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Productive Specialty Eggplant Cultivars Suitable for Small Farms in the Southeastern Coastal Plain

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Abstract. **Specialty eggplants (*Solanum melongena* L.), cultivars with fruit shapes, sizes, and colors different from the typical teardrop-shaped, dark purple eggplant fruit, are an underproduced vegetable commodity in the southeastern United States. Seven cultivars representing seven different fruit types were grown in Charleston, SC, USA, in Spring and Fall 2018 and 2019 to assess cultivar productivity and net return. Despite year-to-year variability, Hansel (Chinese type), Millionaire (Japanese type), and Gretel (white fruit) generally had greater weights of both marketable (US Fancy and No. 1 fruit) and edible (US Fancy, No. 1 and No. 2) fruit than Fairy Tale (Sicilian type) and Patio Baby (Indian type), whereas the globe-fruited cultivars Black Beauty (heirloom) and Rosa Bianca (Italian type), had intermediate yields. Yields of plants after ratooning in the fall were lower than in the spring before ratooning. Prices per carton paid by local food hubs for US Fancy, No. 1, and No. 2 fruit were two to three times greater than wholesale terminal market prices. Nevertheless, fruit weights were a greater determinant of net returns than prices were. Growers in the southeastern coastal plain can maximize net returns from specialty eggplant crops by choosing cultivars that produce high fruit weights.**

Eggplant (*Solanum melongena* L.), also called aubergine or brinjal, is a warm-season, productive vegetable crop grown throughout the world (Prohens et al. 2005). The most common fruit type grown and sold in the United States is the standard globe or tear-drop–shaped fruit (Kahn 2013). In addition, several types of specialty eggplants are suitable for production in the southeastern coastal plain, including Asian, white, miniature, and Sicilian, the latter defined as having a "purple exterior with white stripes" (Kemble et al. 2023; The Packer 2024). In addition to these types, Japanese eggplants are preferred in some markets and by some consumers because the peel and flesh are tenderer than other eggplant types (Clemons 2022; Keinath 2023).

South Carolina ranks in the top 25% of US states producing eggplants, with an official estimate of 44.5 ha in 2017 [US Department of Agriculture (USDA), National Agricultural Statistics Service 2019]. Eggplant was produced on at least 93 farms in 27 of the state's 46 counties. Leading counties are Charleston in the coastal plain and Greenville and Spartanburg in the piedmont.

Various defects reduce marketable yield of globe-type eggplants (Johnson et al. 2018; Kahn 2013; USDA, Agricultural Marketing Service 2013). Six fruit defects are commonly observed: disease, scarring, discoloration, sunburn, insect injury, and misshapen fruit. In both years of a study in Oklahoma, the primary defect on all 11 cultivars was scarring of the fruit surface, which affected 9% to 29% of the fruit in 2005 and 2006, respectively (Kahn 2013). Diseased fruit, affected primarily by Phomopsis blight, was the second most common defect. Discolored fruit, the third most common defect, was much more common on the heirloom 'Black Beauty' than on all hybrid cultivars. In North Carolina, the same six fruit defects were used to group fruit into marketable; edible but unmarketable, including scarred fruit; and inedible and not marketable fruit that were diseased, sunburned, or otherwise damaged (Johnson et al. 2018). Only 10% of the fruit were marketable, whereas 53% and 37% were considered edible and inedible, respectively. Whether cultivars with other fruit types are equally likely to be damaged by these six defects is unknown, as few field trials have included specialty eggplant types.

Another challenge in eggplant production is the variability of yields and quality between years. In Oklahoma, the mean number of marketable fruits per plant and the marketable weight of globe cultivars were reduced by half in the second year of the study due to hotter and drier growing conditions (Kahn 2013). Mean percentage of marketable fruit varied from 72% in 2005 to 45% in 2006, primarily due to an increase in fruit scarring. A statistical comparison of years was not done in that study. Despite year-to-year variability in yields, Santana and Classic were among the highest-yielding cultivars with the highest percentage of marketable fruit in both years. Thus, some cultivars may perform consistently across years or environments.

The objectives of this study were to 1) compare the multiseason productivity of specialty eggplant cultivars representing seven different fruit types; 2) determine which cultivars produced consistently across seasons and years; and 3) estimate which fruit types produced the greatest net returns.

Materials and Methods

Plant growth and fruit harvest. The experiment was done at the Clemson University Coastal Research and Education Center, Charleston, SC, USA. Neither field had been cropped to eggplant in the past 10 years. The soil type in both fields was Yonges loamy fine sand with pH 6.8 in 2018 and 6.0 in 2019. Raised beds, 0.9 m wide on 1.8-m centers, were fertilized with 560 kg·ha^{-1} 15N–0P–10K and then covered with smooth, black, 0.03-mm-thick polyethylene mulch, 1.5-m wide >(Barry Global, Evansville, IN, USA). In 2018, the herbicide halosulfuron-methyl (Sandea 75DG, 39 g·ha^{-1}) was applied under the mulch, and S-metolachlor (Dual Magnum 7.62EC, 2.1 kg·ha^{-1}) and fomesafen (Reflex 2SL, 0.14 kg·ha^{-1}) were applied in the alleys between the mulched beds. In 2019, S-metolachlor and glyphosate 41% (Credit 41 Extra, 4.0 kg·ha^{-1}) were applied under the mulch.

The experimental design was a randomized complete block with seven cultivars chosen to represent common fruit and horticultural types of eggplant (The Packer 2024; Table 1). Three cultivars (Gretel, Fairy Tale, and Hansel) are currently recommended for production throughout the southeastern United States (Kemble et al. 2023). Each of the three replications was located in a separate row. Each plot included a single row of six plants spaced 0.6 m apart, and plots were separated by 1.2 m of non-planted area within the row. Seedlings were transplanted on 16 Apr 2018 and 11 Apr 2019. Plants were ratooned by cutting stems to 15 to 20 and 25 to 30 cm on 10 Aug 2018 and 30 Jul 2019, respectively. Plants were staked and tied as the stems regrew.

Minimal fungicide and insecticide applications were made to reproduce local production practices on small farms. In 2018, malathion (Malathion 57 EC, 1.8 kg·ha^{-1}) was applied once after ratooning to manage leaf-footed bugs. In 2019 pyrethrin (Pyganic 1.4EC, 1.6 g·ha^{-1}) and lambda-cyhalothrin (Cyonara 9.7, 4.7 L·ha^{-1} product) were each applied once before ratooning to manage leaf-footed bugs, and lambda-cyhalothrin and carbaryl (Sevin 4SL, 1.7 kg·ha^{-1}) were each applied once after ratooning to manage leaf-footed bugs and army

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Table 1. Characteristics of seven eggplant fruit types and cultivars tested in Charleston, SC, USA.

Cultivar	Horticultural type	Seed type	Breeder	All-America selection	Fruit shape	Fruit color	Minimum fruit length harvested (cm)
Black Beauty	Globe	Heirloom OP	Burpee	NA[1]	Ovoid	Dark purple	13
Fairy Tale	Sicilian	Hybrid	Seminis	2005	Oblong	Light purple with white flecks	10
Gretel	White	Hybrid	Seminis	2009	Elongated	White	8
Hansel	Chinese	Hybrid	Seminis	2008	Elongated	Purple	8
Millionaire	Japanese	Hybrid	Unknown	NA	Elongated	Dark purple	13
Patio Baby	Indian	Hybrid	PanAmerican Seed	2014	Ovoid	Purple	6
Rosa Bianca	Italian	Heirloom OP	Heirloom	NA	Round	Light purple with white blotches	10

[1] Not applicable.

worms, respectively. Chlorothalonil (Bravo Weatherstik 6SC, 1.7 kg·ha^{-1}) was applied once after ratooning in 2019 to manage Cercospora leaf spot.

Marketable-sized fruits, based on mature fruit length as given by the seed source, in each plot were harvested once per week six times before ratooning (spring season) and seven times after ratooning (fall season) in 2018 and five and nine times in Spring and Fall 2019, respectively (Table 1). To standardize harvest dates for yield data analysis, five harvest dates were selected in each season when all seven cultivars were harvested; dates for spring were 11 Jun to 16 Jul 2018 and 13 Jun to 11 Jul 2019, and dates for fall were 27 Sep to 25 Oct 2018 and 25 Sep to 23 Oct 2019.

Fruits with no visible defects were considered marketable. Fruit with defects were sorted into the six cull classes used by Kahn (2013) based on the type of defect as defined in the US Standards for Grades of Eggplant (USDA, Agricultural Marketing Service 2013). In the fall, spots of Phomopsis blight, caused by the fungus *Diaporthe vexans*, appeared on the calyxes of some fruit and these were included in the diseased category (Keinath 2022). The order of culling was disease, insect injury, scarring, misshapen, discolored, and sunburn (eg, fruits were examined first for diseases, and all fruits with disease were placed in the disease category even if they also had other defects). Misshapen fruit were wider than long or noticeably curved. Fruits were counted and weighed in each category.

Net return calculations and data analysis. The following variables were used to assess yield for different types of production and marketing: total number, total weight, and marketable number as a measure of cultivar productivity; marketable weight as a measure of wholesale market yield of US Fancy and No. 1 fruit; and edible weight as a measure of local market yield of US Fancy, No. 1, and No. 2 fruit (USDA, Agricultural Marketing Service 2013). Edible weight included marketable weight plus weight of fruit graded as misshapen, scarred, and discolored, about the yield of Number 2 grade fruit or fruit labeled edible but not marketable by Johnson et al. (2018). Fruit not marketable in either type of market included diseased fruit, fruit with insect damage, and sunburned fruit (Johnson et al. 2018; USDA, Agricultural Marketing Service 2013).

Prices for marketable fruit (USDA grades fancy and No. 1) were obtained from the USDA, AMS, Market News for representative harvest dates from East Coast terminal markets, generally Baltimore, New York, or Philadelphia (USDA, Agricultural Marketing Service 2023). Dates were chosen when prices were available for six or all seven fruit types (Supplemental Table 1). Mean prices used in value calculations were calculated from two dates each for the spring and fall seasons. The first dates were 9 Jul 2018, which corresponded to the sixth harvest date in Spring 2018, and 11 Sep 2019, the day after the second harvest date in Fall 2019, and prices were averaged between two terminal markets if available. The second dates were 10 Aug 2020 and 19 Oct 2020, when prices for all seven fruit types were available in Philadelphia. Prices were converted to USD per 16.6-kg cartons (equivalent to 1 and one-ninth bushel volume of fruit).

Prices paid to growers for edible fruit (USDA grades fancy, No. 1, and No. 2) were obtained on 14 Jul 2022 from GrowFood Carolina, a local food hub in Charleston, SC, USA (https://www.coastalconservationleague.org/projects/growfood/) and on 12 Sep 2023 from Swamp Rabbit Cafe and Grocery, a food hub in Greenville, SC, USA (www.swamprabbitcafe.com) (Supplemental Table 1). Prices in Charleston were not available for Sicilian or Indian fruits, so the price for the other specialty type fruit was used because the price was identical for Chinese, Japanese, and Italian fruit. The wholesale price (i.e., the price paid to growers) is 80% of the retail price at GrowFood Carolina (Seibert N, personal communication). Food hub prices were averaged and used to calculate net returns for edible fruit.

Crop value was calculated by converting fruit weight to cartons/ha and multiplying by the mean price per carton for each fruit type in spring and fall. Net return was calculated from crop value by subtracting production (preharvest) and harvest costs, based on the 2022 eggplant enterprise budget from the University of Georgia (Fonsah et al. 2022). Pesticide costs in the budget were adjusted to the actual costs of the products applied. For the spring crop, the cost of staking and stringing, and mulch removal were excluded from the input costs. For the fall crop, the only preharvest costs included were staking and stringing, fungicide, insecticide, irrigation, beehive, and scouting.

Data analysis. Data were analyzed with a mixed-model maximum likelihood analysis with SAS PROC GLIMMIX Version 9.4 (SAS, Inc., Cary, NC, USA). Total and marketable numbers and total weights were summed over spring and fall harvests. For these three variables and the weight of individual fruit, the cultivar was considered a fixed effect and year, replication within a year, and the year-by-treatment interaction as random effects (Schabenberger and Pierce 2002). For all other variables, data were analyzed by season with cultivar, year, and the interaction as fixed effects and replication as a random effect. Residuals from analyses of variance were plotted against the predicted mean with the RESIDUALPANEL option and examined for normality to judge model goodness of fit. Total and marketable numbers of fruit were transformed with square root, weight of individual fruit was transformed with base-ten logarithm, and fruit percentages were transformed with arcsine of the square root before analysis; fruit weights did not require transformation. Comparisons among isolate means were based on Fisher's protected least-significant difference calculated with the PDIFF option and a probability value of 0.05. Net returns for each cultivar in each season and year were compared with the expected net return of $6,424/ha with *t* tests (Fonsah et al. 2022).

Results

Cultivar effects on yields. The number of surviving plants, measured at 49 and 56 d after transplanting in 2018 and 2019, respectively, was affected by cultivar ($P < 0.001$) but not year ($P = 0.82$) or season ($P = 0.11$) or any interactions among these factors. 'Black Beauty' had fewer mean surviving plants, 5.1, than all other cultivars, a range of 5.7 to 6.0 plants per plot of six plants transplanted.

The specialty cultivars (Gretel, Hansel, Patio Baby, Fairy Tale, and Millionaire) produced more total and marketable fruits than the globe-fruited cultivars (Black Beauty and Rosa Bianca) when fruit numbers were summed over spring and fall seasons and the year was considered a random effect in the statistical model (Table 2). 'Gretel' and 'Hansel' produced more total and marketable fruits than 'Fairy Tale' and 'Millionaire'.

The weights of individual fruit of the two globe cultivars did not differ from each other and were greater than the fruit weights of all other fruit types (Table 2). Fruit of 'Millionaire' weighed more than the other four specialty types. Fruit weight of 'Gretel' was less

Table 2. Productivity of eggplant cultivars based on fruit number and weight across seasons and years.

Cultivar	Total number/ha[i]	Marketable number/ha[ii]	Wt of individual fruit (g)	Total wt (16.6-kg cartons/ha)
Hansel	410,233 b[iii]	316,368 ab	50.8 c	3054
Gretel	631,980 a	483,845 a	31.5 d	2939
Millionaire	154,744 d	104,862 c	131.5 b	3059
Rosa Bianca	27,573 e	14,341 d	499.2 a	2226
Black Beauty	24,901 e	12,899 d	559.0 a	2232
Patio Baby	305,415 bc	186,824 bc	42.4 cd	1874
Fairy Tale	224,195 cd	146,675 c	47.1 c	1548

[i] Plots were 3.6-m long with six plants. Numbers and weights of fruits were summed over the spring and fall seasons.

[ii] Marketable fruit were those of US Department of Agriculture Fancy and No. 1 quality.

[iii] Cultivar means within a column followed by the same letter do not differ significantly, Fisher's protected least-significant difference test, $P = 0.05$.

than that of all other cultivars except 'Patio Baby'. Total weight of fruit produced over both spring and fall seasons did not differ among cultivars.

Yields and net returns for Fancy and No. 1 fruit. In the spring experiments, there was no year-by-cultivar interaction for marketable weight, but in the fall experiments, five cultivars yielded more in 2019 than in 2018, even though the same numbers of harvests were compared (Table 3). Weight of marketable fruit of 'Rosa Bianca' was greater in 2018 than in 2019.

In both spring experiments and in Fall 2019, cultivars Hansel, Gretel, and Millionaire had greater marketable weight than Fairy Tale, Black Beauty, and Rosa Bianca (Table 3). In both spring experiments and in Fall 2018, 'Hansel' yielded more than 'Millionaire'. In Fall 2018, Hansel had greater marketable weight than all other cultivars, which did not differ significantly from each other. Yields of 'Black Beauty' and 'Rosa Bianca' did not differ from each other in any season or experiment. In Fall 2019, they had lower yields than all five specialty cultivars.

For weight of unmarketable fruit, the cultivar-by-year interaction was significant for both seasons ($P \leq 0.01$). In spring, all cultivars except Patio Baby had a significantly greater weight of unmarketable fruit in 2018. In fall, cultivars Rosa Bianca, Patio Baby, and Fairy Fale had greater weights in 2018 than in 2019 (Table 3).

In Spring 2018, Black Beauty had a significantly greater weight of unmarketable fruit than all other cultivars. Patio Baby had the lowest weight of unmarketable fruit, significantly lower than all other cultivars except Fairy Tale. Conversely, in Spring 2019, Patio Baby had the greatest weight of unmarketable fruit, significantly greater than cultivars Hansel, Gretel, Black Beauty, and Patio Baby.

In Fall 2018, Rosa Bianca had a greater weight of unmarketable fruit than all other cultivars. Black Beauty, on the other hand, had the lowest weight of unmarketable fruit, significantly lower than all other cultivars. In Fall 2019, Millionaire had a greater weight of unmarketable fruit than all other cultivars except Gretel. Gretel, in turn, had a greater weight of unmarketable fruit than cultivars Rosa Bianca, Black Beauty, Patio Baby, and Fairy Tale.

Mean prices for marketable fruit did not differ significantly between spring and fall crops, and the cultivar-by-season interaction also was not significant. Prices for Indian, Chinese, and Italian fruit were >$30/carton and significantly greater than prices for globe, white, and Sicilian fruit. The mean price for Japanese fruit was greater than the mean price for globe fruit (Supplemental Table 1).

The net return from 'Hansel' was the highest or among the highest in all four experiments, >$8000/ha (Fig. 1A and B). In Spring 2019 and Fall 2018, Hansel had a greater net value than the other six cultivars. Net return from 'Millionaire' was >$8000/ha in both spring experiments. In both spring seasons, Hansel and Millionaire had greater net returns than cultivars Patio Baby, Fairy Tale, and Black Beauty. Net returns from 'Gretel' were >$10,000/ha in spring but among the lowest in the fall. Net return from 'Black Beauty' was negative and among the lowest of all cultivars in all four experiments.

Compared with the expected net return of $6424/ha from the University of Georgia enterprise budget for globe eggplants, 'Hansel' exceeded the value in spring and matched the value in fall, that is, the mean net return was significantly greater and not significantly different from the expected net return (t tests, $P = 0.05$) (Fig. 1A and B). Net return of 'Millionaire' matched or exceeded the expected net return in three experiments. Net returns of 'Gretel' and 'Rosa Bianca' matched or exceeded the expected net return in spring but were significantly lower in fall. Net return of 'Patio Baby' matched the expected value in 2018 and Fall 2019 but was significantly lower in Spring 2019. Net returns of 'Fairy Tale' and 'Black Beauty' were significantly lower than the expected value in all four experiments.

Yields and net returns for Fancy, No. 1, and No. 2 fruit. In spring experiments, weight of edible fruit was significantly greater than weight of marketable fruit for all cultivars in both years except 'Fairy Tale' and 'Hansel' in 2019 ($P \leq 0.05$ based on t tests). In fall experiments, weight of edible fruit was

Table 3. Marketable yields of seven eggplant cultivars with different fruit types based on weight of fruit of US Department of Agriculture Fancy and No. 1 quality.

	Marketable wt (16.6-kg cartons/ha)			Wt not marketable (16.6-kg cartons/ha)[i]			
		Fall		Spring		Fall	
	Spring[ii]	2018		2018		2018	
Source of variation	P value	P value	2019	P value	2019	P value	2019
Year	0.586	<0.0001	—	0.0006	—	0.176	—
Cultivar	<0.0001	<0.0001	—	<0.0001	—	<0.0001	—
Year × cultivar	0.067	<0.0001	—	<0.0001	—	0.008	—
Cultivar							
Hansel	1999 a[iii]	359 bc	401 b	783 c	189 gh	217 bcd	161 cde
Gretel	1872 ab	146 ef	578 a	653 cd	261 fgh	249 bcd	247 bcd
Millionaire	1612 b	179 de	640 a	1220 b	432 def	238 bcd	271 ab
Rosa Bianca	1000 c	170 de	8 g	1417 b	359 efgh	352 a	146 ef
Black Beauty	1056 c	86 efg	44 fg	1791 a	261 fgh	98 ef	72 f
Patio Baby	946 c	121 efg	351 bc	428 efg	543 cde	264 bc	149 ef
Fairy Tale	827 c	137 ef	282 cd	521 de	149 h	222 bcd	131 ef

[i] Weight not marketable includes all six cull classes.

[ii] The year-by-cultivar interaction was not significant for marketable weight in spring. Means were calculated across years.

[iii] Cultivar means within a column followed by the same letter do not differ significantly, Fisher's protected least-significant difference test, $P = 0.05$. Year means within seasons followed by the same letter do not differ significantly, Fisher's protected least-significant difference test, $P = 0.05$.

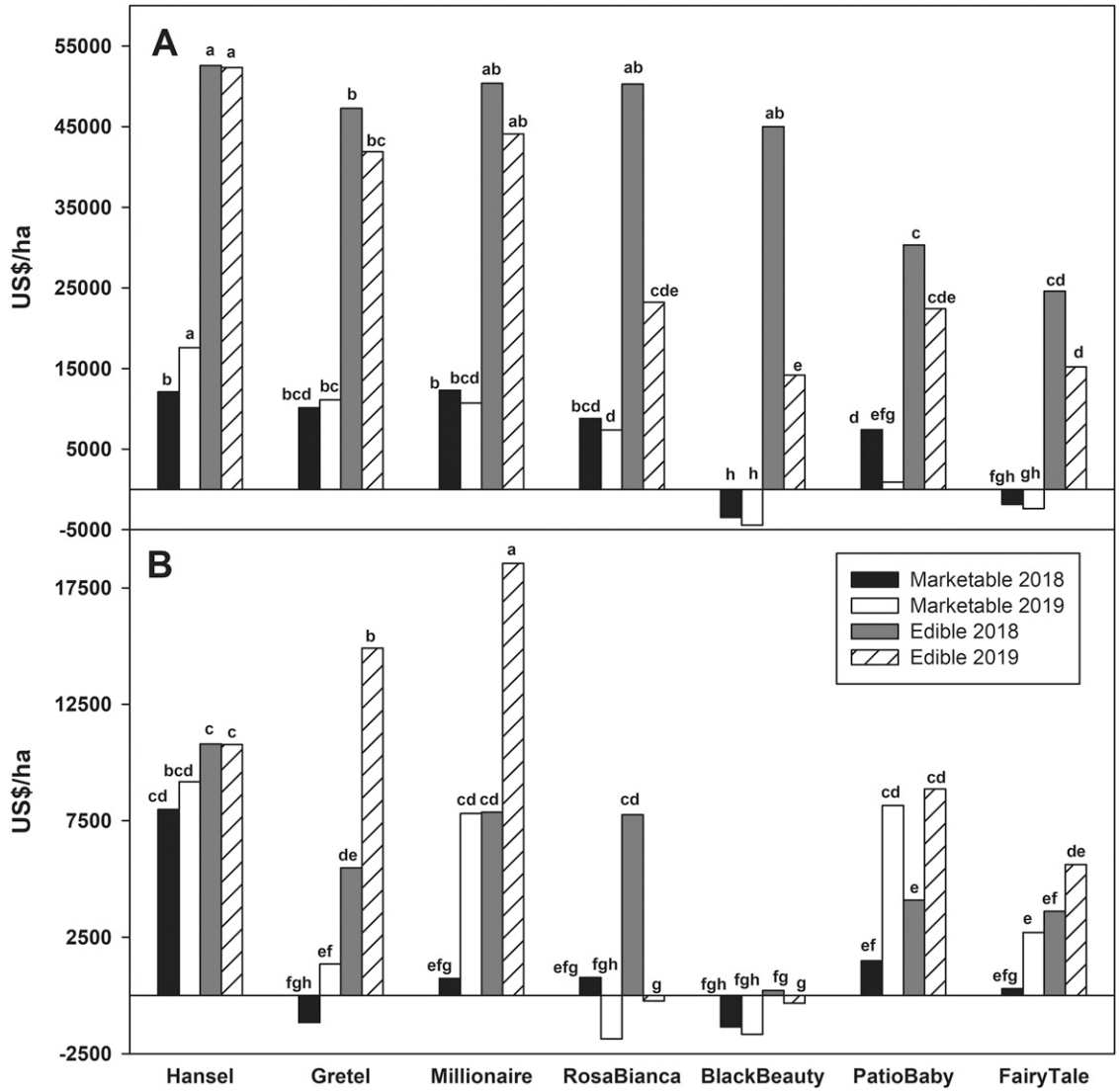

Fig. 1. Net returns ($/ha) for marketable fruit (US Fancy and No. 1) and edible fruit (US Fancy, No. 1, and No. 2) in spring (**A**) and fall (**B**).

significantly greater than the weight of marketable fruit for all cultivars in both years except 'Black Beauty' in both years and 'Fairy Tale' in 2019 (Table 4, Fig. 2).

In spring experiments, the year-by-cultivar interaction was mainly due to Black Beauty, which had a greater weight of edible fruit than all other cultivars except Hansel in 2018 but a low yield in 2019. In the spring seasons, weight of edible fruit of the five specialty cultivars did not differ between years, while the two globe cultivars, Black Beauty and Rosa Bianca, yielded more in 2018 than in 2019 (Table 4). In the fall, the year-by-cultivar interaction was due largely to different yields of Rosa Bianca, which was the third highest-yielding cultivar in 2018 but the lowest yielding in 2019. In fall seasons, weights of cultivars Gretel, Millionaire, and Patio Baby were greater in 2019 than in 2018.

In Spring and Fall 2018, cultivars Hansel and Millionaire yielded more edible fruit than Patio Baby and Fairy Tale. In Spring and Fall 2019, cultivars Hansel, Gretel, and Millionaire yielded more than Fairy Tale, Black Beauty, and Rosa Bianca. In both spring experiments, 'Fairy Tale' had low yields, while in both fall experiments, 'Black Beauty' had low yields.

Cull fruit with fruit rots, insect injury, or sunburn were considered inedible and unmarketable as US No. 2 fruit (Johnson et al. 2018; USDA, Agricultural Marketing Service 2013). In spring, the globe-fruited cultivars, Rosa Bianca and Black Beauty, had a greater cull weight than cultivars Hansel, Fairy Tale, and Patio Baby (Table 4).

In the fall, Millionaire was the only cultivar with significantly greater weights of cull fruit in 2019 than in 2018 (Fig. 2). In 2018, Patio Baby had a greater weight of cull fruit than cultivars Gretel, Black Beauty, and Millionaire, whereas Millionaire had lower cull weight than all other cultivars. In Fall 2019, weight of cull fruit did not differ significantly among cultivars.

Net returns for edible fruit, based on mean local food hub prices in Charleston and Greenville, SC, USA, were greater than net returns based on marketable fruit for all cultivars (Supplemental Table 1). Net returns from edible fruit of Hansel and Millionaire were among the highest of all cultivars in three experiments and did not differ from each other (Fig. 1). In Fall 2019 only, 'Millionaire' had a greater value than 'Hansel'. In both years in the spring, cultivars Hansel, Millionaire, and Gretel had greater net returns than cultivars Patio Baby and Fairy Tale. Net returns from cultivars Fairy Tale, Patio Baby, and Black Beauty were among the lowest of all cultivars in three experiments. In Spring 2018, however, 'Black Beauty' had a greater net return than 'Fairy Tale' and 'Patio Baby'. In Fall 2018, Rosa Bianca had greater net returns of edible fruit than Black Beauty, whereas these two globe cultivars did not differ in Fall 2019.

In both spring experiments, most cultivars had a greater net return for edible fruit than the expected net return for marketable fruit, $6424/ha; 'Fairy Tale' in both springs and 'Black Beauty' in Spring 2019 had net returns not significantly different from the expected net return (Fig. 1). In Fall 2018, the net return for edible fruit of six cultivars was not significantly different from the expected net return for marketable fruit; only Black

Table 4. Yields of seven eggplant cultivars with different fruit types based on edible weight of fruit of US Department of Agriculture Fancy, No. 1, and No. 2 quality.

	Edible wt (16.6-kg cartons/ha)[i]				Not marketable wt (16.6-kg cartons/ha)[ii]		
	Spring		Fall			Fall	
	2018		2018		Spring[iii]	2018	
Source of variation	*P* value	2019	*P* value	2019	*P* value	*P* value	2019
Year	0.007	—	0.0005	—	0.003	0.677	—
Cultivar	<0.0001	—	<0.0001	—	0.026	0.009	—
Year × cultivar	0.0001	—	<0.0001	—	0.216	0.026	—
Cultivar							
Hansel	2,424 ab[iv]	2,414 ab	519 b	518 b	37 b	111 ab	44 abcd
Gretel	2,350 b	2,118 b	323 cde	730 a	82 ab	47 bc	94 abc
Millionaire	2,335 b	2,080 b	400 bc	833 a	65 ab	17 d	78 abc
Rosa Bianca	2,331 b	1,234 cd	396 bcd	72 h	149 a	111 ab	78 abc
Black Beauty	2,789 a	1,144 cd	119 fgh	89 gh	150 a	46 bc	39 bcd
Patio Baby	1,522 c	1,202 cd	247 def	441 bc	51 b	122 a	51 abc
Fairy Tale	1,290 cd	909 d	228 efg	309 cde	49 b	115 ab	103 ab

[i] Edible weight includes marketable weight plus weight of fruit graded as misshapen, scarred, and having poor color.
[ii] Not marketable fruit includes fruit with disease, insect damage, or sunburn.
[iii] The year-by-cultivar interaction was not significant for not marketable fruit in spring.
[iv] Cultivar means within a column followed by the same letter do not differ significantly, Fisher's protected least-significant difference test, $P = 0.05$. Year means within seasons followed by the same letter do not differ significantly, Fisher's protected least-significant difference test, $P = 0.05$.

Beauty had a significantly lower net return. In Fall 2019, net returns for edible fruit of cultivars Hansel, Millionaire, and Gretel exceeded the expected net return, while Patio Baby and Fairy Tale had net returns for edible fruit that were not significantly different from the expected net returns, but Black Beauty and Rosa Bianca had net returns lower than expected.

Losses by different cull classes. Numbers of fruit in the six cull classes were summed across seasons to reduce inequality of variances in the analyses of variance due to low numbers in some cull classes. Scarring was the major reason for culling fruit in the fall (Fig. 3A). All cultivars had scarred fruit in both years (effects of year and the cultivar-by-year interaction were not significant, $P \geq 0.16$). Cultivars Millionaire, Gretel, and Hansel had ≥ 45% scarred fruit, a significantly greater percentage than Rosa Bianca and Fairy Tale, which had ≤18% (Table 5).

Sunburn was present only in 2018 on two cultivars, Patio Baby (29%) and Rosa Bianca (7%), which had significantly more fruit with sunburn than cultivars without sunburn.

Misshapen fruit of cultivars Millionaire, Gretel, and Hansel were excessively curved, while misshapen fruit of the other cultivars were two fused fruits (Fig. 3B). Misshapen fruit occurred in both years (effects of year and the cultivar-by-year interaction were not significant, $P \geq 0.33$). Cultivars Millionaire, Gretel, and Hansel had ≥9% misshapen fruit, significantly more than the other four cultivars, which had ≤1%.

Some fruit of all cultivars were discolored in both years except Black Beauty and Rosa Bianca in 2018. The cultivar-by-year interaction resulted from a significantly higher percentage of discolored Rosa Bianca fruit in 2019 (35%), the highest percentage of any

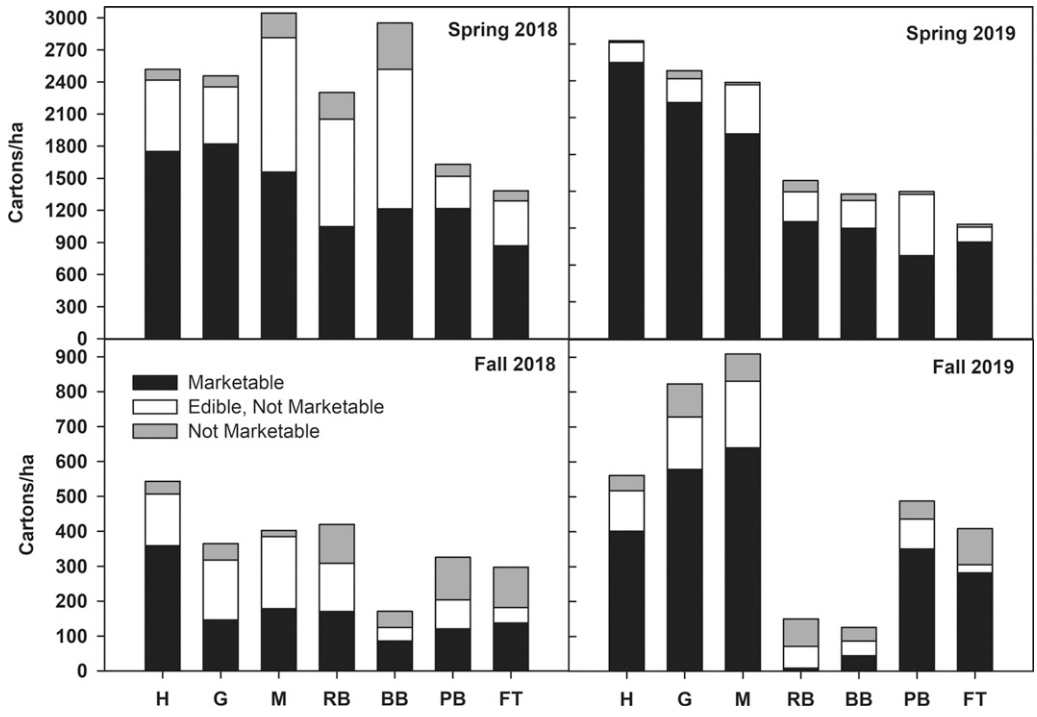

Fig. 2. Distribution of fruit by weight as marketable (US Fancy and No. 1), edible but not marketable (US No. 2), and not marketable in four experiments. Cultivars on the x-axes are Hansel (H), Gretel (G), Millionaire (M), Rosa Bianca (RB), Black Beauty (BB), Patio Baby (PB), and Fairy Tale (FT). Fall harvests were from ratooned plants.

Fig. 3. Common fruit defects included (**A**) scarring, shown on 'Gretel'; (**B**) misshapen fruit, shown on 'Hansel'; (**C**) discolored fruit, shown on 'Fairy Tale'; and (**D**) lesions of Phomopsis blight on the calyx, shown on 'Black Beauty'.

cultivar in the study, than in 2018 (P = 0.003). Cultivars Patio Baby and Fairy Tale had >12% discolored fruit in both years (Fig. 3C). The stem end of 'Fairy Tale' (<25% of the area) was most likely to be colored normally, while the blossom end (>75%) was very pale purple or gray. Patio Baby had a significantly greater percentage of discolored fruit than cultivars Millionaire, Black Beauty, and Gretel.

Insect injury, despite applications of insecticides, affected a greater percentage of cultivars Black Beauty, Fairy Tale, and Rosa Bianca fruit in 2018 than in 2019. Insect damage was observed on ≥12% of 'Gretel' and 'Fairy Tale' fruit in both years. In 2018, 'Patio Baby' and 'Rosa Bianca' also had >12% fruit with insect injury.

Phytophthora fruit rot, caused by *Phytophthora nicotianae*, was observed on 5% of Millionaire fruit in Fall 2018, significantly more fruit than the other six cultivars. 'Black Beauty' had no fruit with *Phytophthora* fruit rot. This disease also affected fruit in Spring 2018, as reported previously (Keinath 2023). *Phytophthora* fruit rot did not occur in 2019.

Lesions of Phomopsis blight were observed on the fruit calyxes of all cultivars in both years, but only in the fall (Fig. 3D). This symptom was particularly common on Black Beauty fruit in 2019, when 59% of the fruit were culled, significantly more than all other cultivars except Fairy Tale (Table 5). Cultivars Fairy Tale and Rosa Bianca had >15% affected fruit in both years. Phomopsis fruit rot also was present on all cultivars in both fall experiments as reported previously (Keinath 2022).

Earliness of cultivars. All cultivars flowered later in 2019 than in 2018 (Fig. 4A). In both years, Millionaire and Patio Baby flowered earlier than the other five cultivars. In 2019 only, cultivars Gretel and Hansel flowered earlier than Black Beauty and Rosa Bianca (year-by-cultivar interaction, P = 0.013). In the fall, the number of days to flowering differed between years but not among cultivars. In 2018, when plants were ratooned later and cut shorter, they flowered a mean of 25.3 d after ratooning, whereas in 2019, when plants were ratooned earlier and left taller, they flowered 16.1 d after ratooning.

In the spring, 'Black Beauty' and 'Fairy Tale' produced ≥1 fruit ≥2.5 cm long sooner in 2018 than in 2019, but 'Millionaire' produced fruit sooner in 2019 than in 2018 (year-by-cultivar interaction, P < 0.001) (Fig. 4B). Cultivars Gretel, Hansel, and Patio Baby produced small fruit 50 d after transplanting in both years, the soonest for any cultivars. In both years, 'Black Beauty' and 'Rosa Bianca' took the longest time to produce small fruits, ≥ 63 d, significantly longer than all specialty types. Thus, these two cultivars had no marketable-sized fruits at the first two harvests, and Millionaire had no mature fruit at harvest one.

In the fall, the time to produce fruit ≥2.5 cm long was longer in 2018, a mean of 45.1 d, than in 2019, 33.2 d (P = 0.004). In both years, Black Beauty took longer to produce fruit than the other six cultivars. In Fall 2018, 'Black Beauty' and 'Rosa Bianca' had no mature fruit at harvest one. In Fall 2019, 'Black Beauty' had no mature fruit at harvests one and two.

The main difference in the environmental conditions between 2018 and 2019 was in the pattern of the precipitation (Supplemental Table 2). Spring 2018 was wetter than Spring 2019, and almost six times as much rain fell in Fall 2019 as in Fall 2018. Much of the increased rainfall in 2019 occurred in early September during Hurricane Dorian. Total yearly rainfall and the number of days on which rain fell, however, were similar between the two years.

Discussion

Seasonal and annual effects on the yield of eggplants of different fruit types are a significant source of variability and potential risk (Kahn 2013). Nevertheless, across seasons and years, cultivars Hansel (Chinese-type fruit), Millionaire (Japanese-type fruit), and Gretel (white fruit) generally had greater marketable and edible weights than Fairy Tale (Sicilian-type fruit) and Patio Baby (miniature Indian type fruit), whereas the two globe-fruited cultivars, Black Beauty (US heirloom) and Rosa Bianca (Italian heirloom), were intermediate (Fig. 2). Marketable weight of Black Beauty was more than twice the weight produced by this cultivar in a previous study in Oklahoma in which polyethylene mulch was not used, when yields were based on 10 harvests in that study and the current study (Kahn 2013).

Hansel and Millionaire, the two cultivars with the overall greatest net returns for US Fancy and No. 1 fruit (i.e., marketable fruit) had high yields and high prices relative to the other cultivars. Conversely, Black Beauty and Fairy Tale, the two cultivars with the lowest net returns in the spring and relatively low net returns in the fall, had low yields and low prices. Net returns for Gretel, a high-yielding cultivar in the spring due to a low percentage of culls, were reduced slightly by the lower price, particularly in the fall, when the price was about half of what it was in the spring. Net returns for cultivars Patio Baby and Rosa Bianca were positive and generally greater than net returns for Fairy Tale and Black Beauty because their prices were higher,

Table 5. Six cull classes of eggplant fruit with defects that rendered them not marketable as US Fancy or No. 1 as a percentage of the total number of fruit harvested.[i]

			Discolored		Calyx blight		Insect damage		
Cultivar	Scarring[ii]	Misshapen[ii]	2018	2019	2018	2019	2018	2019	Sunburn[iii]
Hansel	45.9 ab[iv]	16.3 ab	16.7 abcd	6.4 cdef	11.2 bcd	3.6 cd	6.1 cd	9.6 bcd	1.9 bc
Gretel	47.4 ab	17.8 a	0.7 f	1.1 ef	6.3 cd	10.8 bcd	20.9 bc	12.4 bcd	0.0 c
Millionaire	55.9 a	9.4 b	0.7 f	2.6 ef	11.2 bcd	1.9 d	3.4 de	7.7 bcd	0.0 c
Rosa Bianca	18.3 c	0.2 c	0.0 f	34.7 a	16.7 bcd	23.0 bc	22.6 ab	2.0 de	7.2 b
Black Beauty	30.4 abc	0.0 c	0.0 f	4.2 def	4.2 cd	59.0 a	6.4 cd	0.0 e	0.0 c
Patio Baby	24.8 bc	1.2 c	23.3 abc	29.0 ab	9.2 bcd	12.3 bcd	17.0 bc	3.1 de	29.2 a
Fairy Tale	9.3 c	0.3 c	19.6 abcd	12.0 bcde	17.6 bcd	33.2 ab	44.1 a	11.7 bcd	0.9 c

[i] Cull classes were used as defined by Kahn (2013). Numbers of fruit were summed over spring and fall seasons.
[ii] The year-by-cultivar interaction was not significant for scarred or misshapen fruit.
[iii] Sunburn data are for 2018, as this defect did not occur in 2019.
[iv] Cultivar means for each defect within both year columns followed by the same letter do not differ significantly, Fisher's protected least-significant difference test, P = 0.05. Year means within defects followed by the same letter do not differ significantly; Fisher's protected least-significant difference test, P = 0.05.

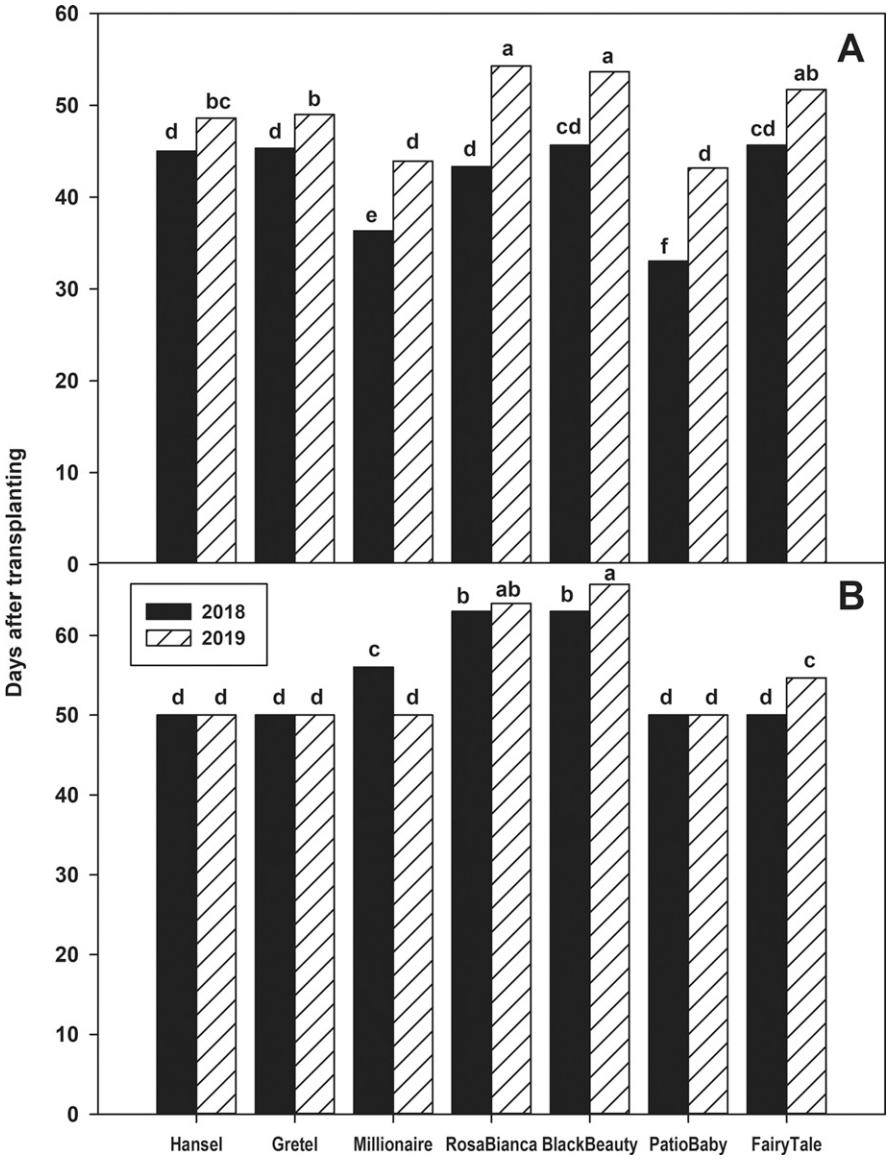

Fig. 4. Mean days to first flowers (**A**) and fruits >2.5 cm long (**B**) for seven cultivars of specialty eggplants in Spring 2018 and 2019.

even though yields generally were similar across these four cultivars (Fig. 1).

Based on consumer surveys along the US East Coast, there is a strong market demand among Asian consumers for locally produced Indian and Chinese eggplants (Govindasamy et al. 2010). In addition, all available prices for Chinese-type eggplant fruit were for fruit produced in Honduras. Because 'Hansel' is a Chinese-type fruit, there appears to be a market, at least at some locations, for domestically produced Chinese-type eggplants. Harvested weight, however, had a greater impact on net return than prices did, both for marketable quality fruit and edible quality fruit (US Fancy, No. 1 and No. 2 grades). Thus, growers may have a better likelihood of increasing net returns by choosing consistently productive cultivars than by choosing cultivars with higher mean prices. Planting specialty cultivars with small fruit, such as Hansel or Gretel, that mature early may be useful for growers who market eggplants locally at farmers markets, roadside stands, or through subscription services.

Considering scarred, misshapen, and discolored fruit to be edible and marketable locally significantly increased the yields of most cultivars in both seasons. Thus, finding markets for scarred, misshapen, and discolored fruit would increase crop value and net returns. For example, specialty eggplants observed at the Charleston Farmers Market (www.charlestonfarmersmarket.com/) in July 2019 included fruit that were scarred, misshapen, and slightly discolored, corresponding to the edible or US No. 2 category (Keinath A, personal observation). In an in-person preference survey in Ohio, consumers rated color and size more highly than shape as a reason for selecting different eggplant types and cultivars (Kleinhenz et al. 2003).

In North Carolina, an on-farm case study sampled marketable, edible but unmarketable, and inedible vegetables to estimate food loss on-farm. In the one globe eggplant field sampled, only 10% of the fruit were graded as marketable according to the US Standards for Grades of Eggplant (USDA, Agricultural Marketing Service 2013). Edible and inedible categories represented 53% and 37% of the fruit, respectively. The authors concluded that the easiest way to increase yields and decrease food waste was to harvest and market the edible fruit, which would increase the salable portion of the crop to 63% by weight. Similarly, in one of the few recent evaluations of hybrid eggplant cultivars, scarring on globe-type fruit was more common than discoloration, which was more prevalent than misshapen fruit (Kahn 2013).

Hybrid globe cultivars newer than Black Beauty are likely to produce net returns closer to the expected value due to greater fruit weights and percentages of marketable fruit. For example, the hybrid cultivars Santana, Classic, Dusky, and Megal had the highest fruit weights and marketable percentages of fruit in both years in Oklahoma, significantly greater than 'Black Beauty' in that study (Kahn 2013).

Although 'Fairy Tale' was a national winner in the All-America Selections edible category, it did not perform well in Charleston, SC, USA. The most common reasons for culling fruit were insect injury and diseased calyxes. Whether other cultivars with Sicilian or graffiti-type fruit are similarly susceptible to insects and Phomopsis blight is unknown. Applying more effective insecticides and applying fungicides to manage Phomopsis blight may be necessary to increase yields of 'Fairy Tale'.

In the fall, Phomopsis fruit rot affected >20% of the fruit of 'Black Beauty' (Keinath 2022). Phomopsis blight lesions on the calyxes also contributed to the high percentage of inedible fruit in 2019. Although open-pollinated Black Beauty was the most susceptible cultivar, hybrid globe-type cultivars are also susceptible. In Oklahoma, half of the cultivars evaluated had fruit rot percentages similar to those of 'Black Beauty' (Kahn 2013). Protecting fall crops from fruit rot with fungicides may increase yields and net returns.

Whether ratooning contributed to the lower total yields in the fall than in the spring could not be determined because fall crops were produced only on ratooned plants. Yields, however, were greater, and fruit were produced quicker in Fall 2019, when plants were ratooned earlier and left taller, than in Fall 2018. Whether the different ratooning practices or the dry weather in the weeks after Hurricane Dorian in Sep 2019 increased productivity could not be determined. If spring crops had not been ratooned, they could have been harvested longer. In a North Carolina greenhouse study, both trellis type and degree of pruning affected yields (Gu et al. 2019).

Growers can maximize net returns from specialty eggplant crops by choosing cultivars, such as Hansel and Millionaire, that consistently produce high fruit weights in spring and fall and across years with different rainfall patterns. Because the seven cultivars ranked in the same order based on mean

marketable weights and net returns, yields are a greater determinant of net returns than prices. Alternatively, local food hubs that offer higher prices than terminal markets may increase net returns, particularly if they accept scarred, misshapen, or slightly discolored fruit. To maximize yield and net returns in fall crops, additional research is necessary that directly compares the yields of fall-transplanted crops, ratooned spring crops, and non-ratooned spring crops to determine which production system produces the greatest yield.

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