the field. During the nursery stage, BR transplants received approximately 211 hours of chilling, while SP transplants, which were grown in Florida, did not accumulate chilling hours prior to field transplanting. The lack of chilling hour accumulation may lead to a higher requirement of photo-inductive cycles before bud break, compared to the BR transplants. Continuous vegetative development and delayed flower initiation of the SP treatments in the early stages of the experiment may be the reason for lower early yield (12 WAT) compared to the BR treatments (Table 1).

High early yield is a major target for strawberry growers due to the high profit margins that growers receive during this short time frame. According to the U.S. Department of Agriculture (2014), strawberry prices during the first two weeks of December are 45% higher than the average seasonal price. The results showed comparable performance of Florida-produced plugs compared to BR transplant for specific cultivars in regard to total yield. However, 'Florida Radiance' and 'Florida127' BR transplants resulted in the highest early yield at 12 WAT. 'Strawberry Festival' 4-week-old SP transplants and BR transplants resulted in the same early and total yield. Likewise, 'Florida127' 4-week-old SP transplants resulted in the same total yield as their BR control. Moreover, 'Florida Radiance' SP treatments resulted in higher total yield than their BR control.

Table 1. Effects of cultivar and transplant type on cumulative early, and total yields, Balm, FL, 2014–15 strawberry season.

	(MT·ha^{-1}) [x]								
	Weeks after transplanting								
	12			16			22		
	Transplant type[z]								
Cultivars[z]	BR[y]	4 SP[y]	6 SP	BR	4 SP	6 SP	BR	4 SP	6 SP
Florida Radiance	1.72 b A	0.47 b C	1.00 a B	12.31 ab B	11.89 bc B	16.38 a A	27.80 a B	30.70 a AB	33.76 a A
Strawberry Festival	1.32 b A	1.21 a A	0.23 b B	9.62 c B	10.52c A	10.49 b A	24.35 b A	23.13 b A	21.77 c B
Florida 127	2.51 a A	0.93 ab B	0.72 ab B	13.92 a AB	15.85 a A	12.77 bc B	29.78 a A	31.51 a A	26.52 b B

[z]Values followed by the different uppercase letters (rows) indicate that the means of treatments are significantly different ($P \leq 0.05$) according to Fisher's-protected least significant difference test within transplant type; values followed by the different lowercase letters (columns) indicate that the means of treatments are significantly different ($P \leq 0.05$) according to Fisher's-protected least significant difference test within cultivars.

[y]BR = Bare-root transplants, SP = Strawberry plug transplants.

[x]1 MT·ha^{-1} = 0.4461 ton/acre.

Even though little research has been done with Florida-produced plug transplants without previous floral induction conditions, similar results were found by Menzel and Toldi (2010), who reported no differences in total yield for three strawberry cultivars when using bare-root and plug transplants. In another study, Hochmuth et al. (2006a) concluded that plug transplants had earlier flowering compared to BR transplants, which directly increased early yield. However, even though the Hochmuth study was conducted in Florida, the production of the SP transplants was in Andreus, North Carolina. Thus, the flower induction period in these SP transplants may have begun before being planted in Florida, which would explain the increased early yields observed.

Containerized transplants allow the plants to arrive at the field with a fully functional root system, which leads to faster establishment and could lead to earlier flowering, if the weather conditions are adequate and the chilling requirement is fulfilled. More research is required to refine the plug production techniques for Florida conditions since it has potential for significant water savings during plant establishment. In this study, all plug treatments were established without any type of overhead irrigation. Thus, the use of plug transplants could potentially result in a water saving of six billion gallons per season (Hochmuth et al., 2006a). By utilizing proper production techniques to grow plug transplants for strawberries in Florida it is possible to obtain yield equivalent to bare-root transplants, with significant water savings for the state. However, it is important to mention that total yield and water saving are not the only defining factors influencing the decision process of what transplant type to be utilized for strawberry production in Florida. In this study, early yield for the three cultivars was consistently higher for BR transplants, with some similarities to 4-week-old SP for 'Strawberry Festival' (Table 1). However, the yield trends for all three cultivars showed an erratic yield pattern of the plugs compared to a steadier trend of the BR transplants (Fig. 1).

In conclusion, considering only one year of study, using 'Florida Radiance' or 'Florida127', BR transplants may result in the highest early yield. However, 'Strawberry Festival' might be planted as BR or 4-week-old SP transplant without differences in early yield. For total yield, 'Florida 127' and 'Strawberry Festival' resulted in the same yield when planted as BR or 4-week-old transplants. Furthermore, 'Florida Radiance' planted as 4- or 6-week-old SP transplants will result in higher total yield than BR transplants. Future studies should be conducted evaluating the feasibility of plug production from an economic stand point in Florida and how it interacts with the trend of production, early and total yields. Plug production in Florida may have a future; however, it is important to investigate the cost of production of SP in the state, alternative SP production practices that may increase both early and total yield, and potential options for flower induction of the SP transplants.

Literature Cited

Bish, E.B. and D.J. Cantliffe. 2002. Temperature conditioning and container size affect early season fruit yield of strawberry plug plants in a winter, annual hill production system. HortScience. 37(5):762–764.

Bish, E.B., D.J. Cantliffe, and C.K. Chandler. 2002. Temperature conditioning and container size affect early season fruit yield of strawberry plug plants in a winter, annual hill production system. HortScience. 37(5):762–764.

Bish, E.B., D.J. Cantliffe, G.J. Hochmuth, and C.K. Chandler. 1997a. Development of containerized strawberry transplants for Florida's winter production system. Acta Hort. 439(1):469–474.

Bish, E.B., D.J. Cantliffe, G.J. Hochmuth and C.K. Chandler. 1997b. Transplant container shape and strawberry transpant growth. HortScience. 32(3):505.

Crawford, T.D., D.G. Himelrick, J.L. Sibley, and J.A. Pitts. 2000. Effect of runner plantlet size on performance of strawberry plug plants. Small Fruit Rev. 1(1):15–21.

Durner, E.F., E.B. Poling, and J.L. Maas. 2002. Recent advances in strawberry plug transplant technology. HortTechnology. 12(4):545–550.

Gilreath, J.P., B.M. Santos, J.W. Noling, S.J. Locascio, D.W. Dickson, E.N. Rosskopf, and S.M. Olson. 2006. Performance of containerized and bare-root transplants with soil fumigants for Florida strawberry production. HortTechnology. 16(3):461–465.

Hochmuth, G., D. Cantliffe, C. Chandler, C. Stanley, E. Bish, E. Waldo, D. Legard, and J. Duval. 2006a. Containerized strawberry transplants reduce establishment period, water use and enhance early growth and flowering compared with bare-root plants. HortTechnology. 16(1):46-54.

Hochmuth, G., D. Cantliffe, C. Chandler, C. Stanley, E. Bish, E. Waldo, D. Legard and J. Duval. 2006b. Fruiting responses economics of containerized and bare-root strawberry transplants established with different irrigation methods. HortTechnology. 16(2):205–210.

Menzel, C.M. and A. Toldi. 2010. An evaluation of containerized plants for strawberries growing in a subtropical environment. HortTechnology. 20:786–793.

Mossler, M. 2010. Florida crop/pest management profiles: strawberries. Inst. Food Agr. Sci. Univ. Florida. CIR 1239. 5 Aug. 2013. <http://edis.ifas.ufl.edu/pi037>.

Santos, B.M., N.A. Peres, V.M. Whitaker, P.J. Dittmar, S.A. Smith and S.M. Olson. 2014. Strawberry production in Florida, p. 145–152. In: B.M. Santos and G.E. Vallad (eds.). Vegetable production handbook for Florida 2013-2014. Univ. Fla.IFAS, Gainesville, FL.

Southwest Florida Water Management District. 2000. Use of containerized strawberry transplants for water conservation and increased early production under a winter annual production system in Florida. Southwest Florida Water Management District, Florida.

Tanino, K.K. and R. Wang. 2008. Modeling chilling requirement and diurnal temperature differences on flowering and yield performance in strawberry crown production. HortScience. 43(7):2060–2065.

U.S. Department of Agriculture, 2014. 2013 State agricultural review. U.S Dept. Agr. 5 July. 2015. <http://www.nass.usda.gov/QuickStats/AgOverview/stateOverview.php?state=F LORIDA>.

U.S. Department of Agriculture. 2012. Table 6-U.S. strawberry prices received by growers, major States, by use, 1970-2012. U.S Dept. Agr. 7 Jan. 2015. <http://usda.mannlib.c ornell.edu/MannUsda/viewDocumentInfo.do?documentID=1381>.

Wu, F., Z. Guan and A. Whidden. 2012. Strawberry industry overview and outlook. 5 Aug. 2013. <http://w ww.fred.ifas.ufl.edu/pdf/webinar/Strawberry.pdf>.