Yields, Postharvest Storage, and Response to Pruning of Eggplant Cultivars Grown in High Tunnels in New Hampshire, USA

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Abstract. **We grew eight cultivars of eggplant (*Solanum melongena*) over 2 years in four experiments conducted in high tunnels located in Durham, NH; North Haverhill, NH; and Ossipee, NH, USA. The marketable yields of eggplant harvested over 14 to 15 weeks ranged from 925 to 3269 g per plant (2.5–8.8 kg·m^{-2}), depending on year and cultivar. Significant differences in marketable yield among cultivars were observed in three of the four experiments, but trends were not consistent. Parthenocarpic cultivars developed for greenhouse production, including Angela, Annina, Aretussa, Jaylo, and Michal, did not produce significantly greater yields than the cultivars developed for field production (Nadia, Traviata, and White Star). In two experiments, using a subset of cultivars, we explored the effects of training plants to four leaders compared with the standard practice of no pruning. Pruning treatment did not impact significantly the number or weight of marketable fruit, or the percentage of cull fruit, and there was no cultivar-by-pruning treatment interaction. In three separate experiments in Durham NH, USA, weight loss, browning, and softness were evaluated after 2 weeks of storage in one of three conditions: within the ideal range of temperatures (average of 50–64 °F), too warm (63–73 °F), and too cool (38–49 °F). Overall, responses to conditions that were warmer or cooler than ideal were as predicted, and weight loss, softness, and browning were all minimized when fruit were stored at 50 or 60 °F. We did, however, see some differences among cultivars in susceptibility to common postharvest storage problems. In conclusion, we found that cultivar choice can be important for high-tunnel eggplant producers, especially if postharvest storage conditions are not ideal. We also found that pruning and parthenocarpy did not enhance marketable yields, allowing growers to reduce labor and seed costs without impacting yield or fruit quality negatively.**

Many crops are commonly grown in high tunnels to extend the growing season and to protect crops from environmental stresses (Carey et al. 2009; Fitzgerald and Hutton 2012). Although tomato (*Solanum lycopersicum*) remains the most widely grown crop in high tunnels, recent surveys of high-tunnel producers in northern New England, USA, by us revealed that eggplant (*Solanum melongena*) was grown by ~11% of respondents in 2016, and the number increased to 28% in 2019 (Sideman et al. 2019).

In eggplant, adverse environmental conditions, including high or low temperatures and humidity, low light intensity, and rainfall, can impede reproduction and fruit set (Donzella et al. 2000; Makrogianni et al. 2018). In many parts of the world, eggplant fruit production has been enhanced by growing in protected environments such as unheated or heated tunnels or greenhouses and by applying plant growth regulators to promote fruit set (Caruso et al. 2017; Passam and Khah 1992). Although eggplant produces perfect flowers that can self-pollinate, the degree to which self-pollination takes place is highly variable, likely as a result of heterostyly (in which styles have different lengths relative to stamens, reducing self-fertilization) and a degree of self-incompatibility (Kowalska 2008). Parthenocarpic cultivars that set fruit without pollination are now widely cultivated in Europe; however, plant growth regulators are reportedly required to improve productivity in these cultivars (Donzella et al. 2000; Kikuchi et al. 2008). The degree to which these cultivars have been adopted in the United States is unknown.

In the northeastern United States, eggplant growers have commonly used the same cultivars for field and high-tunnel production. In 2016, regional seed suppliers began to offer and promote parthenocarpic eggplant cultivars that had been developed specifically for protected culture. The performance of these cultivars, especially in comparison with standard cultivars for field production, has not been described.

Although eggplant is grown in protected environments worldwide (Caruso et al. 2017; Gül et al. 2022), there is a paucity of published literature addressing eggplant production in protected environments in the United States. Aside from our study, we could only find two examples. Gu et al. (2019) evaluated four eggplant cultivars under two trellis systems in North Carolina, USA, and Shaik et al. (2023) compared yields of eggplant under high-tunnel and open field systems in Texas, USA.

Although typically not pruned in open-field culture, eggplant is often pruned when grown in protected culture. Caruso et al. (2017) noted that eggplant grown in tunnels and greenhouses in Poland are typically pruned to maintain three to four branches, and Buczkowska (2010) demonstrated positive effects of pruning to two to four branches on yield and earliness. At the same time, pruning to a single leader has been shown to reduce yields (Buczkowska 2010; Gu et al. 2019). Commercial production guidelines from our region state that eggplant grown in protected culture should be pruned to two to four stems and grown at a density of five to eight stems per square meter (Johnny's Selected Seeds 2016), but evidence to support this recommendation is not available in the published literature.

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Diversified farms in our region maintain a limited number of postharvest storage environments, and crops are frequently stored or held for sales in conditions that are not ideal. The ideal storage conditions for eggplant are 10 to 12 °C and 90% to 95% relative humidity (Siller-Cepeda 2016). Eggplant is generally susceptible to fruit softening and reduction in quality attributes when stored at warmer temperatures, and to chilling injury (CI) at temperatures less than 10 °C. Zaro et al. (2014) suggested that fruit harvested at the "baby" stage should be stored at temperatures as low as 0 °C because of their high susceptibility to dehydration at warmer temperatures, whereas Utami et al. (2018) found that Thai eggplant, which is also consumed at "baby" stages, was quite sensitive to CI at temperatures less than 10 °C. This suggests that cultivars may differ in susceptibility to postharvest quality stressors, and that some cultivars may be better able to withstand suboptimal storage conditions.

We report the results of a 2-year study conducted in three locations. Our primary objective was to compare yields of eggplant cultivars in high-tunnel production conditions. We evaluated new parthenocarpic cultivars as well as standard field cultivars, and had two additional objectives: 1) to determine whether pruning to four stems would enhance yields compared with no pruning and 2) to compare the quality of different cultivars in postharvest storage under different conditions.

Materials and methods

All cultivars evaluated were hybrids that produce oval to cylindrical fruit that are purple/black, white, or striped (Table 1). We selected five cultivars described by seed suppliers as adapted to greenhouse or protected culture, and three adapted to field culture. In 2019, one of the cultivars evaluated in 2018, White Star, was unavailable and was replaced with a newly available cultivar: Annina.

A total of four high-tunnel experiments were conducted in three New Hampshire, USA, sites in 2 years, as follows. In Durham in 2018, we compared the performance of seven cultivars and conducted a small pilot study to compare pruning systems. In 2019, in both Durham and in North Haverhill, we compared cultivar performance. In both Durham and Ossipee, we compared two pruning treatments for a subset of three cultivars in Durham and two cultivars in Ossipee. Last, in Durham, we conducted three separate experiments (one in 2018 and two in 2019) to evaluate the cultivars' postharvest storage characteristics. Site location, soil types, and details about the high-tunnel structures used are presented in Table 2. Cultural practices used at each site are described next.

Tunnel management. Tunnels at each site were equipped with manual rollup sides and automatic ventilation fans set to operate when interior temperatures exceeded 75 °F (Durham and Ossipee, NH, USA) or 70 °F (North Haverhill, NH, USA). In the spring and fall, the rollup sides were closed each night when temperatures were predicted to fall below 50 °F (Durham and Ossipee) or 60 °F (North Haverhill). When nighttime temperatures stayed consistently above 50 °F (Durham and Ossipee) or 60 °F (North Haverhill), the sides were raised permanently for the summer and were closed only briefly during storm events.

Bed preparation. In Durham, NH, USA, soil in the high tunnel was prepared by rototilling, fertilizing, and forming raised beds using a small tractor-mounted bed former with 36-inch black plastic mulch and a single line of drip tape (12-inch emitter spacing) placed slightly off center in each row. In North Haverhill, NH, USA, soil in the high tunnel was prepared by rototilling, fertilizing, and forming beds by hand with 36-inch black plastic mulch and a single line of drip tape (12-inch emitter spacing) placed slightly off center in each row. In Ossipee, NH, USA, soil in the high tunnel was prepared by broadfork and surface tillage with a collinear hoe, and fertilizing and forming raised beds by hand with a with a 36-inch bed size and a single line of drip tape (12-inch emitter spacing) place slightly off center in each row.

Transplant production. Plants were seeded on 12 Apr 2018 and 25 Mar 2019. Seeds were germinated in a climate-controlled greenhouse in peat-based medium (Pro-Mix BX; Premier Tech, Quakertown, PA, USA), and seedlings were transplanted into 36-cell trays at the cotyledon stage. Beginning 1 week after transplanting, plants were fertilized weekly at a rate of 300 ppm nitrogen (N) with 15N–2.2P–12.5K water-soluble fertilizer (Peters Professional 15–5–15 Cal–Mag; Everris International, Geldermalsen, The Netherlands). Plants were transplanted into the high tunnel on 1 Jun 2018 and on 20 May 2019 in Durham, NH, USA, on 14 Jun 2019 in North Haverhill, NH, USA, and on 25 Jun 2019 in Ossipee, NH, USA.

Plants were transplanted by hand into single rows to create a final spacing of 12 inches between plants and 48 inches between rows. The experimental design for all experiments was a randomized complete block design with four replications of eight cultivars, with six plants per experimental unit and two guard plants at both ends of each row.

Fertility. Preplant fertilizers were broadcast uniformly across the soil surface and incorporated into the soil before planting. At all three sites, nutrients were applied according to soil test recommendations from the University of New Hampshire Cooperative Extension. In both years in Durham, NH, USA, we applied 55 lb/acre N

Table 1. Eggplant cultivars grown in high-tunnel experiments in New Hampshire, USA, in 2018 and 2019.

Type	Cultivar	Fruit color	Source[i]	Estimated seed cost[ii]
Greenhouse	Angela	Striped	JSS	$1.43
Greenhouse	Annina	Striped	HMS	$0.54
Greenhouse	Aretussa	White	JSS	$0.27
Greenhouse	Jaylo	Purple	JSS	$1.14
Greenhouse	Michal	Purple	HMS	$0.23
Field	Nadia	Purple	JSS	$0.04
Field	Traviata	Purple	HMS	$0.31
Field	White Star	White	Harris	$0.18

[i] Harris = Harris Seeds (Rochester, NY, USA), HMS = High Mowing Seeds (Wolcott, VT, USA); JSS = Johnny's Selected Seeds (Albion, ME, USA).
[ii] Individual seed costs are estimated from a Feb 2024 search of commercial seed suppliers, assuming a purchase of 100 seeds.

Table 2. Experimental sites where eggplant was grown in high tunnels in New Hampshire, USA, in 2018 and 2019.

Site	Durham, NH, USA	North Haverhill, NH, USA	Ossipee, NH, USA
Locations	lat. 43°15′N, long. 70°93′W	lat. 44°04′N, long. 72°01′W	lat. 43°41′N, long. 71°8′W
Soil type[i]	Charlton fine sandy loam (coarse loamy, mixed, superactive, mesic Typic Dystrudepts)	Windsor loamy sand (mixed, mesic Typic Udipsamments)	Paxton fine sandy loam (coarse loamy, mixed, active, mesic Oxyaquic Dystrudepts)
Tunnel dimensions and manufacturer[ii]	30 × 60 ft, Ledgewood	22 × 72 ft, Rimol	26 × 84 ft, Ledgewood
Tunnel covering[iii]	One layer of 4-year, 6-mil IR plastic (K50-IR, Klerk's)	Two layers of 4-year, 6-mil clear IR plastic with anticondensate feature (Rimol)	One layer of 4-year, 6-mil IR plastic (K50-IR, Klerk's)

[i] Source: US Department of Agriculture, Soil Survey Staff, Natural Resources conservation Service (2016).
[ii] Tunnel manufacturers: Ledgewood = Ledgewood Farm Greenhouses (Moultonborough, NH, USA); Rimol = Rimol Greenhouse Systems LLC (Hooksett, NH, USA). 1 ft = 0.3048 m.
[iii] Plastics were obtained from Klerk's (Klerk's Plastic Products Manufacturing, Richburg, SC, USA) or Rimol. IR = infrared retaining. 1 mil = 0.0254 mm.

and 120 lb/acre potassium (K) using soybean meal (7N–0.9P–1.7K; Blue Seal, Muscatine, IA, USA) and potassium sulfate (0N–0P–42.3K; North Country Organics, Bradford, VT, USA). In North Haverhill, NH, USA, we applied 55 lb/acre N and 120 lb/acre K using Naturesafe nitrogen fertilizer (13N–0P–0K; Darling Ingredients Inc, Irving, TX, USA) and potassium sulfate (0N–0P–42.3K; North Country Organics). In Ossipee, NH, USA, we applied 50 lb/acre N, 13 lb/acre phosphorus and 83 lb/acre K using Pro-Gro organic fertilizer (5N–1.3P–3.3K; North Country Organics) and sulfate of potash magnesia (0N–0P–18.3K; North Country Organics).

Irrigation. In Durham and in North Haverhill, NH, USA, soil moisture was monitored with two tensiometers installed 2 to 4 inches from the drip line, in the center of the plant row. Plants were irrigated when the soil water tension at a depth of 6 inches exceeded 15 to 20 kPa. This generally resulted in irrigation for 2 to 3 h two to three times per week throughout the growing season. In Ossipee, NH, USA, plants were irrigated once per day for 45 min.

Pruning. In 2019, we established experiments to compare the performance of unpruned plants with those trained to four leaders. Unpruned plants were supported by twine that ran along each row, parallel to the ground, on either side of each plot, and that looped around vertical poles placed between each plot (e.g., every six plants). Approximately five layers of twine were added throughout the growing season, ∼6 to 8 inches apart. Plants in the four-leader system were pruned using clippers to maintain four main stems, or leaders. Each leader was supported with a single twine tied to one of two supports spaced 2 ft apart, centered over the row. As axillary shoots (suckers) developed from each main stem, each sucker was ended just above the first flower.

Pests and diseases. Plants were scouted weekly for pests and diseases. In Durham, NH, USA, pyrethrins and neem (Azera; MGK, Minneapolis, MN, USA) was applied on 27 Jun 2018 to control aphids (Aphididae), and acequinocyl (Shuttle-O; OHP Inc., Bluffton, SC, USA) was applied once on 10 Aug to control spider mites (Tetranychidae). In 2019, Shuttle-O was applied once on 16 Aug to control spider mites. No pest control products were applied in North Haverhill or Ossipee, NH, USA. In Durham, a very small number of plants in each year showed symptoms of Verticillium wilt (*Verticillium dahliae*), which was confirmed by our plant diagnostic laboratory. Those plants were removed, and plot counts and yields were adjusted accordingly.

Harvest. All fruit that had reached marketable size based on the cultivar description were harvested weekly until plants were killed by frost. Fruit were counted, weighed, and sorted into marketable and unmarketable (scarred or misshapen).

Postharvest storage. It is common for diversified direct-market operations to lack controlled-temperature storage at the ideal conditions for all crops they grow, and it is also typical for them to hold some crops for a week or more before sale. In three separate experiments (one in 2018, two in 2019) we held eggplant for 2 weeks under different storage conditions typical of diversified farms in the region to determine whether cultivars differ in susceptibility to postharvest problems due to improper storage. The three storage conditions used in each experiment are described in detail in Table 3. They were 1) refrigerated storage, which is cool enough to cause CI; 2) the packhouse, which is warmer and drier than optimum during the summer months; and 3) a cooler maintained at the appropriate temperature for warm-season vegetables such as tomato and eggplant. In 2018, the cooler was held at a temperature of just above 60 °F, but in 2019, we lowered this to the recommended 50 to 54 °F. Storage conditions were monitored using HOBO temperature and relative humidity loggers (HOBO H21 Micro Station Data Logger; Onset Computer Corp., Bourne, MA, USA), and detailed temperature conditions in each treatment are presented in Table 3.

During each postharvest experiment, one fruit per cultivar was placed in each of eight boxes subjected to each storage treatment, and boxes were treated as replicates. During storage, individual fruit were weighed and rated for browning and softness weekly, and the weight loss percentage was calculated for each fruit. Softness was rated on a scale of 1 to 5, where 1 = flesh firm and does not compress in response to finger pressure, and 5 = flesh very soft and compresses more than 1 cm in response to finger pressure. Browning was rated on a scale of 0 to 5, where 0 = no browning and 5 = browning and pitting evident over the entire fruit surface.

Table 3. Postharvest storage conditions in postharvest experiments conducted in 2018 (Expt. 18.1) and 2019 (Expts. 19.1 and 19.2).

Storage location and Expt. No.	Temperature (°F), avg ± *SD*[i]			Relative humidity (%), avg ± *SD*
	Minimum	Maximum	Avg ± *SD*	
Packhouse, Expt. 18.2	63.3	79.4	73.1 ± 2.3	76.1 ± 6.6
Packhouse, Expt. 19.1	63.1	78.9	70.6 ± 2.2	76.8 ± 7.1
Packhouse, Expt. 19.2	66.8	76.1	71.3 ± 1.9	67.6 ± 8.8
Cooler at 60 °F, Expt. 18.2	60.0	64.3	62.5 ± 0.9	90.1 ± 3.5
Cooler at 50 °F, Expts. 19.1 and 19.2	49.9	56.8	51.6 ± 1.0	93.5 ± 3.9
Refrigerator	38.3	49.5	42.5 ± 2.1	94.6 ± 5.1

[i] °C = (°F − 32) ÷ 1.8. *SD* = standard deviation.

Data analysis. The effects of treatments on all dependent variables were analyzed by analysis of variance (ANOVA) using statistical software (JMP Pro 15; SAS Institute Inc., Cary, NC, USA). In overall ANOVAs, significant interactions were detected for some variables in some of the postharvest experiments. In these cases, data were analyzed and are presented separately according to experiment or treatment. Percentage data (e.g., frequency of unmarketable fruit) were arcsine-transformed before performing ANOVA, but back-transformed means are presented. When the overall F test was significant ($P \leq 0.05$), differences between treatments were evaluated using Tukey's honestly significant difference tests at the $P \leq 0.05$ level or, when only two comparisons were being made, using a *t* test at the $P \leq 0.05$ level. To make comparisons between greenhouse and field cultivars, marketable yield data were analyzed using the general linear models procedure using orthogonal contrasts.

Results

Production. Harvest began on 6 Jul 2018 and 3 Jul 2019, 35 and 44 d after transplanting, respectively. Although marketable yields (measured in grams per plant) differed significantly between cultivars in Durham, NH, USA, in 2018 and in North Haverhill, NH, USA, in 2019, the trends were not consistent (Table 4). In 2018 in Durham, the cultivars Angela and Nadia produced significantly greater yields than White Star. In 2019, the cultivars Traviata and Annina produced significantly greater yields than Angela in North Haverhill, but there were no significant differences in yields in Durham. Contrasts comparing greenhouse cultivars with field cultivars in each year revealed no significant differences in Durham ($P = 0.943$ and $P = 0.104$ for 2018 and 2019, respectively), but did show a significant difference in North Haverhill ($P < 0.001$), with field cultivars producing a greater yield than greenhouse cultivars.

The number of fruit produced per plant varied significantly among cultivars in both sites in 2019. 'Traviata' produced the most fruit (significantly more than several cultivars) in North Haverhill, NH, USA, and 'Aretussa' produced the most fruit (significantly more than several cultivars) in Durham, NH, USA.

The percentage of cull fruit varied significantly among cultivars in Durham, NH, USA, in both years, but not in North Haverhill, NH, USA, where it was consistently low (2.3%–3.5%). In Durham in 2018, the white cultivar White Star produced the highest percentage of cull fruit (30.7%), which was significantly greater than all other cultivars. This cultivar was included only this year because it had several plants that produced off-type fruit, and it was replaced with 'Annina' in subsequent experiments. In Durham in 2019, the other white cultivar, Aretussa, produced the highest percentage of cull fruit (5.8%). In all experiments, the most common reason fruit were considered unmarketable was visible scarring, followed by misshapen fruit.

To evaluate seasonal production patterns, cumulative yields over 2-week time intervals were calculated. In both years, 'Traviata' produced the greatest and 'Nadia' produced the lowest yields in the first 2-week harvest period, but there were only minor differences in subsequent harvests (Fig. 1). Also in both years, fruit production peaked three times—in late July, late August, and late September—

Table 4. Yield (number and weight of marketable fruit per plant) and percent cull fruit of eggplant cultivars grown in high tunnels in Durham, NH, USA, in 2018 and 2019, and in North Haverhill, NH, USA in 2019.

Cultivar	Durham, 2018			Durham, 2019			North Haverhill, 2019		
	Fruit (no./plant)	Yield (g/plant)[i]	Cull (%)	Fruit (no./plant)	Yield (g/plant)	Cull (%)	Fruit (no./plant)	Yield (g/plant)	Cull (%)
Angela	11.0	2763 a[ii]	6.1 b	11.1 b	2975	0.3 ab	5.5 b	1363 c	3.1
Annina	—	—	—	11.7 ab	3012	0.0 b	7.8 ab	2127 ab	1.2
Aretussa	9.8	2121 ab	14.1 b	16.1 a	2986	5.8 a	6.0 ab	1350 bc	2.2
Jaylo	8.7	2256 ab	12.7 b	9.4 b	2542	5.5 ab	5.5 b	1529 bc	3.5
Michal	8.1	2335 ab	15.6 b	9.5 b	2960	0.2 ab	5.9 b	1629 bc	2.0
Nadia	9.4	2865 a	8.9 b	10.6 b	3229	4.0 ab	8.6 a	2570 a	2.8
Traviata	9.3	2618 ab	12.0 b	11.3 b	3269	2.8 ab	7.6 ab	2000 a–c	2.0
White Star	8.9	1582 b	30.7 a	—	—	—	—	—	—
P value	0.401	0.027	<0.001	0.002	0.445	0.009	0.004	<0.001	0.808

[i] 1 g = 0.0353 oz.
[ii] Within a column, means followed by the same letter are not significantly different by Tukey's HSD test ($P \leq 0.05$).

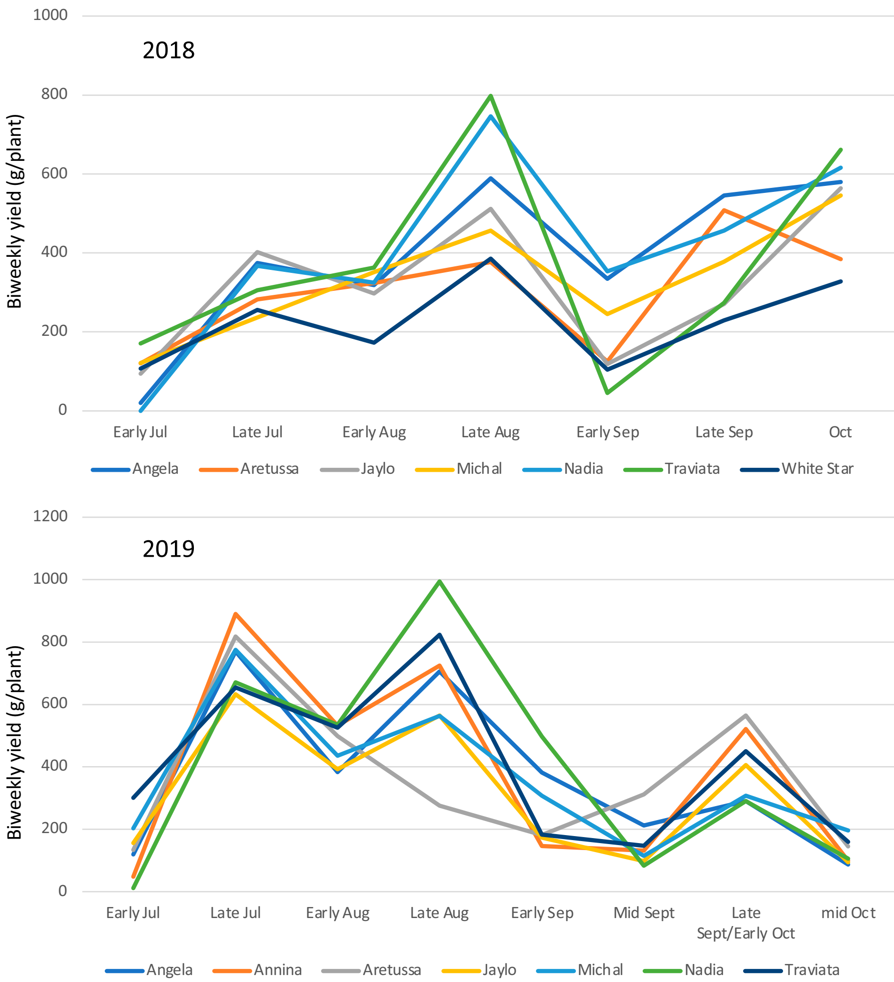

Fig. 1. Seasonal production patterns of high-tunnel eggplant in Durham, NH, USA, in 2018 and 2019. Cumulative yields (measured in grams per plant) over 2-week time intervals are shown throughout each harvest season. 1 g = 0.0353 oz.

with dips in production between each peak.

Pruning. For three purple cultivars (Michal, Nadia, Traviata) in Durham, NH, USA, and two cultivars (Nadia, Traviata) in Ossipee, NH, USA, we explored the effects of training plants to four leaders compared with the standard practice of no pruning (Table 5). Although we observed significant differences among cultivars in some cases, the pruning treatment did not have significant effects on number or weight of marketable fruit, or the percentage of cull fruit. Furthermore, there was no cultivar-by-pruning treatment interaction.

Postharvest. In three separate experiments in Durham, NH, USA, weight loss, browning, and softness were evaluated after 2 weeks of storage at one of three storage conditions: packhouse (mean temperature, 70.6–73.1 °F, depending on the experiment), refrigerator (mean temperature, 42.5 °F), and cooler (mean temperature, 62.5 °F in 2018 and 51.6 °F in 2019). Storage conditions affected weight loss, browning, and softness in all experiments; cultivar affected all variables in all but one experiment (Table 6). Interactions plots are presented in Fig. 2 for experiments and variables that had significant interactions.

Weight loss of eggplant fruit was greatest in warmest and least under coolest conditions. Significant interactions were observed in Expt. 19.1 (Fig. 2). 'Michal' lost the most weight in all three experiments, although not significantly more than some other cultivars, including Aretussa. In all three experiments, Angela lost significantly less weight than 'Michal'.

Softness corresponded well with weight loss, and was also greatest in warmest and least in coolest storage conditions. Significant differences among cultivars were observed only in Expt. 18.2, where Angela was significantly less soft than several other cultivars (Fig. 2).

Table 5. Effects of pruning plants to four leaders on marketable yield and fruit number for three cultivars of eggplant in Durham, NH, USA, and in Ossipee, NH, USA, in 2019.

	Durham 2019			Ossipee 2019		
Variable	Fruit (no./plant)	Yield (g/plant)[i]	Cull (%)	Fruit (no./plant)	Yield (g/plant)	Cull (%)
Cultivar						
Michal	10.0 ab[ii]	3000	1.2			
Nadia	9.0 b	2792	2.9	4.5 a	2959 a	0.3
Traviata	11.0 a	3183	2.6	2.6 b	925 b	1.9
Pruning treatment						
Four-leader	9.7	2881	2.1	3.4	1471	1.1
None	10.3	3101	2.4	3.7	1413	1.1
ANOVA *P* value[iii]						
Cultivar	0.047	0.272	0.371	0.034	0.013	0.293
Treatment	0.328	0.263	0.782	0.702	0.875	0.995
Cultivar × treatment	0.114	0.121	0.312	0.984	0.719	0.627

[i] 1 g = 0.0353 oz.
[ii] Within a variable, means followed by the same letter are not significantly different by Tukey's HSD test ($P \leq 0.05$).
[iii] ANOVA = analysis of variance.

Table 6. Weight loss, browning, and softness of eggplant after 2 weeks of storage postharvest as affected by cultivar and storage conditions.

Storage condition and cultivar	Expt. 19.1[i]			Expt. 19.2			Expt. 18.1		
	Wt loss (%)[ii]	Browning (0–5 scale)[iii]	Softness (1–5 scale)[iv]	Wt loss (%)	Browning (0–5 scale)	Softness (1–5 scale)	Wt loss (%)	Browning (0–5 scale)	Softness (1–5 scale)
Storage									
Packhouse	12.8	0.1	3.99 a[v]	18.5 a	0.0	3.14 a	12.6 a	0.4	3.3
Cooler, 50 °F	6.5	0.2	1.99 b	7.9 b	0.1	1.92 b	NI	NI	NI
Cooler, 60 °F	NI[vi]	NI	NI	NI	NI	NI	9.4 b	0.0	2.3
Refrigerator	4.3	1.6	1.32 c	6.4 b	2.6	1.28 c	4.1 c	1.9	1.8
P value[vii]	—	—	0.351	0.026	—	0.023	0.001	—	—
Cultivar									
Annina	7.3	0.4	2.6	6.5 ab	0.7	1.9 a	NI	NI	NI
Angela	7.2	1.0	2.5	6.0 b	0.2	1.6 a	7.2 b	0.3	1.6
Aretussa	8.0	1.3	2.3	6.8 ab	0.8	2.0 a	9.5 a	1.2	2.9
Jaylo	8.7	0.4	2.6	6.0 b	0.1	1.7 a	8.2 ab	0.0	2.3
Michal	8.7	0.5	2.5	8.2 a	0.4	1.9 a	10.5 a	1.0	2.7
Nadia	8.1	0.5	2.3	6.7 ab	0.5	1.8 a	8.4 ab	0.8	2.8
Traviata	6.9	0.3	2.3	6.4 ab	0.1	1.6 a	8.5 ab	0.3	2.3
White Star	NI[vi]	NI	NI	NI	NI	NI	8.6 ab	1.0	2.5
P value	—	—	0.351	0.026		0.023	0.009	—	—
Cultivar × Storage									
P value	0.008	<0.001	0.470	0.548	<0.001	0.121	0.572	<0.001	0.02

[i] Expts. 19.1, 19.2, and 18.1 are described in Table 3.
[ii] Weight loss corresponds to the percentage of weight lost during a 2-week period.
[iii] Browning was rated on a scale of 0 to 5, where 0 = no browning and 5 = browning and pitting evident over the entire fruit surface.
[iv] Softness was rated on a scale of 1 to 5, where 1 = flesh is firm and does not compress in response to finger pressure, and 5 = flesh is very soft and compresses more than 1 cm in response to finger pressure.
[v] Within a variable, means followed by the same letter are not significantly different by Tukey's HSD test ($P \leq 0.05$).
[vi] NI = treatment not included in this experiment.
[vii] When a cultivar × storage interaction was significant, main/simple effects are not shown.

Browning was negligible except in chilling conditions (refrigerator), when cultivar differences became apparent. The cultivars Angela and Aretussa (in Expt. 19.1); Annina, Aretussa, and Nadia (Expt. 19.2); and Aretussa, Michal, Nadia, and White Star (Expt. 18.2) were more susceptible to browning than other cultivars. We did observe some inconsistency. For example, 'Annina' showed less browning than 'Angela' under refrigerator conditions in Expt. 19.1, but the opposite was seen in Expt. 19.2. Despite this, the cultivars Jaylo and Traviata were among the least susceptible to browning in all experiments.

Discussion

In the northeastern United States, unheated or minimally heated high tunnels are widely used for season extension in the spring for warm-season crops such as tomato, bell pepper (*Capsicum annuum*), and eggplant. In our study, we measured marketable yields of eggplant in high tunnels, which ranged from 925 to 3269 g per plant (2.5–8.8 $kg\cdot m^{-2}$) over 14 to 15 weeks, depending on year and cultivar. To the best of our knowledge, these are the first data from a multiyear experiment to document eggplant cultivar performance in high tunnels in our region.

Our yields were roughly comparable to those reported from unheated tunnel production of grafted eggplant in southern France (Mazollier and Sassi 2018; Mazollier et al. 2017). In those studies, fruit were harvested for a period of 16 weeks and produced 2.3 to 7.5 $kg\cdot m^{-2}$ in 2017 and between 9.2 and 11.2 $kg\cdot m^{-2}$ in 2018. In Romania, Stoleru et al. (2016) measured yields of 12.7 to 16.4 $kg\cdot m^{-2}$ in "wooden tunnels," although the length of the harvest season was not clear. A Polish study conducted in a controlled greenhouse environment (Ambroszczyk et al. 2008) documented similar yields of 9.9 to 11.3 $kg\cdot m^{-2}$, and an Australian study of high-technology glasshouse production described yields ranging from 19.7 to 29.5 $kg\cdot m^{-2}$ harvested over a 6-month period, confirming that greater eggplant yields may be possible with good environmental control. In contrast, open-field production of eggplant in New England, USA, from 2017 to 2021 produced yields ranging from just 0.73 to 1.25 $kg\cdot m^{-2}$ (US Department of Agriculture, National Agricultural Statistics Service 2022). This suggests that producers may gain yield advantages from the increased environmental control over field production.

Cultivars marketed specifically for greenhouse conditions did not outyield field cultivars under summer high-tunnel production conditions in New Hampshire, USA. In fact, one of the traditional field cultivars, Nadia, was among the greatest yielding cultivar in three of four experiments. During the production season, the high-tunnel sides are frequently open to maximize ventilation, and insects are not prevented from entering the tunnel. Although reduced visitation by pollinators has been demonstrated in high tunnels (Hall et al. 2020), that study and others have documented visits by diverse pollinators on crops in high tunnels (Nobes et al. 2022). Thus, we suspect that parthenocarpy is less important than it would be in closed greenhouse environments, where pollinator access would be eliminated. Notably, seed costs vary widely among cultivars (see Table 1), and our results show that the most expensive seeds did not produce the greatest yields of marketable fruit.

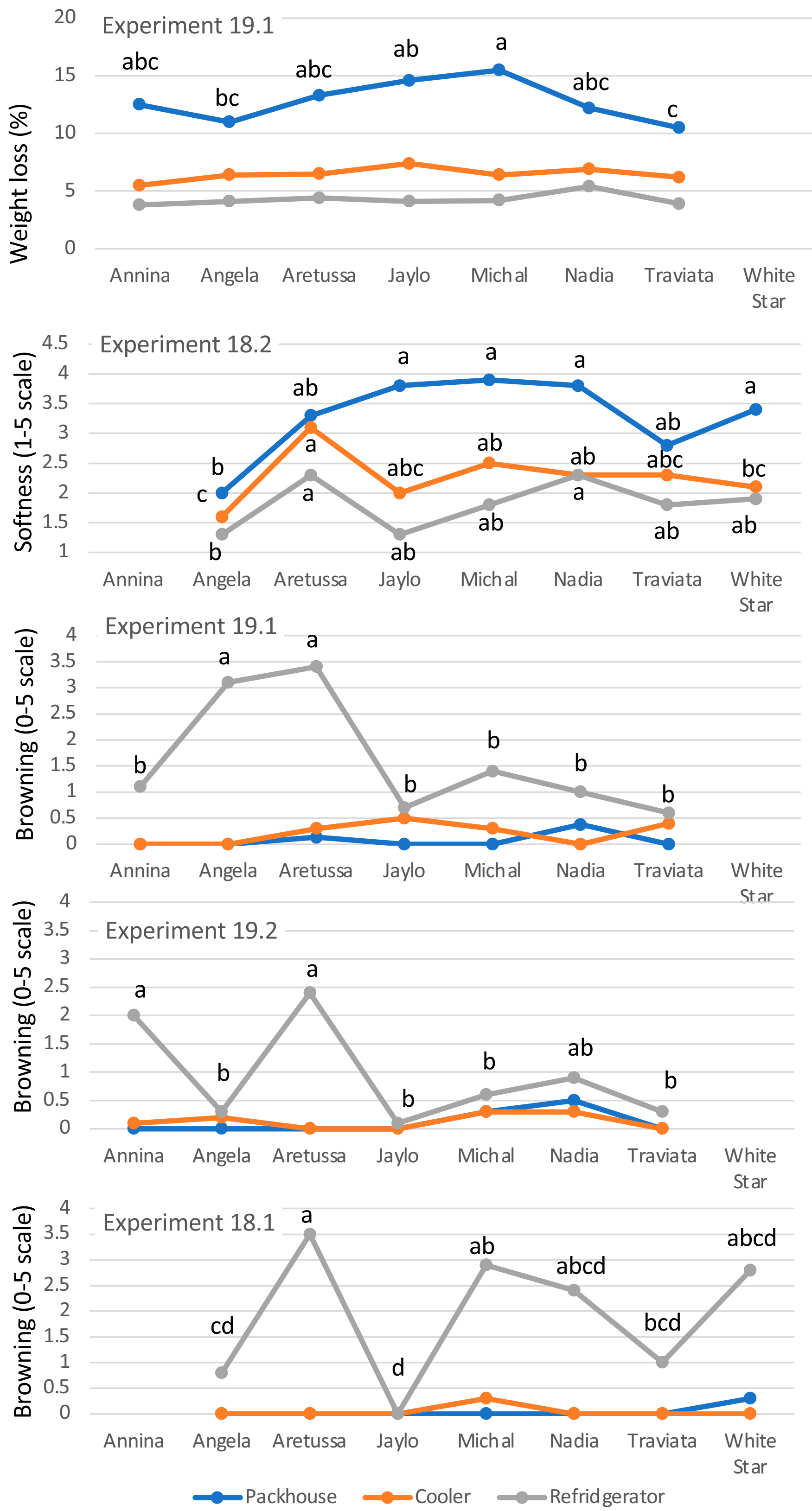

Fig. 2. Interactions between eggplant cultivar and postharvest storage treatment. Interactions are presented only for experiments and response variables for which interactions were statistically significant ($P < 0.05$). Weight loss corresponds to the percentage of weight lost during a 2-week period. Softness was rated on a scale of 1 to 5, where 1 = flesh is very firm and 5 = flesh is very soft. Browning was rated on a scale of 0 to 5, where 0 = no browning and 5 = browning and pitting evident over the entire fruit surface. Experimental conditions for each experiment number are as described in Table 3.

Passam and Karapanos (2008) state that eggplant susceptibility to chilling varies with cultivar, maturity of fruit at harvest, and preharvest growth conditions, but little information about cultivar-specific differences in response to storage is available. For several cultivars, we observed responses to postharvest storage in conditions that were too warm, too cool, and close to ideal. Overall, responses to conditions that were warmer or cooler than ideal were as predicted, and weight loss, softness, and browning were all minimized when fruit were stored at 50 or 60 °F. We did, however, see some differences among cultivars in susceptibility to common postharvest storage problems. In particular, the white cultivar Aretussa showed more browning under chilling conditions than most cultivars, whereas the purple cultivars Jaylo and Traviata showed less. Similarly, the purple cultivar Michal showed more weight loss and softening under too-warm conditions (average temperature, ~70 °F in our conditions), and the striped cultivar Angela showed less. This suggests that producers may be able to select cultivars that are more resilient to the suboptimal storage conditions they may experience.

Although in a pilot study we found that pruning to four leaders increased marketable fruit yields compared with no pruning (data not shown), this result was not confirmed in our replicated study. This is inconsistent with greenhouse eggplant production guidelines and other published work that has shown yield benefits from pruning to two, three, or four stems (Buczkowska 2010). However, these benefits have been small in some cases and inconsistent in others. For example, Mazollier et al. (2017) found that pruning to a goblet shape (removing interior branches) and trimming secondary flowers increased yields compared with unpruned control plants in one year, whereas in a different year, pruning did not increase yields (Mazollier and Sassi 2018). It is possible that the benefits of pruning become greater with longer harvest seasons, and therefore pruning may be more important in better controlled environments. Additional work is needed to determine the optimum system for training and pruning eggplant in high tunnels in the northeastern United States, but at this point we do not have evidence to suggest that the benefits of pruning outweigh the additional labor it requires.

Conclusion

All but one of the eggplant cultivars evaluated produced good yields of high-quality fruit in a high tunnel in New Hampshire, USA, when unpruned. The cultivar White Star was dropped from the study because of poor performance in the first year, and as a result, we cannot recommend that cultivar. Our results suggest that it is not necessary or beneficial to select greenhouse cultivars of eggplant for growing in summer, ventilated high-tunnel conditions in our region, because two of the field cultivars we evaluated (Nadia and Traviata) were among the best performers. In addition, the results of our study may help producers choose cultivars that meet market demands while minimizing susceptibility to postharvest browning in chilling conditions or postharvest weight loss in excessively warm conditions.

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