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Florida Pearl® 'FL 16.78-109' Pineberry

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White-fruited strawberries have existed for centuries as white-fruited forms of *Fragaria chiloensis* cultivated by native individuals in South America (Finn et al. 2013). Hybrids of these forms with cultivated strawberries (*Fragaria ×ananassa* Duchesne ex Rozier) have been called "pineberries" because of the presence of a pineapple-like aroma. Newer cultivars with fruit size similar to that of red strawberries have recently emerged as high-value products in Asia. However, existing pineberry cultivars are not suitable for commercial production in Florida and many other production areas because of their low yield and small, soft fruit. Therefore, there is an opportunity for pineberry cultivars that are adapted for commercial production in Florida and other regions so that pineberries can be grown at scale and made available to the public.

The Florida Pearl® 'FL 16.78-109' pineberry (hereafter referred to as 'FL 16.78-109'; U.S. PP33,477) has an attractive white color with a pink blush and red achenes when fully ripe under a variety of commercial conditions. The fruit have a sweet taste and unique aroma sometimes reminiscent of pineapple, peach, and/or apricot. Trials of the research plots of the University of Florida Gulf Coast Research and Education Center (GCREC) in Wimauma, FL, at the Florida Strawberry Growers Association headquarters in Dover, FL, and trials of commercial farms in west-central Florida and southern Spain have been conducted.

Origin

In 2012, pineberries (cultivar unknown) were purchased in a market in Japan, and the seeds were extracted and germinated at the University of Florida GCREC at Wimauma, FL. One seedling was recovered with a small, white fruit, and it was given the experimental designation FL 12.65-2. Then, this selection was crossed as a male to FL 12.67-25, a naturally occurring mutant from the elite breeding population of the University of Florida with a nearly white internal color and unusually light red external color. The seedlings from this cross were evaluated by a field trial performed during the 2014–15 Florida strawberry season, and a white-fruited seedling with improved fruit size, firmness, and yield was selected and designated FL 14.29-62. This selection was crossed as a male to unreleased selection FL 12.90-53, which was chosen as a female parent because of its large fruit size, yield, and disease resistance. The seedlings from this cross were evaluated during the 2016–17 season, resulting in 'FL 16.78-109' (Fig. 1). This modified backcrossing and selection strategy resulted in a genetic background similar to elite red-fruited germplasm. A comparison with 10,269 FanaSNP array markers (Hardigan et al. 2020) showed 53% marker identity-by-state for 'FL 16.78-109' and 'Florida Brilliance' compared with 47% for 'Florida127' and 'Florida Brilliance'. In all crosses between white-fruited and red-fruited parents, color segregated approximately 1:1, and genetic analyses confirmed that the white color was conferred by a mutation in one of the three homeologs of a MYB transcription factor regulating anthocyanin biosynthesis in fruit, namely, *FaMYB10-2* (Castillejo et al. 2020). During this same study, DNA markers were developed and have been used for subsequent pineberry breeding efforts.

During the 2019–20 and 2020–21 seasons, yield and fruit quality data were collected from replicated trials conducted at the GCREC. Field plots were prepared and maintained according to current commercial practices for annual strawberry plasticulture in Florida (Whitaker et al. 2022). Beds were spaced 1.2 m on the center and were 90 m long, 70 cm wide, 15 cm high at the edges, and 18 cm high in the center; furthermore, they were covered with a single layer of black, high-density polyethylene mulch. Preplant fumigation consisted of a 65:35 mixture of 1,3-dichloropropene and chloropicrin (Telone C35, Dow AgroSciences). Each bed contained two rows of plants spaced 38 cm apart within rows and 28 cm apart between rows within beds. All trials were conducted using bare-root plants. Five replicate plots (10 plants per plot) of each genotype were planted in a randomized complete block design at the GCREC. The two leading strawberry cultivars in Florida were used as standards in the trial. 'Florida Brilliance' (U.S. PP30,564) (Whitaker et al. 2019) was commercialized in 2018 and accounted for ∼55% of acreage in west-central Florida in 2022. Sweet Sensation® 'Florida127' (Whitaker et al. 2015), which is referred to as 'Florida127' (U.S. PP25,574) hereafter, was commercialized in 2014 and accounted for ∼30% of acreage in 2022. The trial was planted between 9 Oct and 11 Oct in each year; the commercial planting period ranges from ∼25 Sep to 20 Oct. Overhead irrigation from impact sprinklers was applied for plant establishment during daylight hours for up to 10 d after transplanting; thereafter, water and fertilizer were applied exclusively through a single drip tape.

All ripe fruits (with red achenes and pink blush) were harvested, graded, counted, and weighed twice per week from December through March. Fruits that were diseased, misshapen, small (<10 g), or rain-damaged were considered unmarketable, and the remaining fruits were weighed to determine the marketable yield in grams on a per-plant basis. Fresh fruit were transported by air-conditioned vehicles to the US Department of Agriculture–Agricultural Research Service, US Horticultural Research Laboratory in Fort Pierce, FL, once each month during the 2019–20 season for flavor evaluations by a trained sensory panel and measurement of the soluble solids content, pH, and titratable acidity (% citric acid equivalents) of fruit from the same field plots using previously described methods (Plotto et al. 2013).

Separate field trials were conducted during the 2019–20 season to determine resistance to fruit, foliar, and crown pathogens. Inoculation and rating methods for anthracnose fruit rot (caused by *Colletotrichum acutatum* species complex), charcoal rot (caused by *Macrophomina phaseolina*), Phytophthora crown rot (caused by *Phytophthora cactorum*), and Colletotrichum crown rot (caused by *Colletotrichum gloeosporioides* species complex) were described previously (MacKenzie et al. 2006; Seijo et al. 2011, 2022a, 2022b). The natural disease incidences for powdery mildew (caused by *Podosphaera aphanis*) and Botrytis fruit rot (caused by *Botrytis cinerea*) were determined.

During all statistical analyses, blocks were considered fixed effects, and mean separations were only performed if genotype effects were significant. Residuals were checked for normality and homogeneity, and the percentage data were modeled with GLIMMIX using logit link

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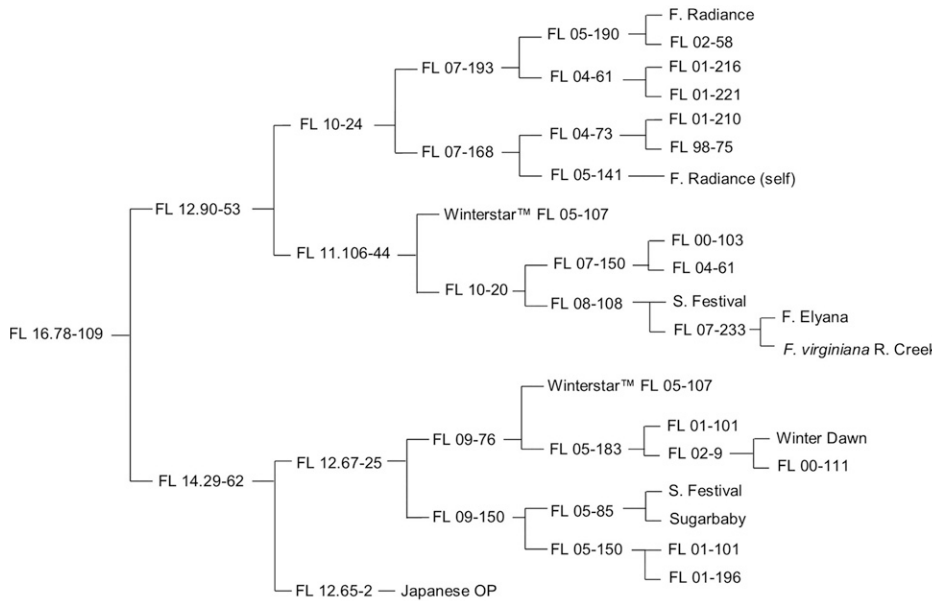

Fig. 1. Pedigree of 'FL 16.78-109' pineberry. The female parent is listed on the upper side of each bifurcation.

functions and binomial distributions (SAS version 9.4; SAS Institute Inc., Cary, NC).

Description

'FL 16.78-109' is a short-day pineberry adapted to annual plasticulture growing systems for winter and early spring production. The plant is moderately compact yet robust. 'FL 16.78-109' produces fruit that are moderately firm, juicy, and conical in shape, with a medium green (colorimeter $L^* = 50.1$; $a^* = -16.8$; $b^* = 24.7$) calyx that is reflexed. The fruit is completely white internally ($a^* = -2.5$); externally, it has red achenes and a pink blush on the sunward side of the fruit when fully ripe ($a^* = 12.9$) (Fig. 2). The degrees of epidermal and achene anthocyanin accumulation depend on the level of sun exposure, with lower levels accumulating during cooler, cloudy weather or in high tunnel production systems (Fig. 3). The fruit size is medium, but it is smaller than that of both commercial standards (Table 1).

Trained sensory panels gave 'FL 16.78-109' sweetness ratings that were similar to those of 'Florida Brilliance' (Table 2). However, the sourness ratings were lower than those of at least one of the commercial standards on three of the four harvests evaluated. This is consistent with its lower titratable acidity compared to that of the standards on two of four harvests and its high pH on all four harvests (Table 3). Panelists detected primary flavors other than the standard strawberry flavor, reporting "peach flavor" and "fruity but not strawberry." The low-acid flavor profile and fruitiness of FL 16.78-109 pineberry are atypical and not directly comparable to those of red strawberries, highlighting the opportunity to market this cultivar as a product that is distinct from red strawberries. 'FL 16.78-109' also had lower sensory firmness on some dates (Table 2), which is consistent with its slightly softer texture than that of the red-fruited commercial standards.

Field Performance

During replicated trials, the total yields of 'FL 16.78-109' were approximately 75% of the commercial standards (Table 1). The yields were also distributed slightly later, with December or January yields often lower than those of at least one of the commercial standards. On-farm trials showed yields similar to those of the replicated trials (data not shown). During all trials, consistent pollination and conical fruit shape were observed, with the fruit size being generally larger in Spain than in Florida (Figs. 2 and 3).

Fig. 2. Fruit of 'FL 16.78-109' pineberry in Feb 2020 at the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) Gulf Coast Research and Education Center in Wimauma, FL. Photo credit: Cristina Carizzosa, UF/IFAS Photography.

Fig. 3. Fruit of 'FL 16.78-109' pineberry in Nov 2019 harvested from under high tunnels on a farm in southern Spain.

Table 1. Marketable yield and average fruit weight of ‘Florida Brilliance’, ‘Florida127’, and ‘FL 16.78-109’ at the University of Florida Gulf Coast Research and Education Center (GCREC) at Wimauma, FL, during the 2019–20 and 2020–21 seasons.

	Marketable yield (g/plant)						
Cultivar	November	December	January	February	March	Total	Wt/fruit (g)[i]
			2019–20				
FL Brilliance	4.3 b[ii]	104.0 a	180.7 b	436.3 a	180.7 b	905.8 a	22.4 b
Florida127	8.3 a	80.2 b	259.8 a	446.7 a	141.3 c	936.2 a	27.3 a
FL 16.78-109	1.2 b	37.8 c	162.4 b	309.5 b	250.4 a	759.5 b	18.0 c
			2020–21				
FL Brilliance	3.2 b	48.8 a	114.2 a	473.1 b	189.5 a	1044.3 a	23.0 b
Florida127	17.8 a	15.5 b	56.1 b	712.6 a	164.7 a	1078.8 a	29.1 a
FL 16.78-109	1.7 b	15.6 b	37.2 b	442.7 b	169.2 a	810.5 b	20.8 c

[i] Mean fruit weight was determined by dividing the total marketable fruit yield per plot by the total marketable fruit number per plot.
[ii] Mean separations within years and columns were determined by Tukey’s honestly significant difference test, $P \leq 0.05$.

Table 2. Trained sensory panel ratings (10-cm linear scale with the words “low” and “high” at either end to represent increasing intensity) for ‘Florida Brilliance’, ‘Florida127’, and ‘FL 16.78-109’ from four harvests during the 2019–20 season. Fruit samples from the same harvest and field replication were measured to determine fruit chemical attributes shown in Table 3.

Cultivar	Firmness	Sweetness	Sourness	Strawberry flavor	Green/unripe flavor
			Dec 2019 (n = 9[i])		
FL Brilliance	6.7 a[ii]	3.9 b	5.3 a	3.8 b	2.5 a
Florida127	5.4 b	4.9 a	4.8 a	5.5 a	1.6 b
FL 16.78-109	4.0 c	4.1 ab	3.6 b	3.4 b	1.1 b
			Jan 2020 (n = 9)		
FL Brilliance	4.5 a	5.5 a	3.3 ab	4.7 a	1.0 ab
Florida127	4.1 a	5.8 a	3.8 a	4.8 a	1.4 a
FL 16.78-109	3.8 a	5.5 a	2.5 b	4.1 a	0.5 b
			Feb 2020 (n = 10)		
FL Brilliance	4.5 a	4.1 ab	5.0 a	3.8 ab	1.3 a
Florida127	4.3 a	4.7 a	4.7 a	4.2 a	1.1 a
FL 16.78-109	4.2 a	3.8 b	3.2 b	3.0 b	1.6 a
			Mar 2020 (n = 9)		
FL Brilliance	6.3 a	4.7 a	4.6 a	4.0 a	1.1 a
Florida127	4.6 b	4.8 a	3.9 a	4.3 a	1.2 a
FL 16.78-109	4.0 b	4.8 a	3.3 a	3.7 a	0.9 a

[i] Number of trained panelists.
[ii] Mean separations within harvest dates and columns were determined by Fisher’s least significant difference test for multiple comparisons, $P \leq 0.05$.

The disease resistance profile of ‘FL 16.78-109’ is favorable, with disease levels similar to those of the more resistant of the two commercial standards for five of the six diseases tested (Table 4). However, regarding anthracnose fruit rot, ‘FL 16.78-109’ was more susceptible than both commercial standards, but it was not considered highly susceptible. This balanced disease resistance profile should aid the production of ‘FL 16.78-109’ in Florida and its adaptation to various environments and production systems worldwide.

Commercialization

‘FL 16.78-109’ was approved for release by the Florida Agricultural Experiment Station in 2020, and U.S. PP33,477 was granted in 2021. Plant breeder’s rights applications

Table 3. Soluble solids content (SSC), pH, titratable acidity (TA), and SSC/TA for ‘Florida Brilliance’, ‘Florida127’, and ‘FL 16.78-109’ fruit from four harvests during the 2019–20 season.

Cultivar	SSC (%)	pH	TA (%)	SSC/TA
		Dec 2019		
FL Brilliance	6.41 b[i]	3.67 b	0.81 a	7.96 b
Florida127	8.68 a	3.82 b	0.72 a	12.13 ab
FL 16.78-109	8.15 a	4.10 a	0.56 a	14.45 a
		Jan 2020		
FL Brilliance	8.43 a	3.67 b	0.82 a	10.56 b
Florida127	9.09 a	3.63 b	0.86 a	10.54 b
FL 16.78-109	9.76 a	4.13 a	0.51 b	19.16 a
		Feb 2020		
FL Brilliance	6.14 b	3.76 b	0.56 a	10.87 a
Florida127	7.62 a	3.75 b	0.61 a	12.56 a
FL 16.78-109	7.04 ab	3.93 a	0.58 a	12.31 a
		Mar 2020		
FL Brilliance	8.28 ab	3.63 b	0.82 a	10.09 b
Florida127	9.63 a	3.73 b	0.78 a	12.34 a
FL 16.78-109	8.03 b	3.87 a	0.63 b	12.78 a

[i] Mean separations within harvest dates and columns are by Tukey’s honestly significant difference test, $P \leq 0.05$

Table 4. Disease incidence and mortality for 'Florida Brilliance', 'Florida127', and 'FL 16.78-109' from field trials during the 2019–20 and 2020–21 seasons. Incidence of anthracnose fruit rot (caused by *Colletotrichum acutatum*) and Botrytis fruit rot (caused by *Botrytis cinerea*) are based on twice weekly fruit harvests. Incidence of powdery mildew (caused by *Podosphaera aphanis*) describes foliar symptoms only. Mortality rates attributable to Colletotrichum crown rot (caused by *Colletotrichum gloeosporioides*), Phytophthora crown rot (caused by *Phytophthora cactorum*), and charcoal rot (caused by *Macrophomina phaseolina*) were assessed at the conclusion of the harvest season or when mortality of highly susceptible individuals reached ≥75%.

	Incidence (%)[i]			Mortality (%)		
Cultivar	Anthracnose fruit rot	Botrytis fruit rot	Powdery mildew	Colletotrichum crown rot	Phytophthora crown rot	Charcoal rot
2019–20						
FL Brilliance	22.8 b[ii]	8.7 ab	0.7 b	62.5 a	37.5 ab	7.5 a
Florida127	6.1 c	10.6 a	10.2 a	2.8 b	53.5 a	20.0 a
FL 16.78-109	37.9 a	5.4 b	2.1 b	15.0 b	22.5 b	7.5 a
2020–21						
FL Brilliance	31.5 b	–[iii]	–	65.0 a	53.8 a	50.0 a
Florida127	18.5 c	–	–	35.0 b	67.5 a	13.3 b
FL 16.78-109	57.1 a	–	–	2.5 c	20.5 b	10.0 b

[i] Disease from natural inoculum for powdery mildew and Botrytis fruit rot and artificial inoculations for anthracnose and crown rot diseases.
[ii] Means are based on four replications of 10 to 12 plants each. Mean separations within columns were determined by Tukey's honestly significant difference test, $P \leq 0.05$.
[iii] Data of Botrytis fruit rot and powdery mildew were not collected in 2020–21 because of the low incidence.

were filed in foreign territories. Information about nurseries licensed to propagate this cultivar can be obtained from Florida Foundation Seed Producers, Inc., 3760 NW 83rd Street, Suite 2, Gainesville, FL, 32606 (http://ffsp.net).

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