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'USDA Lumina' Strawberry

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'USDA Lumina' is an early-season short-day strawberry (*Fragaria ×ananassa* Duch. ex Rozier) developed by the US Department of Agriculture (USDA) Agricultural Research Service strawberry breeding project in Beltsville, MD, USA. It was released because no other cultivar currently available for the Mid-Atlantic and adjacent regions combined the following key qualities: early season; consistently good, sweet flavor; large fruit size; high yield for an early-season cultivar; winterhardiness in the Mid-Atlantic; and resistance to anthracnose fruit rot caused by members of the *Colletotrichum acutatum* species complex. The name 'USDA Lumina' is in reference to the appearance of the fruits. They consistently have a bright red color, glossy skin, and uniform symmetry similar to cone-shaped light bulbs. In Maryland, a high percentage of 'USDA Lumina' fruit have been marketable with low rot at harvest and after postharvest storage, although no fumigation or fungicides were used in the field during its development. 'USDA Lumina' is expected to be adapted to the Mid-Atlantic region of the United States and regions with a similar climate and soil type.

Origin and Development

The origins and early history of the USDA strawberry breeding program were described by Darrow (1966). The program used recurrent mass selection since 1910. 'USDA Lumina' was derived from a cross-pollination of B2475 by B2197, planned in 2016, and executed in 2017. The pedigrees of each parent are available for 12 generations except for the parentage of two progenitors of the pollen parent B2197; one progenitor is in the sixth generation (MDUS5130) and the other progenitor is in the twelfth generation (BK-46) (Fig. 1A, 1B).

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'USDA Lumina' was selected in a Beltsville, MD, USA, seedling field in a plasticulture production system (Black et al. 2002) in Spring 2019 and assigned the selection number B2875. Plants clonally propagated from runners of B2875 were evaluated in an observation plot in annual plasticulture production in 2020 in Beltsville, MD, USA. After evaluation in the observation plot, the original mother plant of B2875, 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). B2875 tested negative for both viruses and was further propagated in an outdoor screenhouse. The plants were grown in fiberglass tubs that were 37 cm wide × 54 cm long and 26 cm deep; six 1-cm drainage holes were drilled through the bottoms and placed on tables approximately 1 m high. The tubs were half-filled with Pro-Mix HP high-porosity potting mix (Premier Tech; Rivière-du-Loup, Quebec City, Canada). The screening covering the screenhouse was the Xsect Xtra fine-mesh screen with 0.15-mm × 0.21-mm holes small enough to exclude thrips, virus vectors, aphids, and white flies (U.S. Global Resources, Seattle, WA, USA). Daughter plants dug from these tubs each winter were used to propagate runner tips to make the plug plants needed for annual replicated evaluations and companion observation plots from 2021 through 2023. 'USDA Lumina' has not been tested outside of Beltsville, MD, USA.

Production system. 'USDA Lumina', as B2875, was evaluated with other selections and cultivars on the North Farm of the USDA-Agricultural Research Service (ARS) Henry A. Wallace Beltsville Agricultural Research Center in Beltsville, MD, USA (lat. 39°01′48.42″N, long. 76°56′07.99″W; 49.4 m elevation) on Downer-Hammonton complex loamy sand and Russet-Christiana complex fine sandy loam soils (USDA Natural Resources Conservation Service 2023) supplemented each year with potassium (K), sulfur (S), and boron (B) to correct deficiencies reported by annual soil tests. These soils have existing high levels of phosphorus (P) and moderate levels of K. Calcitic lime was used to adjust soil pH to 6.3 to 6.5. No fumigants were used. The fields had rotation crops for 4 years since the previous strawberry planting.

Observation plots and replicated plots were established annually during plasticulture production (Black et al. 2002) using raised beds with two lines of trickle irrigation 7 cm below the surface and covered with black plastic mulch. Six-plant plots were established with plug plants that were pegged from daughter plants or purchased in the case of some reference cultivars that were not from the Beltsville breeding program. B2875 was established and evaluated in 2019 and 2020 with other new selections, older selections, and reference cultivars in unreplicated six-plant observation plots. In subsequent years, B2875 was established annually for further plant and fruit evaluations with other selections and reference cultivars using both an observation plot and three additional plots in randomized complete blocks. The fields for this stage of the evaluation were established annually in the summers of 2020 to 2022. Evaluations were performed the year of establishment during fall and again during the following spring (2021–23).

Fertigation supplied nitrogen (N) at a rate of 112 kg·ha^{-1} N per year as potassium nitrate and calcium nitrate. Starting 1 week after planting in August, a total of 79 kg·ha^{-1} N was applied through fertigation using five or six weekly injections until mid-September. During the following spring, 1 week after the initial irrigation in early April, an additional 34 kg·ha^{-1} N was applied using six or seven weekly injections until mid-May. No fungicides were used. Frost protection of spring flowers was provided from early April using microsprinklers on 30.5-cm stakes (SuperNet Jr.; Netafim, Fresno, CA, USA) when temperatures decreased below 2 °C and overhead impact sprinklers at an elevation of 1 m when temperatures decreased below 1 °C.

Subjective evaluations of observation plots. Observation plots were subjectively evaluated after planting in late October to determine vigor, disease, and runner production. They were evaluated during the following May, 1 d before the first harvest, for season determination. In May and June, they were subjectively evaluated to determine the fruit quality and fruit load at the beginning of their fruiting peak. After fruiting, they were evaluated again to determine a second rating of vigor, disease, and runner production. Plots were rated 3 months after planting and immediately after they finished fruiting to determine the incidence and severity of any type of crown rot as well as foliar powdery mildew [*Podosphaera aphanis* (Wallr.) U. Braun & S. Takam], leaf scorch [*Diplocarpon earlianum* (Ellis & Everh.) F.A. Wolf], leaf blight [*Paraphomopsis obscurans* (Ellis & Everh.) Udayanga & Castl.] (Udayanga et al. 2021), and bacterial angular leafspot disease (*Xanthomonas fragariae* Kennedy and King). Individual plots were given subjective scores. Subjective scores of 0.0 (worse) to 9.0 (best) were used for all traits except runner production. A score of 7.0 was considered minimum cultivar quality. Scores of 6.5 were concerning, and scores of 6.0 or less were possible reasons for rejection as a potential cultivar. For runner production, a different scale with scores of 0.0 (no runners) to 5.0 (so many runners that failure to remove them would interfere with harvesting) was used. Scores of 2.5 to 3.0 were considered optimum because strong runner production is valued by matted-

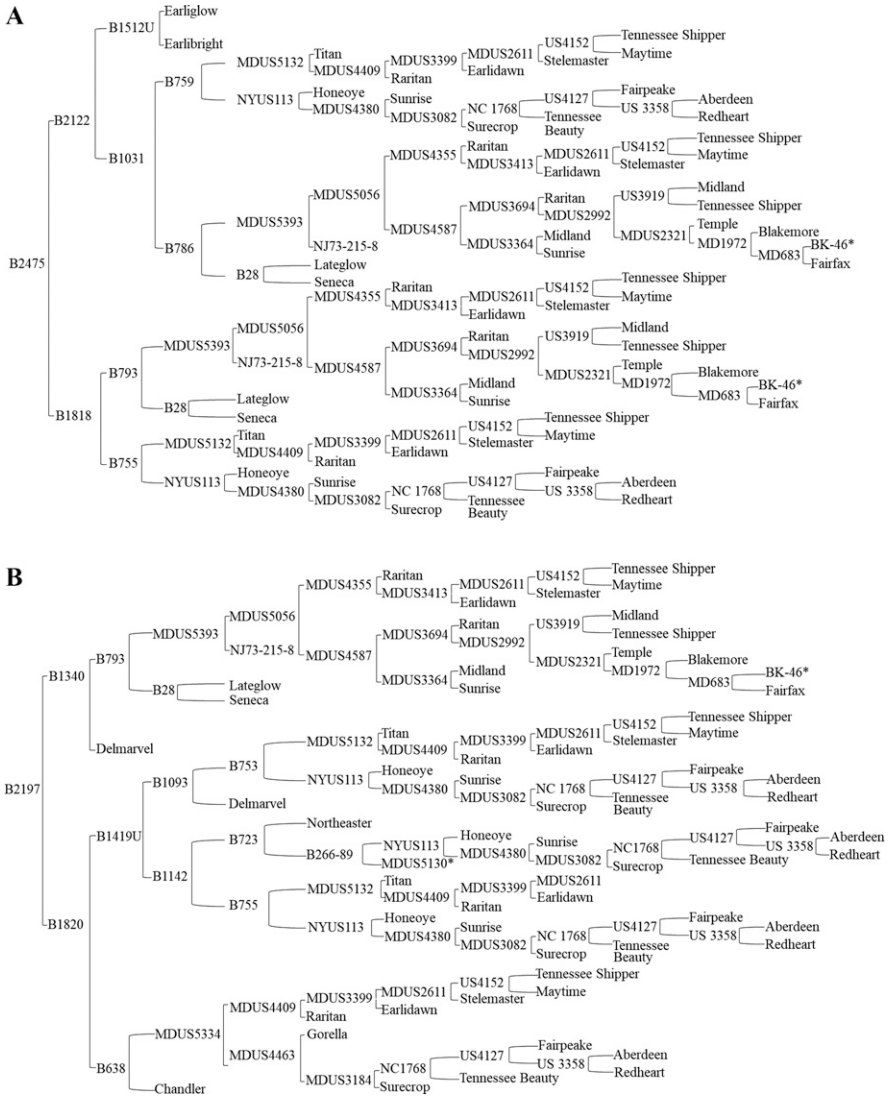

Fig. 1. Pedigree of 'USDA Lumina' strawberry, developed at the US Department of Agriculture Agricultural Research Service (USDA-ARS) Beltsville Agricultural Research Center, Beltsville, MD, USA. The pedigrees of the seed parent B2475 (**A**) and pollen parent B2197 (**B**) are listed separately because of size. Seed parents are represented above pollen parents. Two progenitors in the pedigree are marked with an asterisk to indicate that the pedigrees for these progenitors were not found.

row growers and nurseries propagating plants for sale; however, too many runners can lead to high labor expenses for removing runners in the annual plasticulture system.

A season score was subjectively estimated each year, the day before the first harvest. The ratings were based on the stage of ripening progression from flowers to ripe fruits. The ratings were subjective and ranged from 0 (latest with just flowers) to 9 (earliest with ripe fruits). During fruiting, observation plots were subjectively evaluated at the peak of their season to determine yield, size, appearance, symmetry, firmness, skin toughness (resistance to abrasion when rubbed with a thumb), skin color, flesh color, and flavor. Appearance ratings were influenced by size, symmetry, shape, uniformity, coloration (too orange, too purple, white "shoulders"), and signs of degradation such as bronzing, bruising spots, sun scald, or skin-splitting as a result of rain damage. Fruits from the plots were also rated in terms of specific diseases of anthracnose fruit rot (*Colletotrichum acutatum* J.H. Simmonds) and botrytis fruit rot (*Botrytis cinerea* Pers.:Fr.). To estimate sweetness and tartness, three to five fruits from each six-plant plot were hand-squeezed in the field near the beginning of peak of harvest for that genotype. The juice was measured using a refractometer (Pocket refractometer PAL-1; ATAGO USA, Inc., Bellevue, WA, USA) to obtain estimates of the percent soluble solids and a pH meter (LAQUAtwin-pH-22; HORIBA Scientific, Edison, NJ, USA) to obtain estimates of acidity (pH). A penetrometer with a 3.5-mm head was used to measure fruit firmness. The colors of fruit and fruit parts were determined using Royal Horticultural Society (RHS) color fans (Royal Horticultural Society and Flower Council of Holland 1986).

Replicated evaluations. Replicated yield evaluations of a randomized complete block design with one replication in each of three blocks were performed. The reference cultivars planted each year for comparison varied somewhat based on availability and program needs and resources (Tables 1–3). Statistical analyses were calculated using the data of 'USDA Lumina' and 13 reference cultivars in 2021, and with the data of 10 reference cultivars in 2022 and 2023.

Plots were harvested twice weekly. Fruits from each plot were harvested into two separate containers per plot: one for rotted fruits and one for fruits that showed no sign of rot. The containers were weighed separately. These weights were used to determine the total yield, total nonrotted yield, and total rotted yield for each plot for the year. The weights were adjusted for plant stand to provide data regarding the yield per plant. All fruits from the container showing no signs of rot were counted to obtain an average fruit weight for that plot and harvest (weight divided by the number of fruits). The average fruit weight across all harvest dates for a cultivar was recorded as that cultivar's average fruit weight for the year. The average fruit weight from the date when the fruit weight was greatest was recorded as that cultivar's peak fruit weight for the year.

From the container of fruits showing no signs of rot, the fruit were given a subjective market score ranging from 2.0 (worst) to 9.0 (best). A score of 0.0 was reserved for genotypes that did not flower, and a score of 1.0 was reserved for genotypes that flowered but did not produce fruit. Size, shape, uniformity, glossiness, cracking, splitting, and coloration (bronzing, bruising, white "shoulders") were key features used to determine the market score. A market score of 7.0 or more was given to a container when all or nearly all fruit appeared suitable for fresh eating. A score of 6.5 was given to a container when many fruits appeared acceptable for fresh eating but several fruits appeared unacceptable. Scores of 6.0 or less were given to a container when more than half the fruit was 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.

From each container rated marketable at that harvest, up to 12 fruits from the container showing no signs of rot were selected for the shelf life evaluation. The fruits were placed calyx-down in a labeled clear plastic egg carton. The fruits that were free of signs of injury and relatively uniform in size, shape, and maturity were selected. Egg cartons with fruit were placed in rigid plastic egg boxes and taken to a walk-in cooler set at 0.5 °C without humidity control. The egg boxes were stacked two-boxes-high and covered loosely with a black plastic trash bag. At 1 week and 2 weeks after harvest, 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, wrinkling, loss of gloss, dark blotches resembling bruises, a fruit turning

Table 1. First harvest dates and peak harvest weeks for strawberry cultivars grown in plasticulture at Beltsville, MD, USA. "Season" was the average of a subjective rating of each plot recorded the day of the first harvest, with higher values reflecting the observation of fruit that was riper than fruit from plots with lower values. Cultivars are ordered according to approximate season. Not all cultivars in the table were planted each year.

	Year								
	2021			2022			2023		
Cultivar	Season	First harvest date	Peak harvest week	Season	First harvest date	Peak harvest week	Season	First harvest date	Peak harvest week
Sweet Charlie				7.5	5 May	16–20 May	6.6	1 May	22–26 May
Earliglow	7.6	3 May	17–21 May	6.7	5 May	16–20 May	6.5	1 May	15–19 May
USDA Lumina	6.4	3 May	17–21 May	6.3	5 May	16–20 May	6.2	1 May	22–26 May
Galletta	7.0	3 May	24–28 May	6.3	9 May	16–20 May	6.1	1 May	15–19 May
Northeaster	7.5	3 May	17–21 May						
AC Wendy				5.8	12 May	16–20 May			
Ruby June	6.9	3 May	24–28 May						
Chandler	5.5	6 May	24–28 May	5.0	5 May	23–27 May	5.1	1 May	15–19 May
Camarosa	4.8	10 May	24–28 May				5.6	4 May	22–26 May
Flavorfest	4.7	10 May	1–4 Jun	5.1	16 May	23–27 May	5.0	8 May	15–19 May
Keepsake	4.6	10 May	1–4 Jun	4.2	16 May	23–27 May	4.7	8 May	22–26 May
Allstar	4.9	6 May	24–28 May				3.8	11 May	22–26 May
Jewel							2.9	11 May	22–26 May
Cordial	3.1	13 May	7–11 Jun	2.7	19 May	30 May–3 Jun	2.3	15 May	29 May–2 Jun
AC Valley Sunset	2.8	17 May	7–11 Jun	2.1	16 May	31 May–3 Jun			
Ovation	2.5	13 May	1–4 Jun						
Malwina	1.0	4 Jun	14–18 Jun	1.0	6 Jun	13–17 Jun			

all dark, soft wet spots, soft dry spots, small depressions between achenes, and small dark depressions. The numbers of fruits that still appeared marketable also were recorded.

Annual cultivar averages across replications were used in analyses of variance to compare USDA Lumina to the reference cultivars ($P = 0.05$) using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA). A mixed model was used to determine whether significant differences existed; cultivar was a fixed effect and year was a random effect. A general linear model was used to obtain separations of means and least significant differences between means. Traits that were analyzed included 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 the percentages of marketable, rotted, and degraded fruits at 1 week and 2 weeks.

Description

Harvest season. The average subjective season ratings for 'USDA Lumina' across 2021, 2022, and 2023 was 6.3, which was typical of an early-midseason cultivar; the ratings of 'Sweet Charlie' (US PP8729P), 'Earliglow' (Scott and Draper 1975), 'Ruby June' (US PP27,190 P3), 'Northeaster' (Galletta et al. 1995), and 'Galletta' (US PP19,763 P2) were 7.1, 6.9, 6.9, 6.8, and 6.5, respectively (Table 1). 'USDA Lumina' usually started fruiting and had peak harvest dates at the same time as early-season cultivars Sweet Charlie and Earliglow. In 2023, following a mild winter during which no row covers were used, 'USDA Lumina' started fruiting with 'Earliglow' and 'Sweet Charlie'. Although 'Earliglow' reached peak production early, 'USDA Lumina' and 'Sweet Charlie' reached peak production later during the same week as that when the midseason and late-midseason cultivars Camarosa (US PP08,708 P), Keepsake (US PP30 578 P2), Allstar (Galletta et al. 1981), and Jewel (Sanford et al. 1985) reached peak production (Table 1).

Yield: total, percent nonrotted, and percent marketable. The total yield (decayed and nondecayed fruits) of 'USDA Lumina' was generally greater than that of other early-season and early-midseason cultivars, but not as high as that of midseason and late-season cultivars (Table 2). Yields varied considerably by year. Across cultivars, yields in 2021 were higher than usual, and yields in the other two years were lower than usual for this site, historically.

The percentage of nonrotted yield of 'USDA Lumina' was consistently among the highest, similar to that of other early-season cultivars Earliglow and Sweet Charlie and early-midseason cultivars Galletta and Northeaster (Table 3). The percentage of nonrotted yield for the early-midseason cultivar Ruby June was much lower than that of these other cultivars because of losses from anthracnose fruit rot.

The percentage of the total yield that was marketable was influenced by the percentage of rotted fruit. The percentage of rotted fruit in Spring 2023 was very low because of unusually cool and dry weather. With low rot, the percentage of marketable yield was higher and affected more by other factors such as size and symmetry. The percentage of marketable yield from 'USDA Lumina' was among the highest every year, partly because of its fruit rot resistance, large size, uniform symmetry, bright color, and glossy skin. In 2021, some size variability was noted; in 2022, some rain damage

Table 2. USDA Lumina strawberry total fruit yield compared with that of 16 other cultivars grown in an annual plasticulture system at the US Department of Agriculture Agricultural Research Service (USDA-ARS) Beltsville Research Center, Beltsville, MD, USA, from 2021 through 2023. Cultivar means with different letters indicate statistically significant differences for each year. Cultivars are arranged according to season, as determined by the first and peak harvest dates.

	Year		
Cultivar	2021 Total yield (g/plant)	2022 Total yield (g/plant)	2023 Total yield (g/plant)
Sweet Charlie		276 c–g	69 k
Earliglow	551 hij	159 g–j	388 g–j
USDA Lumina	1,003 d–g	270 dgg	387 f–k
Galletta	864 fg	110 j	372 ijk
Northeaster	823 f–i		
AC Wendy		185 g–j	
Ruby June	383 j		
Chandler	734 ghi	114 ij	501 d–j
Camarosa	770 ghi		807 a–d
Flavorfest	1,197 b–e	248 f–i	317 jk
Keepsake	1,178 b–e	344 c–f	446 e–j
Allstar	935 efg		715 b–f
Jewel			667 c–i
Cordial	1,303 a–d	496 ab	1,019 ab
AC Valley Sunset	736 ghi	283 c–g	
Ovation	1,002 d–g		
Malwina	525 ij	407 bc	

Table 3. Percentages of nonrotted and marketable strawberry fruit yield of USDA Lumina compared with 16 other cultivars grown in an annual plasticulture system at the US Department of Agriculture Agricultural Research Service (USDA-ARS) Beltsville Research Center, Beltsville, MD, USA, from 2021 through 2023. Percentage nonrotted yield was calculated from the weight of nonrotted yield divided by the weight of total yield. Percentage marketable yield is the weight of harvests with a market score of 7.0 or above divided by the total yield. Cultivar means with different letters indicate statistically significant differences for each year. Cultivars are arranged according to season, as determined by the first and peak harvest dates.

	Year					
	2021		2022		2023	
Cultivar	Nonrotted (%)	Marketable (%)	Nonrotted (%)	Marketable (%)	Nonrotted (%)	Marketable (%)
Sweet Charlie			95 a	68 abcde	100 a	65 def
Earliglow	95 a	58 defgh	99 a	68 abcde	98 ab	67 cdef
USDA Lumina	86 abcd	85 a	98 a	92 a	97 ab	80 abcde
Galletta	91 ab	87 a	100 a	42 efg	98 ab	89 abcd
Northeaster	86 abcd	63 cdefg				
AC Wendy			89 ab	9 h		
Ruby June	37 lm	15 i				
Chandler	48 kl	18 i	76 bc	34 gh	98 ab	83 abcde
Camarosa	75 cdefgh	15 i			98 ab	97 a
Flavorfest	83 abcde	81 ab	97 a	91 a	96 ab	39 f
Keepsake	84 abcde	79 ab	96 a	69 abcd	99 ab	69 bcde
Allstar	65 ghij	49 fgh			96 b	59 ef
Jewel					96 b	81 abcde
Cordial	70 efghi	67 bcde	98 a	90 a	96 ab	72 abcde
AC Valley Sunset	56 jk	48 gh	64 cd	44 defg		
Ovation	80 bcdef	61 defg				
Malwina	83 abcde	6 i	51 d	40 fg		

at one harvest for all three plots was noted. Low market scores of 'Earliglow' often included size toward the latter part of its season. Low market scores of 'Sweet Charlie' were associated with variable size, symmetry, and/or color. Low market scores of 'Galletta' were often associated with variable size and, in 2022, rain and sun damage. Low market scores of 'Northeaster' were associated with poor symmetry. Notes regarding 'Ruby June' almost always referenced anthracnose fruit rot and sometimes mentioned a claw-shaped symmetry and split fruit.

Appearance of fruits. 'USDA Lumina' fruits were large, symmetrically uniform, firm, tough, and very glossy (Figs. 2–4). The fruit skin color was bright red (RHS86 red group 45A, RHS86 red group 44B). Fruits were conic, with no noticeable difference in shape between primary and secondary fruits. The firmly attached reflexed calyx was generally not showy, had a sized that varied from smaller than to greater than the diameter of the fruit, and was positioned evenly with the top of the fruit or above a slight neck. Generally, there was a very narrow band of fruit below the calyx with no achenes. Achenes, which were flush with the fruit surface, were red (RHS86 red group 45A) on the sun-exposed side of the fruit to yellow green (RHS86 yellow group 153A, yellow-green group 152C) on the underside of the fruit. Interior flesh color was unevenly distributed; it was mostly red (Red Group 44A) with a small lighter red core, paler red halo, and the same paler red in a small area near the calyx. Attractive, lighter-colored vascular tissue radiating from the fruit center to the achenes was clearly visible.

Fruit weight. The peak fruit weight (28.3 g) of 'USDA Lumina' was not significantly different from that of cultivars with the largest fruit, and was larger than fruit of the cultivars Allstar, Chandler (USPP4481P), Jewel, and early-season cultivars Earliglow and Sweet Charlie (Table 4). The fruit weight of 'USDA Lumina' decreased slightly as the season progressed. The average fruit weight (14.0 g) of 'USDA Lumina' was statistically lower than that of the late-season cultivars AC Valley Sunset (Jamieson et al. 2010) and Cordial (USPP33636) and greater than that of Allstar and early-season cultivars Earliglow and Sweet Charlie (Table 4).

Fruit firmness and toughness. Fruits from individual observation plots planted each year were rated subjectively in terms of firmness and toughness and were measured with a hand-held penetrometer with a 3.5-mm head. 'USDA Lumina' fruits were subjectively rated among the firmest and toughest, but fruits from 'Camarosa' (8.31 $kg \cdot cm^{-2}$), known for its firmness, had significantly higher penetrometer measurements (Table 4). The fruit penetrometer mean of 'USDA Lumina' was 6.00 $kg \cdot cm^{-2}$, which was significantly higher than that of 'Ruby June' (2.63 $kg \cdot cm^{-2}$) and early-season cultivar Sweet Charlie (3.83 $kg \cdot cm^{-2}$).

Fruit percent soluble solids and pH. 'USDA Lumina' fruits tasted sweet and had a notable creamy texture in 2021 and 2022, but they were less creamy in 2023. Notes taken at harvests included many comments such as "sweet," "very sweet," "super sweet," "juicy," "fruity," and "creamy." The notes also included a few comments such as "mild," "refreshing,"

Fig. 2. Overhead view of a six-plant plot of 'USDA Lumina' strawberry during fruiting.

Fig. 3. Close-up of 'USDA Lumina' strawberry fruits showing color and glossiness.

"sugar water," and one comment indicating "tart." The subjective flavor ratings were among the highest (Table 4). The percent soluble solids and pH of fruit from every plot at every harvest were measured. The average percent soluble solids rating of 'USDA Lumina' fruit juice (9.2%) was above average (8.5%), but it was not as high as that of 'Ruby June' (10.7%) or that of the early-season cultivar Earliglow (10.5%) (Table 4). The average pH of 'USDA Lumina' fruit juice was among the highest and was significantly higher than that of fruit from cultivars Flavorfest (Lewers et al. 2017), Galletta, Malwina (USPP23246), and Ovation (Lewers et al. 2004).

Fruit postharvest quality. The percentage of 'USDA Lumina' fruits that was marketable after 1 week in refrigerated storage (91%) was above average, but it was not significantly different from that of other cultivars, except for early-season cultivar Earliglow (98%) (Table 5). After 2 weeks in storage, the percentage of 'USDA Lumina' fruits that were still marketable was 53%, which was significantly lower than that of early-season cultivar Sweet Charlie (85%) and higher than that of early-midseason 'AC Wendy' (Jamieson et al. 2009) (9%) and 'Ruby June' (19%). The percentage of degraded 'USDA Lumina' fruits after 1 week of refrigerated storage (45%) was not significantly different from that of other cultivars except for the midseason cultivar Chandler (90%) (Table 5). At 2 weeks, the percentage of degraded 'USDA Lumina' fruits (94%) was significantly less than that of early-midseason cultivars AC Wendy (99%) and Galletta (98%) and the midseason cultivar Chandler (99%). All cultivars showed some form of degradation; however, the most common was slight desiccation evidenced by minute wrinkles on the skin. Notes recorded during evaluations in 2021 and 2022 indicated that 'USDA Lumina' fruits in storage acquired an unusual pink blush between the achenes 1 week after harvest that was not present at harvest or 2 weeks after harvest. This color change was not unattractive, unlike the extreme darkening seen in other cultivars such as Chandler and Camarosa, that can make them look overripe or bruised.

The percentage of rotted 'USDA Lumina' fruits at 1 week (2%) was not significantly different from that of most other cultivars except for the late-season cultivar Malwina (35%) (Table 5). At 2 weeks after storage, the percentage of rotted fruits (20%) was not significantly different from that of most cultivars, but it was greater than that of the early-season cultivar Earliglow (2%), early-midseason cultivar Galletta (1%), late-midseason cultivar Jewel (4%), and late-season cultivars Cordial (2%) and Ovation (3%).

Plants. USDA Lumina produced an open globose plant with medium to high crown and foliage density greater than that of the low-density early-season cultivar Galletta and the medium-density early-season cultivar Earliglow (Fig. 2). Plant vigor was medium to strong and similar to that of 'Earliglow' but more vigorous than that of 'Galletta'. Inflorescences presented at or below the canopy, which can be advantageous for an early-season cultivar likely to experience frost during flowering.

'USDA Lumina' was relatively resistant to 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) during fall or spring. The average score in spring, after fruiting, was 7.2 for powdery mildew; individual plot ratings ranged from 7.0 to 8.5, indicating that symptoms were present every year but that the plots still looked healthy. These scores were superior to those of the early-season cultivar Earliglow (6.9), but not as good as those for the early-midseason cultivars Ruby June (8.9) and Galletta (8.2). The average spring scores for leaf blight, a disease that can cause serious plant stress, was 8.6 (range, 8.0–9.0), which was statistically superior to that of all other early-season and early-midseason cultivars. The average spring score of 'USDA Lumina' for leaf scorch (8.8) was similar to that of the other early-season and early-midseason cultivars (range, 8.5–9.0). 'USDA Lumina' plots showed very mild bacterial angular leafspot disease symptoms and had scores (average, 8.7; range, 7.0–9.0) similar to those of the other early-season and early-midseason cultivars and superior to those of the late-midseason cultivars Allstar and Jewel.

Subjective field evaluation scores of 'USDA Lumina' plots for crown rot were 9.0, which is a perfect score, in every plot until 2023, when the field became infested with anthracnose crown rot (*Colletotrichum siamense*). Anthracnose crown rot caused by *C. siamense*

Fig. 4. 'USDA Lumina' fruit from a single harvest of a six-plant plot showing the uniform shape and variation in size.

Table 4. USDA Lumina strawberry fruit traits compared with those of 16 other cultivars grown in an annual plasticulture system at the US Department of Agriculture Agricultural Research Service (USDA-ARS) Beltsville Research Center, Beltsville, MD, USA, 2021 through 2023. Average fruit weight, percent soluble solids, and pH of fruits from each plot at each harvest were measured. The average weight of the cultivar was the weight of a fruit averaged overall plots and harvests. The peak weight was that of the harvest with the highest average fruit weight for the season. Penetrometer measurements and subjective ratings for flavor, firmness, and skin toughness were performed for fruits from a single six-plant observation plot each year. A subjective rating or score ranging from 0.0 (worst) to 9.0 (best) was used; 7.0 was considered minimum "cultivar quality." N is the number of years of evaluation for each cultivar–trait combination. Cultivar means with different letters indicate statistically significant differences for each year. Cultivars are arranged according to season, as determined by the first and peak harvest dates.

Cultivar	N	Peak wt (g)	Avg. wt (g)	Flavor rating	Soluble solids (%)	pH	Penetrometer reading ($kg \cdot cm^{-2}$)	Firmness	Toughness
Sweet Charlie	2	16.0 def	9.3 efg	7.0 c	8.5 cde	3.55 abc	3.83 ef	7.3 b–e	7.3 bc
Earliglow	3	11.7 f	6.3 g	7.7 ab	10.5 a	3.50 a–d	4.50 def	7.0 de	7.5 abc
USDA Lumina	3	28.3 abc	14.0 bcd	8.0 a	9.2 cd	3.55 ab	6.00 bcd	7.5 a–d	8.0 a
Galletta	3	21.7 cde	13.3 b–e	6.7 c	7.8 ef	3.39 cde	5.60 cde	7.5 a–d	7.5 abc
Northeaster	1	21.0 b –f	10.3 c–g	6.5 c	8.5 c–f	3.39 b–f	5.13 b–f	7.5 a–e	8.0 abc
AC Wendy	1	23.0 b–f	10.3 c–g	7.0 bc	6.2 g	3.71 a	7.37 abc	8.0 abc	8.0 abc
Ruby June	1	17.0 c–f	10.3 c–g	6.5 c	10.7 ab	3.62 ab	2.63 f	7.5 a–e	7.5 abc
Chandler	3	17.0 def	10.7 def	7.2 bc	7.9 ef	3.36 def	5.53 cde	7.3 b–e	7.2 c
Camarosa	2	18.0 c–f	11.8 c–f	7.0 c	8.3 def	3.49 a–d	8.31 a	8.0 ab	8.0 ab
Flavorfest	3	25.0 b–e	11.7 c–f	7.7 ab	8.3 de	3.39 cde	5.10 cde	7.7 abc	7.7 abc
Keepsake	3	26.3 bcd	11.7 c–f	8.2 a	9.4 bc	3.55 ab	7.20 ab	7.7 abc	8.0 a
Allstar	2	15.5 ef	8.8 fg	7.0 c	8.1 ef	3.46 bcd	5.76 b–e	7.3 b–e	7.3 bc
Jewel	1	14.0 def	8.3 d–g	7.0 bc	8.1 c–f	3.39 b–f	4.99 b–f	7.5 a–e	7.0 c
Cordial	3	37.7 a	16.3 ab	7.0 c	7.2 fg	3.58 ab	5.97 bcd	8.0 a	8.0 a
AC Valley Sunset	2	34.5 ab	18.8 a	8.0 a	8.6 cde	3.60 ab	5.47 b–f	7.5 a–e	7.5 abc
Ovation	1	25.0 a–e	13.3 a–f	7.0 bc	8.2 c–f	3.16 f	5.03 b–f	7.0 cde	7.0 c
Malwina	2	23.0 cde	15.8 abc	7.8 ab	8.6 cde	3.25 ef	3.90 ef	6.8 e	7.3 bc
Average		24.3	13.0	7.4	8.3	3.43	5.75	7.5	7.5

was considered mostly limited to Florida in the eastern United States until 2017, when it was reported in North Carolina (Adhikari et al. 2019). In 2023, the average subjective score for crown rot in spring after harvest was 7.7 across all cultivars (range, 0.0–9.0). The crown rot score for USDA Lumina plots was above average compared to that of other cultivars that had been propagated in Beltsville, MD, USA, without fungicides, but it was lower than that of for purchased cultivars.

The average subjective rating for 'USDA Lumina' runner production in the fall after planting was 1.7, which was not statistically different from that of most of the other cultivars and significantly less than that of the late-season cultivar Ovation (3.5). In spring after fruiting, the average runner production subjective score was much higher at 3.4 (range, 2.0–4.0) and statistically similar to that of early-season cultivars Sweet Charlie (2.4) and Earliglow (2.7) and early-midseason cultivars Galletta (2.6) and Northeaster (2.3); however, it was statistically greater than that of early-midseason cultivars AC Wendy (0.4) and Ruby June (0.2). The tendency for less runner production during fall and more runner production during the following spring after fruiting could be advantageous to nurseries as well as producers using matted-row production systems (Black et al. 2002). Daughter plant production was 9.3 per plant, which was similar to that of 'Galletta' (7.7) and three- to four-times that of 'Earliglow' (2.5).

Availability

'USDA Lumina' was approved for release in 2023 and patented in Sep 2024 as US PP36,100 P2. The sale of plants 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. The use of plants as parental material in cross-pollinations is encouraged. 'USDA Lumina' is maintained by the USDA-ARS National Clonal Germplasm Repository at

Table 5. 'USDA Lumina' strawberry fruit percent marketable, percent degraded, and percent rotted 1 week and 2 weeks after refrigerated storage at 0.5 °C. USDA Lumina was compared with 16 other cultivars grown in an annual plasticulture system at the US Department of Agriculture Agricultural Research Service (USDA-ARS) Beltsville Research Center, Beltsville, MD, USA, from 2021 through 2023. At each harvest, fruits without any visible flaws were placed in clear plastic egg cartons and refrigerated. The number of marketable, rotted, and degraded fruits were counted at 1 week and 2 weeks after harvest. N is the number of years of evaluation for each cultivar–trait combination. Cultivar means with different letters indicate statistically significant differences for each year. Cultivars are arranged according to season, as determined by the first and peak harvest dates.

		Percentage marketable		Percentage degraded		Percentage rotted	
Cultivar	N	Week 1	Week 2	Week 1	Week 2	Week 1	Week 2
Sweet Charlie	2	92 a–d	85 a	85 ab	84 cd	1 e	9 cde
Earliglow	3	98 a	51 bc	46 bcd	97 abc	1 e	2 ef
USDA Lumina	3	91 bcd	53 bc	45 bcd	94 bcd	2 cde	20 abc
Galletta	3	95 ab	42 cde	28 d	98 a	1 e	1 f
Northeaster	1	89 bcd	44 b–e	20 d	95 a–d	4 b–e	5 c–f
AC Wendy	1	86 bcd	9 f	33 bcd	99 a	9 bcd	15 a–d
Ruby June	1	71 dc	19 def	29 cd	95 a–d	11 abc	14 bcd
Chandler	3	64 d	17 def	90 a	99 a	2 cde	5 cde
Camarosa	2	72 dc	40 cde	49 bcd	90 bcd	3 cde	6 cde
Flavorfest	3	87 bcd	44 bcd	55 a–d	98 abc	5 b–e	7 cde
Keepsake	3	94 ab	69 ab	21 d	92 bcd	2 de	8 cde
Allstar	2	92 abc	53 bc	72 ab	97 abc	1 de	6 cde
Jewel	1	94 abc	74 ab	78 ab	84 cd	4 b–e	4 def
Cordial	3	96 ab	78 a	46 bcd	81 d	2 de	2 ef
AC Valley Sunset	2	65 d	19 def	64 abc	92 bcd	18 abc	34 abc
Ovation	1	61 d	16 ef	87 ab	95 a–d	1 e	3 def
Malwina	2	59 d	25 c–f	87 ab	95 a–d	35 a	43 a
Average		83	44	55	93	6	11

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