

# ‘Keepsake’ Strawberry

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‘Keepsake’, a midseason, “spring-bearing” or “short-day” strawberry (*Fragaria* × *ananassa* Duch. ex Rozier), is a result of a U.S. Department of Agriculture Agricultural Research Service (USDA-ARS) effort at Beltsville, MD, to develop strawberries with increased shelf life. Compared with other current cultivars and breeding selections evaluated after 2 weeks in cold storage, ‘Keepsake’ strawberries had a low proportion of degraded and decayed fruits. The fruits have outstanding flavor with high soluble solids and moderate acidity. They have a pleasing texture and are juicy when eaten. ‘Keepsake’ has consistently provided competitive yields and low field decay with no fumigation or fungicides in annual plasticulture at Beltsville, MD. ‘Keepsake’ fruits are attractive, with good size, color, gloss, and a showy calyx. They are firm and tough enough for handling. ‘Keepsake’ is expected to be best adapted to the Mid-Atlantic and Northeastern United States and adjacent areas.

## Origin

‘Keepsake’ was derived from a cross pollination of B1031 by B1181 (Fig. 1), planned in 2005 by Dr. Kim Lewers and executed in 2006 by Mr. John Enns. B1031 is a full sibling of ‘Flavorfest’ (Lewers et al., 2017). There is a high degree of relatedness in the ‘Keepsake’ pedigree. The maternal parent (B759) of B1031 is a full sibling of the paternal parent (B755) of B1181. The paternal parent of both B1031 and ‘Flavorfest’ is a full sibling to the maternal parent of B1181. In the sixth generation of the ‘Keepsake’ pedigree, ‘Raritan’ was crossed as maternal parent with MDUS3413; in the fifth generation back, ‘Raritan’ was crossed as paternal parent with MDUS3399, a full sibling to MDUS3413; and in the seventh generation back, ‘Raritan’ was crossed with MDUS2992. ‘Tennessee Shipper’ appears in the pedigrees of MDUS2992, MDUS3399, and MDUS3413. Inbreeding is generally expected to result in progeny with low vigor in highly heterozygous species like cultivated strawberry, but ‘Keepsake’ has good vigor.

The high degree of relatedness within the ‘Keepsake’ pedigree does not necessarily contradict the expectation because no step in the pedigree resulted from self-pollination(s), and each selection in the pedigree showed sufficient vigor as a prerequisite for selection.

‘Keepsake’ was selected in a Beltsville seedling field in an annual plasticulture production system (Black et al., 2002) in Spring 2007 by Lewers and Enns and was given the selection number B1806. Plants clonally propagated from stolons or “runners” of B1806 were evaluated in observation plots in plasticulture in 2008 at Beltsville. After selection in observation plots, the original mother plant of B1806, which had been maintained in a greenhouse, was tested using reverse transcriptase polymerase chain reaction for *Strawberry mild yellow-edge virus* (Thompson et al., 2003) and *Strawberry pallidosis-associated virus* (Tzanetakis et al., 2006). B1806 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 in annual replicated evaluations and companion observation plots starting in 2010.

## Technical Description

**Plants.** ‘Keepsake’ produces an open globose plant with moderate density and vigor, slightly less than the related ‘Flavorfest’. Royal Horticultural Society (RHS) petiole color (RHS and Flower Council of Holland, 1986) is light yellow-green (RHS86 yellow-green group 144B) with very sparse pubescence, less so than ‘Flavorfest’. Leaves uniformly comprise 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 terminal leaflets are 1.2 times longer than wide with an average of 27.2 apiculate leaf serrations per leaflet. Stolon production at Beltsville (≈10 per plant) is slightly greater than that of ‘Flavorfest’ (≈8 per plant) with similar moderate levels of anthocyanin pigmentation where exposed to sunlight. Flowers are slightly below the canopy with an average of 5.2 overlapping petals which are slightly wider than long. Flowers have an average of 19.2 anthers per flower, fewer than those of ‘Flavorfest’ with an average of 24.6 anthers per flower.

**Fruits.** Fruits are medium-large, firm, glossy, and red (RHS86 red group 44A,

RHS86 red group 45A, RHS86 red group 46A) (Fig. 2). Fruits are conic to oblate with less difference in shape between primary and secondary fruits than ‘Flavorfest’. The firmly attached calyx is generally showy, larger than (primary fruit) or the same diameter as the fruit, reflexed to spreading, and mostly even to very slightly inserted. There is no neck and only a narrow band with no achenes. Achenes, which are flush with the fruit surface, are less dense than those of ‘Flavorfest’, and red (RHS86 red group 45A) to yellow-green (RHS86 yellow-green group 151B). Interior flesh is mostly orange-red (RHS86 orange-red group 33A) with some white (RHS86 white group 155D), especially near the proximal end, and is creamy, very sweet, and aromatic.

**Molecular markers.** ‘Keepsake’ was characterized with two simple sequence repeat molecular markers linked to repeat fruiting, ChFaM011 and FxaACA02I08C, using the methods of Castro and Lewers (2016). The only reaction product obtained from ChFaM011 was 163 bp long; the 163 bp product is associated with repeat fruiting in a mapping population using the cultivars Tribute and Honoeoye (Castro et al., 2015). The reaction products from using FxaACA02I08C were 138, 142, 143, and 145 bp long; the 145 bp product is associated with repeat fruiting, as a dominant trait, in a mapping population using the cultivars Delmarvel and Selva (Castro and Lewers, 2016). ‘Keepsake’ is not repeat fruiting, but families segregating for repeat-fruiting have resulted from crosses between ‘Keepsake’ and repeat-fruiting genotypes or once-fruiting genotypes with repeat-fruiting progenitors.

## Evaluation

**Production system.** ‘Keepsake’ was evaluated with other selections and cultivars on the Beltsville Agricultural Research Center farm on Rumford series, coarse-loamy, siliceous, thermic Typic Hapludults soils. Plantings were established in 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, and six-plant plots were established in August before each evaluation year. Fertigation supplied nitrogen at a rate of 45 kg·ha<sup>-1</sup> N per year as ammonium nitrate, potassium nitrate, or calcium nitrate on soils with existing high levels of P and moderate levels of K. Calcitic lime was used to adjust soil pH to 6.3 to 6.5. No fungicides were used. Frost protection of spring flowers was provided from microsprinklers on 30.5-cm stakes (SuperNet Jr., Netafim, Fresno, CA) when temperatures dropped below 2 °C and from overhead impact sprinklers at 1 m elevation when temperatures dropped below 1 °C.

**Subjective evaluations of observation plots.** Observation plots were evaluated annually in October after planting and again in April. Individual plots were given subjective scores. Subjective scores for most traits could have ranged from 0.0 (worst) to 9.0 (best), with 7.0 being “cultivar quality.” Scores of

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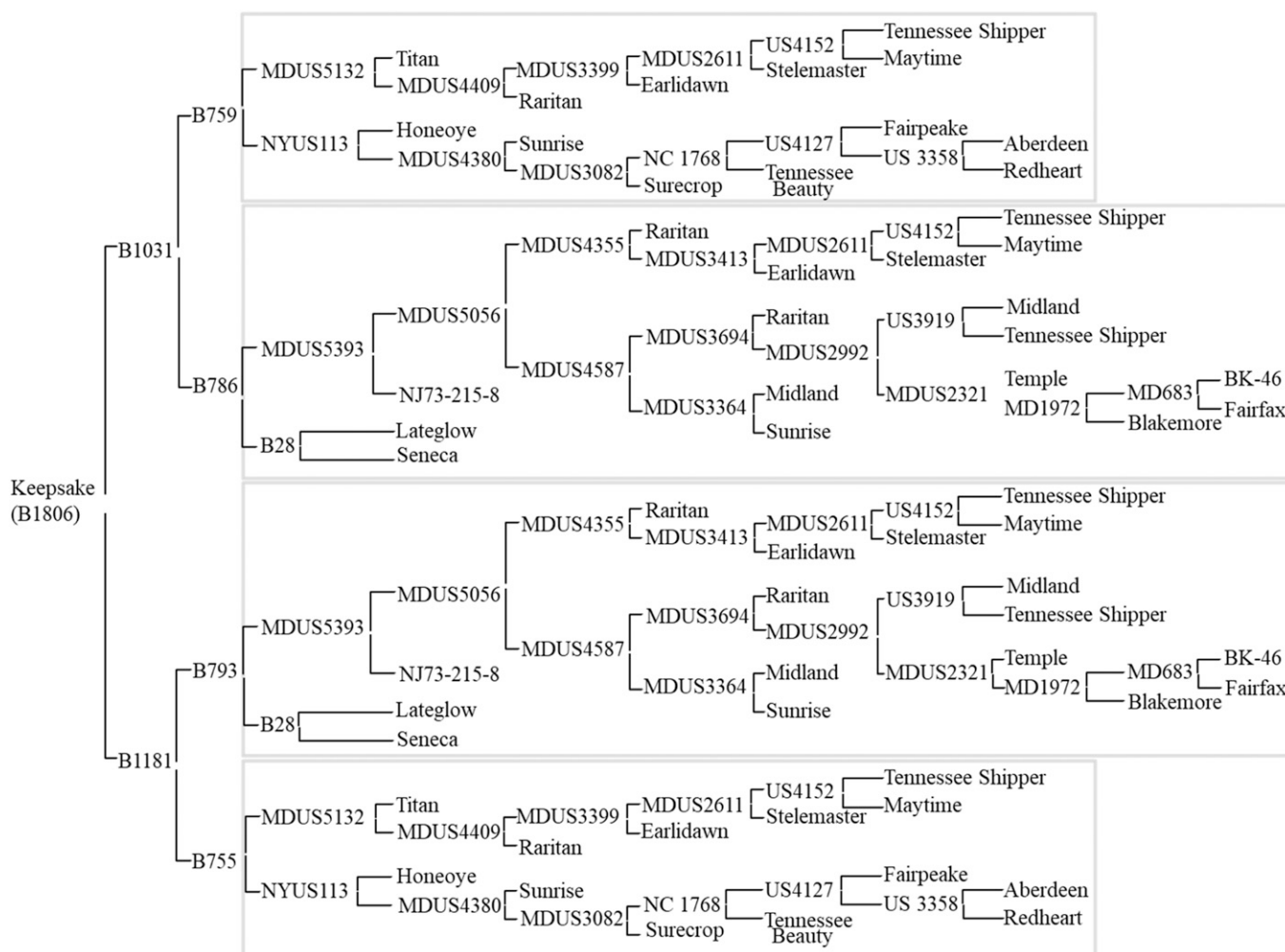


Fig. 1. Pedigree of 'Keepsake' strawberry, developed at the U.S. Department of Agriculture Agricultural Research Service Beltsville Agricultural Research Center, Beltsville, MD. Seed parents are represented above pollen parents.

6.5 for vigor, disease, or fruit quality were cause for concern, and scores of 6.0 or below were possible cause for rejection as a cultivar. Selections were not rejected for season scores, which also could have ranged from 0.0 (late) to 9.0 (early). Stolon production scores ranged from 0.0 (no stolons) to 5.0 (too many stolons). A score of 2.0 to 2.5 was considered a good balance because strong runner production is valued by matted-row growers and by nurseries propagating plants for sale, but too many runners can lead to high labor expenses for removing runners in the plasticulture system.

Plots were evaluated subjectively in fall for vigor, disease, and runner production, then evaluated for relative flowering and fruiting season in April. Plots were again rated after fruiting for vigor and disease. Plots were rated subjectively for incidence and severity of unspecified crown rot, as well as powdery mildew [*Podosphaera aphanis* (Wallr.) U. Braun & S. Takam], leaf scorch [*Diplocarpon earlianum* (Ellis & Everh.) F.A. Wolf], leaf blight [*Phomopsis obscurans* (Ellis & Everh.) Sutton], and bacterial angular leafspot disease [*Xanthomonas fragariae* Kennedy and King].

During the fruiting season, observation plots were subjectively evaluated at the peak

of their season for yield, size, appearance, symmetry, firmness, skin toughness (resistance to abrasion when rubbed with a thumb), skin color, flesh color, and flavor. Plots also were rated for the specific diseases of anthracnose fruit rot (*Colletotrichum acutatum* J.H. Simmonds), botrytis fruit rot (*Botrytis cinerea* Pers.:Fr.), and unspecified soft rot and fruit degradation. The juice of three to five fruits from a six-plant plot, hand squeezed in the field, was measured with a Pocket refractometer PAL-1 (ATAGO USA, Inc., Bellevue, WA) to obtain estimates of percentage soluble solids, and a LAQUAtwin-pH-22 (HORIBA Scientific, Edison, NJ) to obtain estimates of acidity (pH). Means and ranges were determined in lieu of analyses of variance (ANOVA) estimates due to the subjective nature of the measures, the broad range environmental conditions during measurement, and/or the number of measures (n) for each genotype.

**Replicated evaluations.** Replicated yield evaluations were made in a randomized complete block design with one replication in each of three blocks. Plots were harvested twice weekly. For each plot at each harvest, decayed fruits were harvested into separate containers from fruits that showed no sign of decay. The containers were weighed sepa-

ately. Yields were adjusted for plant stands. Ten randomly selected fruits from the container showing no signs of decay were weighed to obtain an average fruit weight for that plot and harvest. If fewer than 10 fruits were available, the average fruit weight was determined from the number available and was not adjusted for fruit number or plot yield. Also from the container showing no signs of decay, up to 12 fruits were selected for shelf-life evaluation and placed in a labeled clear plastic egg carton, calyx down. These fruits were further 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 in a black plastic trash bag. The fruits were stored in a walk-in cooler set at 0 °C. At 1 week and 2 weeks, the numbers of fruits in each egg carton that showed signs of decay or degradation were recorded. A single fruit could be both decayed and degraded. A decayed fruit would show signs of fungal growth. Signs of degradation included desiccation, loss of gloss, dark blotches resembling bruises, a fruit turning all dark, soft wet spots, soft dry spots, small depressions between achenes, and small dark depressions. Each year's

averages for total yield (grams/plant), non-decayed yield (grams/plant), average fruit size (grams/fruit), and the percentage of decayed and/or degraded fruits at 1 week and 2 weeks were used in a second ANOVA of means to compare 'Keepsake' across multiple years with other locally grown cultivars: Earliglow, Camarosa (2017 and 2018), Chandler, Flavorfest, Allstar, and Ovation.

### Fruit Quality

**Flavor.** 'Keepsake' had excellent flavor, with the highest average subjective rating of 8.1, ranging from 7.5 to 8.5 (Table 1). The average flavor rating for 'Earliglow', known as an industry standard for flavor, was 7.8, similar to that of 'Flavorfest' at 7.8. Sugar content, often measured as percentage soluble solids, is considered one of the most important attributes of strawberry fruit quality (Colquhoun et al., 2012). The average percentage soluble solids from observation plots of 'Keepsake' was highest at 8.7%, and ranged from 6.6% to 10.5% (Table 1). The average percentage soluble solids for 'Earliglow' was 8.2%, ranging from 5.7% to 10.7%, slightly more variable. While the flavor ratings for 'Earliglow' and 'Flavorfest' were similar, the average percentage soluble solids for 'Flavorfest' was lower at 7.6%. Another important component of flavor is acidity (pH), and the pH averages of 'Keepsake', 3.6, and 'Flavorfest', 3.6, were higher, less tart, than that of 'Earliglow' at 3.5 (Table 1).

**Shelf life.** 'Keepsake' had better retention of quality in refrigerated storage than all the other cultivars tested (Fig. 3). The portion of fruits degraded at one week was 29%, lower than for all the other cultivars. Only 'Ovation' had a statistically similar portion of degraded fruits at 47%. 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. In addition, 'Chandler' and 'Camarosa' fruits displayed color changes within a week of storage that the other cultivars did not display. 'Chandler' fruits often turned all dark and had a gummy texture when squeezed gently at 2 weeks. Within a week of storage, 'Camarosa' fruits often had large dark blotches resembling bruises located in places unlikely to have been caused by rough handling. The portion of degraded fruits at 2 weeks was statistically the same for all cultivars. The portion of decayed 'Keepsake' fruits at 2 weeks was 10%, similar to all other cultivars except 'Flavorfest', which had a higher portion of decayed fruits, 35%. The portion of decayed fruits at 1 week was statistically similar for all cultivars.

**Appearance and handling.** Firmness was reported subjectively by gently squeezing several individual fruits from observation plots each year (Table 1). 'Keepsake' had the highest average firmness, 7.8, similar to that of Camarosa, a cultivar known for being very firm. 'Keepsake' also had the highest average skin toughness rating of 8.1 (Table 1). Skin tough-



Fig. 2. 'Keepsake' strawberry fruits, produced in plasticulture at the U.S. Department of Agriculture Agricultural Research Service Beltsville Agricultural Research Center, Beltsville, MD.

Table 1. 'Keepsake' strawberry fruit quality compared with other cultivars grown in plasticulture at the U.S. Department of Agriculture Agricultural Research Service Beltsville Research Center, Beltsville, MD, from 2010 to 2018.<sup>a</sup>

Cultivar	Soluble solids (%)		Acidity (pH)		Flavor		Firmness		Skin toughness	
	Avg	Range	Avg	Range	Avg	Range	Avg	Range	Avg	Range
Allstar	7.3	6.1–8.6	3.6	3.2–4.0	7.4	7.0–8.0	7.7	7.0–8.0	7.7	7.5–8.0
Camarosa	6.9	6.4–7.3	3.4	3.4	7.3	7.0–7.5	7.8	7.5–8.0	7.5	7.0–8.0
Chandler	7.4	5.0–9.1	3.5	3.4–3.8	7.4	7.0–8.0	7.1	7.0–7.5	7.5	7.0–8.0
Earliglow	8.2	5.7–10.7	3.5	3.3–3.8	7.8	7.5–8.5	7.2	7.0–7.5	7.3	7.0–8.0
Flavorfest	7.6	6.3–10.3	3.6	3.2–4.0	7.8	7.0–8.0	7.6	7.0–8.0	7.6	7.0–8.0
Keepsake	8.7	6.6–10.5	3.6	3.3–3.8	8.1	7.5–8.5	7.8	7.5–8.0	8.1	8.0–8.5
Ovation	8.3	7.1–10.0	3.5	3.1–3.8	7.5	6.5–8.0	7.5	7.0–7.5	7.2	7.0–7.5

<sup>a</sup>Flavor, firmness, and skin toughness were subjective ratings, agreed on by two researchers for each plot. Firmness was determined with a gentle hand squeeze. Skin toughness was determined by gently rubbing a thumb across each fruit. The juice of three to five fruits from a six-plant plot, hand squeezed in the field, was measured with a Pocket refractometer PAL-1 (ATAGO USA, Inc., Bellevue, WA) to obtain estimates of percentage soluble solids and a LAQUAtwin-pH-22 (HORIBA Scientific, Edison, NJ) to obtain estimates of acidity (pH). Acidity means and ranges were calculated in lieu of analysis of variance estimates due to the subjective nature of the measures, the broad range environmental conditions during measurement, and/or the number of measures (n) for each genotype.

ness was determined from several individual fruits from an observation plot each year.

'Keepsake' average fruit size was similar to that of all the other cultivars, except that all had larger fruit size than 'Earliglow' (Fig. 4). Fruit size for a plot was measured at each harvest and averaged across 10 fruits, or fewer when 10 were unavailable. The average of all the plot × harvest averages was reported as the "average fruit size" for the year. The largest of the plot × harvest averages was reported as the "large fruit size" for the year. 'Keepsake' large fruit size

ranked only under 'Flavorfest', although statistically similar to all cultivars except 'Earliglow'.

### Yield

Over 9 years of replicated testing, 'Keepsake's average total yield (decayed and non-decayed fruits) was 547 g/plant (Fig. 5). The yield for 'Keepsake' ranked between 'Allstar' and 'Ovation' but was not significantly different from any of the cultivars tested. 'Flavorfest' and 'Allstar' yields were

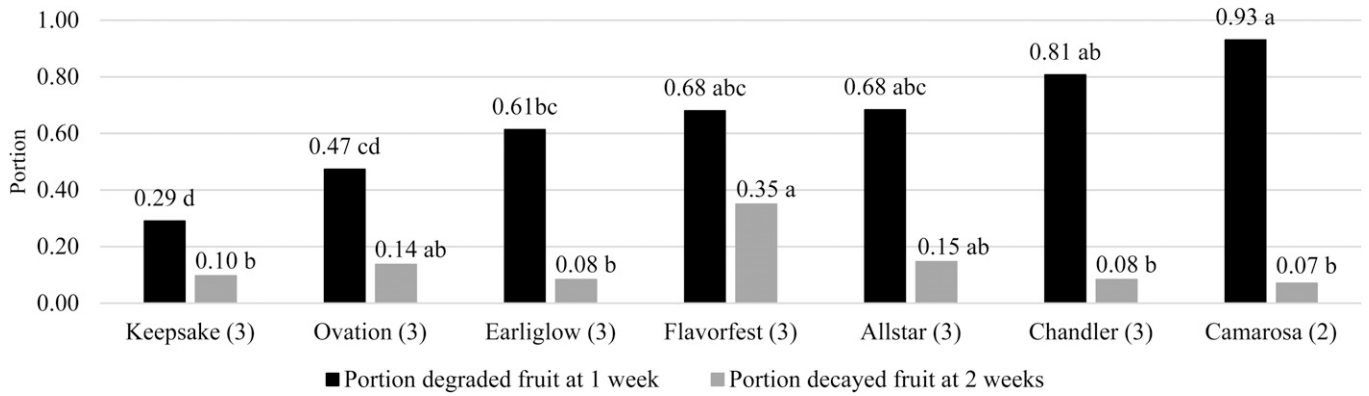


Fig. 3. 'Keepsake' strawberry fruit storage quality compared with other cultivars grown in plasticulture at the U.S. Department of Agriculture Agricultural Research Service Beltsville Research Center, Beltsville, MD, from 2016 through 2018. From field harvests of fruits showing no signs of decay, up to 12 fruits were selected for shelf-life evaluation and placed in a labeled clear plastic egg carton, calyx down. These fruits were further 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 in a black plastic trash bag. The fruits were stored in a walk-in cooler set at 0 °C. At 1 week and 2 weeks, the number of fruits in each egg carton that showed signs of decay or degradation was recorded. A single fruit could be both decayed and degraded. The yearly estimates for decayed or degraded fruits at 1 week and 2 weeks were used in an analysis of variance for genotypic comparison across years. Portion degraded at 1 week provided greater separation of means than at 2 weeks. Portion decayed at 2 weeks showed greater separation of means than at 1 week. Numbers in parentheses after cultivar names indicate the number of years evaluated for this analysis.

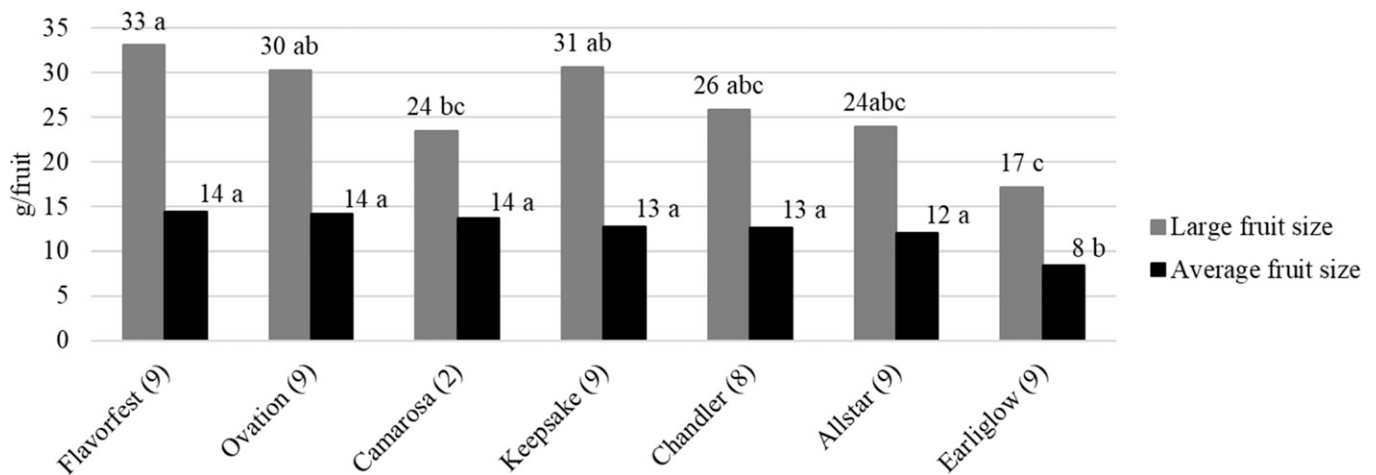


Fig. 4. 'Keepsake' strawberry fruit size compared with other cultivars grown in plasticulture at the U.S. Department of Agriculture Agricultural Research Service Beltsville Research Center, Beltsville, MD, from 2010 through 2018. Ten randomly selected nondecayed fruits were weighed to obtain an average fruit weight for each plot and harvest. The average of all plot × harvest averages for a cultivar was reported as that cultivar's "average fruit size" for the year. The largest of those plot × harvest averages was reported as that cultivar's "large fruit size" for the year. Each year's average for average fruit size (grams/fruit), and largest average fruit size (grams/fruit) for each cultivar was used in an analysis of variance. Numbers in parentheses after cultivar names indicate the number of years evaluated.

significantly larger than those of 'Chandler' and 'Earliglow'.

The yearly averages for nondecayed fruit yield were analyzed separately from total yield to compare cultivars as candidates for growing without fungicides or fumigants. In these conditions, 'Keepsake' nondecayed yields, 468 g/plant or ≈86% of total yield, were similar to nondecayed yields from of other cultivars, except all had statistically higher nondecayed yields than 'Chandler', partly because of the lower total yield in rank for 'Chandler' (Fig. 5). The most common fruit rot for 'Keepsake', 'Flavorfest', 'Allstar', 'Ovation', and 'Earliglow' was botrytis fruit rot. 'Chandler' and 'Camarosa' were more likely to show symptoms of anthracnose fruit rot, followed by botrytis fruit rot.

#### Season

First harvest date of 'Keepsake' at Beltsville ranged from 10 May in 2010 and 2012, to 27 May in 2014. As determined by the relative patterns of actual fruit yield from cultivars and breeding selections each week through the harvest season (Fig. 6), 'Keepsake' fruited with "midseason" genotypes 5 years and late midseason genotypes 4 years. The 'Keepsake' season came after that of 'Flavorfest' every year except 2018, which was an exceptionally late and compressed fruiting year. In eight years of comparison, the 'Keepsake' season came after that of 'Chandler' except for 2014, 2015, and 2018. In addition, each year, the morning of first harvest or the day before, the apparent season for new selections and cultivars also

was determined subjectively in comparison with all other genotypes, including older cultivars with well-known seasons. The ratings were based on the amount of progression of ripening from flowers present to ripe fruits present. The ratings were subjective, from 9 (earliest with ripe fruits) to 0 (latest with just flowers). In this rating system, averaged over all years, the season for 'Keepsake', at 4.9, accurately reflects that 'Keepsake' sometimes fruits with midseason cultivars and sometimes fruits with late-midseason cultivars. Earliglow, a standard early-season cultivar, had an average season score of 7.9. Camarosa at 6.3, Chandler at 5.8, and Flavorfest at 5.2 are standard midseason cultivars; Allstar is a standard late-midseason cultivar at 4.5; and Ovation is a standard late-season cultivar at 2.6.

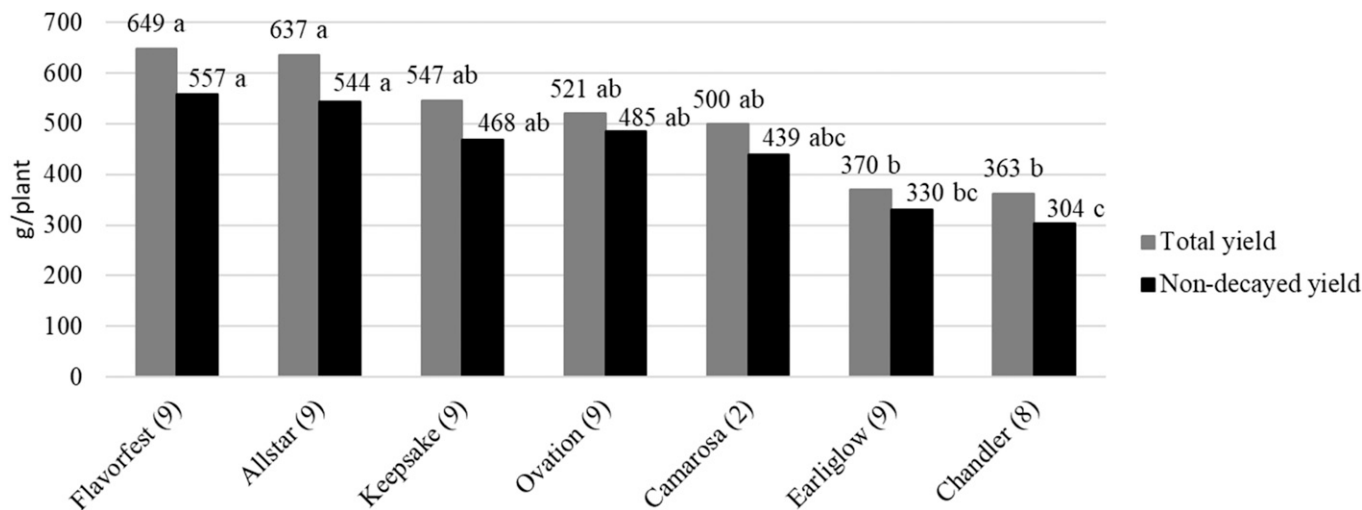


Fig. 5. 'Keepsake' strawberry total annual yield and non-decayed yield compared with other cultivars grown in plasticulture at the U.S. Department of Agriculture Agricultural Research Service Beltsville Research Center, Beltsville, MD, from 2010 through 2018. For each plot at each harvest, decayed fruits were harvested into separate containers from fruits that showed no sign of decay. The containers were weighed separately. Yields were adjusted for plant stands. Each year, analyses of variance (ANOVAs) were performed for total yield and nondecayed yield for comparison within year. The yearly estimates for total yield and nondecayed yield were used in a second analysis of variance for genotypic comparison across multiple years. Numbers in parentheses after cultivar names indicate the number of years evaluated.

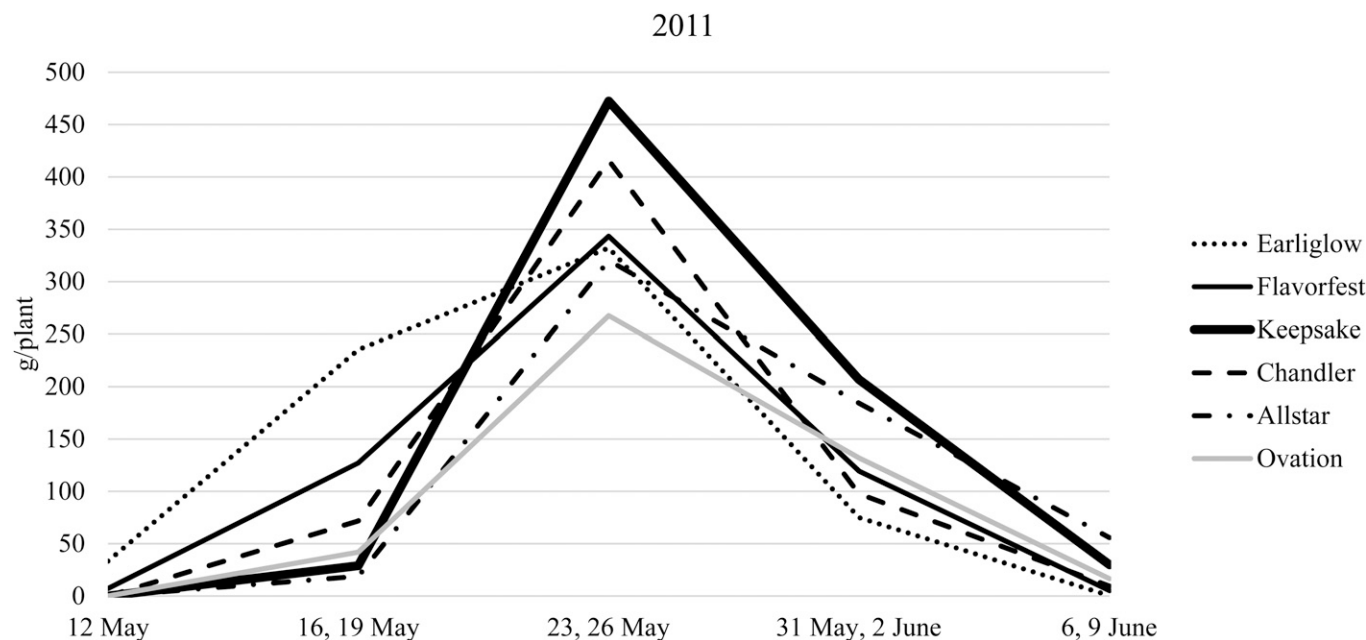


Fig. 6. 'Keepsake' fruiting season compared with other cultivars grown at the U.S. Department of Agriculture Agricultural Research Service Beltsville Research Center, Beltsville, MD, in 2011, a year representative of the season relationships between these cultivars. Plots were harvested twice weekly, and the harvests combined for each week. Yields were adjusted for plant stands and reported as grams/plant each week. Earliglow is a standard early-season cultivar, Keepsake, Camarosa, Chandler, and Flavorfest fruited midseason; Allstar is a standard mid-to-late-season cultivar; and Ovation is a standard late-season cultivar.

## Plant

'Keepsake' was relatively resistant to crown and foliar diseases present in the field. Although no fungicides were used, subjective evaluation scores for foliar diseases included no susceptible ratings in fall after planting, and only two borderline susceptible ratings for leaf blight in spring after fruiting. Averaged scores in spring after fruiting were 7.8 for powdery mildew, with individual plot ratings ranging from 7.5 to 8.5, indicating symptoms were present every year but that

the plots still looked healthy. Average spring scores for leaf scorch was 8.1, ranging from 7.0 to 9.0, and only three plots scored 7.0. Average spring scores for leaf blight, a disease that can cause serious plant stress, was 7.5, ranging from 6.0 to 8.5. Two plots, one in 2011 and one in 2014, received concerning scores below 7.0; the most common score for leaf blight was either 7.5 or 8.0, both considered good. Plots were rated for bacterial angular leafspot disease starting in 2017, when it first appeared across the entire field. 'Keepsake' plots showed bacterial an-

gular leafspot disease symptoms only in 2017, averaging 8.6 for both years and ranging from 7.0 to 9.0. Subjective field evaluation scores of 'Keepsake' plots for crown decay averaged 9.0, with only one plot in 9 years showing slight crown decline, a rating of 8.0, and all other plots receiving a perfect score of 9.0.

'Keepsake' produced about 18 daughter plants per mother plant in propagation by Lassen Canyon Nursery (Redding, CA) compared with 19 daughter plants per mother from 'Camarosa', 15 daughter plants per



mother plant from 'Flavorfest', and 20 daughters per mother from 'Chandler' (Hanna Zeng, personal communication). Relative runner production was confirmed by subjective observation scores averaging 2.2 for 'Keepsake', slightly less than that of 'Camarosa', 2.6, and between that of 'Flavorfest', 1.8, and 'Chandler', 3.2.

#### Availability

'Keepsake' was approved for release in 2018, and a plant patent application for 'Keepsake' has been filed by the USDA-ARS (docket number 126.18). 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. 'Keepsake' is maintained by the USDA-ARS National Clonal Germplasm Repository at Corvallis, OR, as CFRA 2318.001 PL, or PI

688296. 'Keepsake' was increased for distribution from virus-indexed mother stocks by Lassen Canyon Nursery, Redding, CA.

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