‘Cordial’ Strawberry

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Cordial, a late-season, short-day strawberry (*Fragaria × ananassa* Duch. ex Rozier), follows Keepsake as the second cultivar resulting from a U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) effort at Beltsville, MD, to develop strawberries with increased shelf life (Lewers et al., 2019). ‘Cordial’ and ‘Keepsake’ strawberries had similarly low proportions of fruit rot and degradation in 2 weeks of refrigerated storage compared with other cultivars and breeding selections. ‘Cordial’ has consistently provided very high yields and very low rot with no fumigation or fungicides in an annual plasticulture system at Beltsville, MD. ‘Cordial’ strawberries are large, attractive, quite firm, and tough enough for handling. The name, ‘Cordial’, is in reference to the flavor being friendly, not tart, even in rainy weather. ‘Cordial’ is expected to be adapted to the Mid-Atlantic region of the United States and regions with similar climates.

Origin

‘Cordial’ was derived from a cross-pollination of B1893 × B1805 planned in 2010 and executed in 2011. The pedigree of the maternal parent, B1893, is available for 12 generations and is missing information for four progenitors (Fig. 1). The pedigree of the pollen parent, B1805, is identical to that of ‘Keepsake’, which was tested as B1806 (Lewers et al., 2019). ‘Cordial’ was selected in a Beltsville seedling field in an annual plasticulture production system (Black et al., 2002) in Spring 2013, and it was assigned the selection number B2360. Plants clonally

propagated from stolons or runners of B2360 were evaluated in an observation plot during annual plasticulture production in 2014 at Beltsville. After evaluation in the observation plot, the original mother plant of B2360, which had been maintained in a greenhouse, was tested using a reverse-transcription polymerase chain reaction for strawberry mild yellow edge virus (Thompson et al., 2003) and strawberry pallidosis-associated virus (Tzanetakis et al., 2006). B2360 tested negative for both viruses and was further propagated in an outdoor structure covered with screening designed to exclude virus-vector insects. These plants were used during annual replicated evaluations and companion observation plots from 2015 through 2018. ‘Cordial’ has not been tested outside of Beltsville.

Technical Description

Plants. ‘Cordial’ produces an open globose plant with moderate density and moderate to strong vigor between that of the late-midseason, less vigorous cultivar Allstar (Galletta et al., 1981) and the late-season, more vigorous cultivar Ovation (Lewers et al., 2004) (Fig. 2). The Royal Horticultural Society (RHS) petiole color (Royal Horticultural Society and Flower Council of Holland, 1986) is light yellow green (RHS86 yellow-green group 144B) with moderate pubescence density, more so than ‘Allstar’ or ‘Ovation’. Leaves are uniformly composed of three leaflets. Individual leaves are slightly folded to open and medium green in color (RHS86 green group 137A upper surface, RHS86 green group 137C lower surface). The length-to-width ratio of the terminal leaflets is 1:2. The terminal leaflets averaged 28.6 apiculate leaf serrations. The tallest inflorescences produce flowers above the canopy, with primary flowers having an average of eight overlapping petals, which are slightly longer than wide and have a yellow-orange stigma color (RHS86 yellow-orange group 22A). Primary flowers have an average of 33.2 anthers per flower, which is more than those of ‘Allstar’ (24.6 per flower) and ‘Ovation’ (22.2 per flower). Stolon production at Beltsville (≈9 per plant) is greater than that of ‘Flavorfest’ (Lewers et al., 2017) (≈8 per plant), and less than that of ‘Keepsake’ (≈10 per plant), ‘Allstar’ (≈10 per plant), and ‘Ovation’ (≈11 per plant). Stolons have moderate levels of anthocyanin pigmentation where they are exposed to

sunlight that are more than those of ‘Allstar’ and similar to those of ‘Ovation’.

Fruits. Fruits are large, firm, glossy, and red (RHS86 red group 44A, RHS86 red group 45A) (Fig. 3). Fruits are conic to globose-conic, with no noticeable difference in shape between primary and secondary fruits. The firmly attached calyx is generally showy, larger than (primary fruit) or the same diameter as the fruit, reflexed to spreading, and positioned evenly with the top of the fruit. There is no neck, but there may be a very narrow band of fruit with no achenes below the calyx. Achenes, which are flush with the fruit surface, are red (RHS86 red group 45A) on the sun-exposed side of the fruit to yellow-green (RHS86 yellow-green group 153B) on the underside of the fruit. The interior flesh color is very evenly distributed, mostly orange-red (RHS86 orange-red group 33A, RHS86 orange-red group 33B), with a small patch of white (RHS86 white group 155D) near the proximal end. In fruits with a central cavity, the cavity is small. Vascular tissue within the fruit is barely noticeable, unlike the fruits of ‘Allstar’ and ‘Ovation’, which have clearly visible, lighter color vascular tissue radiating from the center to the achenes.

Evaluation

Production system. ‘Cordial’, as B2360, was evaluated with other selections and cultivars on the North Farm of the USDA-ARS Henry A. Wallace Beltsville Agricultural Research Center at Beltsville, MD (lat. 39°01′48.42″N, long. 76°56′07.99″W, 49.4 m elevation), on Downer-Hammonton complex loamy sand, and on Russet-Christiana complex fine sandy loam soils (USDA-Natural Resources Conservation Service, 2020), supplemented each year with potassium, sulfur, and boron to correct deficiencies reported by annual soil tests. These soils have existing high levels of phosphorus and moderate levels of potassium. Calcitic lime was used to adjust the soil pH to 6.3 to 6.5. No fumigants were used.

Observation plots and replicated plots were established during annual plasticulture production (Black et al., 2002) using raised beds with two lines of trickle irrigation 7 cm below the surface. The plasticulture system uses black plastic mulch. Six-plant plots were established in August before each evaluation year. In 2014, only a single six-plant plot of B2360 was established and evaluated. Starting in 2015, four six-plant plots each of B2360 and other selections and cultivars were established and evaluated. Fertigation supplied nitrogen at a rate of 34 kg·ha⁻¹ N per year as ammonium nitrate, potassium nitrate, or calcium nitrate. No fungicides were used. Frost protection of spring flowers was provided by microsprinklers on 30.5-cm stakes (SuperNet Jr.; Netafim, Fresno, CA) when temperatures dropped below 2 °C and by overhead impact sprinklers at 1 m elevation when temperatures dropped below 1 °C.

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white shoulders) were key features when determining the market score. Market scores of 7.0 or more were given to containers with each fruit appearing suitable for fresh eating. A score of 6.5 was given to containers with most fruit appearing acceptable for fresh eating but some fruit appearing unacceptable. Scores of 6.0 or less were given to containers with more than half the fruit unacceptable for fresh eating. Faults and diseases were identified and noted for each plot at every harvest. If the market score was 7.0 or more, then the yield from that harvest of the plot contributed to the total marketable yield for the year.

For the container showing no signs of rot, up to 12 fruits were selected for shelf-life evaluation and placed in a labeled, clear, plastic egg carton with the calyx down. These fruits were selected to be free of signs of injury and relatively uniform in size, shape, and maturity. Fruits in the egg cartons were stacked in plastic egg boxes, stacked two boxes high, and covered loosely with a black plastic trash bag. The fruits were stored in a walk-in cooler set at 0.5 °C. At 1 week and 2 weeks, the numbers of fruits in each egg carton that showed signs of rot or degradation were recorded. A single fruit could be both rotted and degraded. A rotted fruit showed signs of fungal growth. Signs of degradation included desiccation, loss of gloss, dark blotches resembling bruises, a fruit turning dark, soft wet spots, soft dry spots, small depressions between achenes, and small dark depressions. In 2017 and 2018, the numbers of fruits that still appeared marketable were recorded also.

Each year's averages across replications for total yield (g/plant), percent nonrotted yield, percent marketable yield, market score, peak fruit weight (g/fruit), average fruit weight (g/fruit), firmness, toughness, percent soluble solids, pH, and percentages of marketable, rotted, and degraded fruits at 1 week and 2 weeks were used in the analyses of variance to compare genotypes ($P = 0.05$) using SAS software version 9.4 (SAS Institute Inc., Cary, NC). A mixed model was used to determine if significant differences existed, with cultivar as a fixed effect and year as a random effect. A general linear model was used to obtain separations of means and least significant differences between means.

Harvest Season

The first harvest date of 'Cordial' at Beltsville ranged from 18 May to 29 May during 4 years. As determined by the relative patterns of actual fruit yield from cultivars and breeding selections each week through the harvest season, 'Cordial' fruited after late-mid-season or with late-season genotypes. The peak harvest of 'Cordial' was the same as that of 'Ovation' in 2015 and 2018 (Fig. 4). In 2016 and 2017, the peak harvest of 'Cordial' was a half-week ahead of that of 'Ovation'. The peak harvest of 'Cordial' was 1 week (2015, 2017, 2018) or a half-week (2016) after that of 'Allstar'. Subjective season

Fig. 4. Cordial strawberry weekly fruit yield (g/plant) compared with those of eight other cultivars grown in an annual plasticulture system at the USDA-ARS Beltsville Research Center, Beltsville, MD, in 2018.

ratings for 'Cordial' averaged 4.5, which is more typical of a late-midseason cultivar. Allstar is a late-midseason cultivar at 4.9, and Ovation is a late-season cultivar at 3.4. Both approaches to assessing season determined that the season of 'Cordial' is between that of 'Allstar' and 'Ovation'. However, subjective ratings indicated that the bulk of the fruit will likely be later than what might be anticipated from the visual observation of plants at flowering and early fruit set.

Yield: Total, Percent Nonrotted, Percent Marketable

During 4 years of replicated testing, the average total yield (decayed and nondecayed fruits) of 'Cordial' was 789 g/plant (Fig. 5A) compared with 641 g/plant and 606 g/plant for 'Flavorfest' and 'Allstar', respectively, which are two cultivars with reliably high yields over many years of testing at Beltsville. The yield of 'Cordial' was significantly higher than that of 'Ovation' at 534 g/plant, another late-season cultivar, and significantly higher than those of the remaining cultivars tested during this period (Fig. 5A). The percent nonrotted yield of 'Cordial' was 94%, which was similar to that of 'Ovation' (96%) and significantly higher than that of 'Allstar' (88%), a late-midseason cultivar (Fig. 5B). The percent marketable yield of 'Cordial' (93%) was higher than that of all the other cultivars, but it was statistically similar to that of all but 'Earliglow' (Scott and Draper, 1975) (65%) and 'Ovation' (60%) (Fig. 5B).

Fruit

Weight. The peak fruit weight of Cordial (31 g) was statistically similar to those of most of the other cultivars, except for Earliglow (17 g), noted for relatively small fruit but grown for its excellent flavor and early season (Table 1). 'Cordial' fruit weight continued to be good as the season progressed. The average fruit weight of Cordial (18 g) was statistically greater than that of any other cultivar tested, including Keepsake (13 g) and

Flavorfest (13 g), known for large fruit, and Ovation (14 g) and Allstar (10 g), with seasons similar to that of Cordial (Table 1).

Market score. Cordial fruit had the highest average market score (7.6), although it was statistically similar to those of the midseason cultivars, Keepsake (7.0) and Flavorfest (6.9), and of the other late-season cultivar, Ovation (7.0) (Table 1). The average market score for 'Cordial' fruit was statistically greater than that of 'Allstar' (6.5), a cultivar with a fruiting season slightly earlier than that of 'Cordial'. In 2016, 2017, and 2018, notes recorded at harvest indicated sharply contrasting rain tolerance between 'Allstar' fruit and 'Cordial' fruit. After several significant rain events, notes recorded indicated that skin of 'Allstar' fruits were often cracked, split, or etched in appearance, impacting the market score. On the same harvest days, notes for 'Cordial' fruit included comments that it looks dry in the rain and market scores were high.

Firmness and toughness. The subjective rating of fruit firmness showed 'Cordial' fruit to be very firm (8.0), similar to that of 'Keepsake' (7.9) and 'Camarosa' (7.8), known for firm fruit (Table 1). The fruit of 'Cordial' were statistically firmer than those of 'Ovation' (7.5) of the same season, and 'Allstar' (7.5), with a slightly earlier season than 'Cordial'. Subjective ratings of fruit skin toughness showed 'Cordial' fruit to be very tough (8.0) and statistically similar to fruit of 'Keepsake' (8.1), 'Galletta' (7.8), and 'Flavorfest' (7.8) (Table 1).

Percent soluble solids and pH. 'Cordial' fruits tasted mild and pleasant, even after several days of rain. Although the cultivar quality is acceptable, subjective flavor ratings for 'Cordial' (7.3) were not as high as those for the highest-rated cultivars, 'Keepsake' (8.1), 'Earliglow' (7.9), and 'Flavorfest' (7.8). As a measure of sweetness, the percent soluble solids of 'Cordial' fruits (7.6%) was the same as that for 'Flavorfest', and statistically similar to that of the cultivars with the highest percent soluble solids, 'Keepsake' (8.8%) and 'Earliglow' (8.6%), which had the highest flavor ratings (Table 1). There were no differences among cultivars regarding the

Fig. 5. 'Cordial' strawberry total fruit yield (A), percent nonrotted yield, and percent marketable yield (B) compared with eight other cultivars grown in an annual plasticulture system at the USDA-ARS Beltsville Research Center, Beltsville, MD, averaged from 2015 through 2018. Evaluations were conducted for 4 years unless indicated in parentheses after the cultivar name. The percent nonrotted yield is calculated from the weight of nonrotted yield divided by the weight of total yield. Percent marketable yield is the weight of harvests with a market score of 7.0 or more divided by the total yield. The average yield, percent nonrotted yield, and percent marketable yield for each cultivar each year were used in an analysis of variance. Cultivars with different letters indicate statistically significant differences for each trait.

Table 1. 'Cordial' strawberry fruit traits compared with those of eight other cultivars grown in an annual plasticulture system at the USDA-ARS Beltsville Research Center, Beltsville, MD, 2015 through 2018.

Cultivar	N	Peak wt (g)	N	Avg wt (g)	N	Soluble solids (%)	N	Market score	N	Firmness rating	N	Toughness rating
Allstar	4	20 ab	4	10 cd	4	7.5 abc	4	6.5 bc	4	7.5 cde	4	7.6 bcde
Camarosa	2	24 ab	2	14 b	2	6.9 bc	2	6.5 bc	2	7.8 abc	2	7.5 cde
Chandler	4	30 ab	4	12 bc	3	8.6 ab	4	6.8 bc	4	7.1 e	4	7.6 bcde
Cordial	4	31 a	4	18 a	3	7.6 abc	4	7.6 a	4	8.0 a	4	8.0 ab
Earliglow	4	17 b	4	8 d	4	8.6 a	4	6.2 c	4	7.2 de	4	7.2 e
Flavorfest	4	32 a	4	13 b	3	7.6 abc	4	6.9 abc	4	7.5 cde	4	7.8 abcd
Galletta	3	29 ab	3	14 b	3	6.3 c	3	6.7 bc	3	7.6 bc	3	7.8 abc
Keepsake	4	33 a	4	13 b	3	8.8 a	4	7.0 ab	4	7.9 ab	4	8.1 a
Ovation	4	32 a	4	14 b	3	7.8 abc	4	7.0 abc	3	7.5 cd	3	7.3 de

Average fruit weight and percent soluble solids were measured for fruits from each plot at each harvest. The market score was estimated subjectively for each container of fruit. The average weight was the weight of a fruit averaged over all harvests; the peak weight was the highest of those averages. Firmness ratings and toughness ratings were subjective ratings obtained from fruits of a single six-plant observation plot each year. A rating or score of 9.0 (best) to 0.0 (worst) was used, and a score of 7.0 was considered minimum cultivar quality. N is the number of years of evaluation for each cultivar-trait combination. Cultivars with different letters indicate statistically significant differences for each trait.

pH, which is a measure of tartness. The pH of 'Cordial' fruits (3.79) was relatively high, indicating it was less tart. 'Allstar' was the

only cultivar with a higher fruit pH (3.85). A higher pH can be helpful in rainy weather with less sunshine, when fruit sugars tend to

be lower; fruit with low sugar and low pH taste very tart. Notes taken at harvests in the rain and after rain indicated that 'Cordial' fruits did not taste overly tart and that they instead had a pleasant taste.

Postharvest quality. 'Cordial' and 'Keepsake' had significantly higher percent marketable fruits than all the other cultivars (Fig. 6A) at both 1 week and 2 weeks after harvest in 2017 and 2018, the only years when data were collected for this trait. At 1 week, 'Cordial' had 86% marketable fruit and 'Keepsake' had 91% marketable fruit; 'Earliglow' had the next highest rate of marketable fruit (54%). At 2 weeks, both 'Cordial' and 'Keepsake' had 52% marketable fruit. The percent degraded fruits at 1 week for Cordial was 26%, which was statistically similar to that of 'Keepsake' (29%), the first cultivar resulting from the increased effort at Beltsville to improve postharvest quality, and to that of 'Ovation' (47%), the other late-season cultivar (Fig. 6B). The percent degraded 'Cordial' fruits at 2 weeks (50%) was statistically similar to that of

Fig. 6. 'Cordial' strawberry fruit percent marketable (A), percent degraded (B), and percent rotted (C) after 1 week and after 2 weeks in refrigerated storage at 0.5°C. Cordial was compared with eight other cultivars grown in an annual plasticulture system at the USDA-ARS Beltsville Research Center, Beltsville, MD, from 2015 through 2018. The numbers in parentheses indicate the number of years of data collected for each cultivar-trait combination. At each harvest, fruits without any visible flaws were placed in clear plastic egg cartons and refrigerated. The numbers of marketable, rotted, and degraded fruits are counted at 1 week and 2 weeks after harvest. The average for each trait-cultivar combination for each year was used in an analysis of variance. Cultivars with different letters indicate statistically significant differences between cultivars.

'Keepsake' (62%) and 'Ovation' (67%). Notes recorded during evaluation indicated that all cultivars showed some degree of the following types of degradation: desiccation, loss of gloss, soft wet spots, soft dry spots, small depressions between achenes, and small dark depressions. Additionally, notes indicated that 'Chandler' and 'Camarosa' fruits displayed color changes not seen on the other cultivars. After 1 week in storage, 81% of 'Chandler' fruits and 93% of 'Camarosa' fruits were degraded, primarily because of these color changes. 'Chandler' fruits often turned dark evenly over the entire fruit, and 'Camarosa' fruits often had large dark blotches resembling bruises, many of which were located in places unlikely to have been caused by rough handling. The percent rotted 'Cordial' fruits at 2 weeks was 14%, which was statistically similar to that of all other cultivars except 'Flavorfest', which had a higher portion of decayed fruits (38%) (Fig. 6C). The portion of decayed fruits at 1 week was statistically similar for all cultivars.

Plant

'Cordial' was relatively resistant to crown and foliar diseases present in the field. Although no fumigants or fungicides were used, subjective evaluation scores for foliar diseases included no susceptible ratings (<7.0) in fall or spring. Averaged scores in spring, after fruiting, were 7.9 for powdery mildew, with individual plot ratings ranging from 7.0 to 8.5, indicating symptoms were present every year, but that the plots still

looked healthy. The average spring score for leaf scorch was 7.9 (range, 7.0–9.0). The average spring score for leaf blight, a disease that can cause serious plant stress, was 7.7 (range, 7.0–8.0). Plots were rated for bacterial angular leafspot disease starting in 2017, when it first appeared across the entire field. 'Cordial' plots showed very mild bacterial angular leafspot disease symptoms (8.0) in only one plot and only in 2017, averaging 8.9 for both years. The subjective field evaluation score of 'Cordial' plots for crown rot was 9.0, a perfect score, in every plot, every year. The average subjective rating for 'Cordial' runner production was 1.9, which was statistically similar to 'Keepsake' (2.1) and 'Flavorfest' (1.1), and significantly less than that for 'Chandler' (3.4) and 'Galletta' (2.8).

Availability

'Cordial' was approved for release in 2020, and patented as US PP33,636. Distribution during the life of the patent is limited to requestors licensed to propagate. Licensing information can be obtained through the USDA-ARS Office of Technology Transfer. 'Cordial' is maintained by the USDA-ARS National Clonal Germplasm Repository at Corvallis, OR, as PI 693215 or CFRA 2337 0.001 PL.

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