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High Tunnel Colored Pepper Production

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Abstract
Bell pepper varieties developed for unique fruit color characteristics were evaluated as part of the high tunnel project. Previous evaluation of six colored pepper varieties at the Armstrong Research Farm, Lewis, IA and the Horticulture Research Station, Ames, IA in 2007 indicated only Tequila (green to purple) developed full color for commercial production. The major problem seems to be the high daytime temperatures in the tunnel as well as outdoor field production, which produced a high level of rots. Generally, bell peppers take 45 to 55 days from pollination to green market maturity and an additional 15 days to the red stage (70 days total).

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Introduction

Bell pepper varieties developed for unique fruit color characteristics were evaluated as part of the high tunnel project. Previous evaluation of six colored pepper varieties at the Armstrong Research Farm, Lewis, IA and the Horticulture Research Station, Ames, IA in 2007 indicated only Tequila (green to purple) developed full color for commercial production. The major problem seems to be the high daytime temperatures in the tunnel as well as outdoor field production, which produced a high level of rots. Generally, bell peppers take 45 to 55 days from pollination to green market maturity and an additional 15 days to the red stage (70 days total).

The objective of this trial was to identify colored, blocky, sweet bell pepper varieties with good production and fruit quality characteristics suitable for Iowa's variable and often stressful growing season. A combination of high tunnel and field production planting dates were chosen, as well as a double cropping scheme, to maintain a continuous growing season supply. High tunnel production may reduce the maturity time to full color development compared with field production.

Materials and Methods

The project was established at the Armstrong Research Farm (southwest Iowa in a well-drained silt loam soil) and the Horticulture Research Station (central Iowa in a well-drained loam soil). The previous crop at both Armstrong and the Horticulture Station in the high tunnel was peppers. Previous crop at the outdoor site on the Armstrong farm was cucurbits and at the Horticulture Station winter squash. Both sites were fertilized according to soil test recommendations. The cultural system consisted of SRM-olive plastic mulch (wavelength selective) and trickle irrigation. Transplants of six varieties (Table 1) were set in twin rows, 16 in. apart and in-row spacing of 12 in. on a single plastic row bed. Rows were 4.5-ft on center for high tunnel production and 6-ft on center for field production. Irrigation scheduling was via tensiometers. Pest management practices for field production included necessary herbicide, insecticide, and fungicide applications for top production. A major outbreak of aphids occurred at the Horticulture Station, and to a lesser extent at the Armstrong Farm, in both the high tunnel and outdoor field planting. Insecticidal soap was used to keep the population at low levels at Armstrong, but Orthene 75S was necessary to reduce the population at the Horticulture Station. There were three replications of each variety at each site in the high tunnel and the outdoor May and August field plantings.

Transplant dates were: Armstrong high tunnel on April 16 and August 1, and field transplant dates of May 20 and August 1; Horticulture high tunnel on April 17 and August 5; and field transplant dates of May 13 and August 7. For high tunnel production, the April plants were removed and August transplants set in the same planting hole.

Yield data consisted of harvesting every 10 to 14 days with the first harvest of Tequila from the high tunnel on July 2 at both Armstrong and the Horticulture Station. Corresponding field harvest dates for the May plantings were September 2 and July 18 for Armstrong Farm and the Horticulture Station, respectively. Fruit were sorted into marketable and cull (rots, poor fruit color, severely misshapen,

small), fruit size, and fruit length-to-width ratio was determined for marketable fruit.

Results and Discussion

April high tunnel planting. Noticeable differences between the two production sites occurred in yield and fruit characteristics (Table 2). Tequila produced colored fruit the earliest at both locations, about 75 days from transplanting, but marketable yield was greatly reduced at the Armstrong location. This yield reduction effect was similar with the other five varieties with no marketable fruit produced at Armstrong for the July harvests. This was probably the result of frost events in late April (Figure 1). Plants were not killed, but loss of leaf growth, stem damage, and root disease set growth back. The difference between Armstrong and the Horticulture Station was that even though the latter site was colder the pepper transplants were covered with spunbonded row cover (see April 26 date). Also, there was a herbicide drift from neighboring field crops at the Armstrong location in late June that affected plant growth and development. Thus, fruit production was delayed by 5 to 10 days compared with the Horticulture Station. Of the three red varieties we would have expected Red Knight to mature first or about 78 days from transplanting, followed by Aristotle and Paladin at 87 days. Red Knight was the latest (96 days) and Aristotle and Paladin were near expected maturity date (81 days). The growing season was very wet early and cool throughout compared with the long-term average.

The varieties at the Horticulture Station varied in yield and fruit characteristics. Ignoring Tequila (no market available), Aristotle and Paladin produced more than 3 times more marketable fruit than Red Knight, Early Sunsation, and Orange Grande mostly because of their low cullage. Red Knight and Early Sunsation had an undesirable, flattened, squatty shape (Table 2). Because of poor plant growth and development at Armstrong no marketable colored fruit were produced in the high tunnel.

For the final harvest, all marketable fruit (all green, no colored) was harvested from the tunnels the end of July so a second planting could be made for a fall crop. The marketable yield is expressed as boxes/tunnel, rather than fruit, because green mature fruit is commonly sold by the box (Table 3). The Armstrong location continued to suffer from reduced yield compared with the Horticulture Station. The exception was Paladin, which was similar at both locations; however, the Horticulture Station had high cullage on the last harvest, approximately one third of the total harvest. Fruit size was similar for all varieties, except Tequila, which was the smallest. But at Armstrong the green fruit of the three red varieties was larger than the yellow or orange types. Overall, an April planting of colored bell peppers should include Aristotle and Paladin red varieties. And, a grower should be prepared to provide protection from frost and eliminate herbicide drift into the high tunnel where it will concentrate.

If a market price of $1.00 per colored fruit could be achieved, then approximately $2,200 would result from colored fruit production and an additional 57 boxes/tunnel of green fruit at $14/box would provide an additional $784 resulting in $2,984 from high tunnel production by August 1.

August high tunnel planting. The double crop planting was made to determine if the cooler autumn daytime temperatures would improve marketable fruit color. No colored fruit developed at either location by Oct. 27 when nighttime freezing temperatures occurred terminating the study. Thus, all mature green fruit were harvested at both locations. Because only one harvest was made (October 27), yields were relatively low (approximately 40

boxes of green fruit per tunnel for each location and detailed data is not presented).

May field planting. The first field planting occurred May 13 (Horticulture Station) and May 20 (Armstrong). As with April high tunnel planting colored fruit production was delayed by 27 to 40 days at Armstrong, compared with the Horticulture Station (Table 4). The exception was Aristotle, which had only a 6-day difference. Also, Armstrong production was much less for all varieties with the exception of Tequila. The major problem was herbicide drift aborting the initial flower set. It is interesting to note that Paladin was low yielding at both locations, compared with the other large fruited varieties; whereas, in the high tunnels it was one of the highest. Although the Horticulture Station had very high field cullage, approximately 70% (mostly rots) compared with Armstrong, the location still had considerably more marketable fruit than Armstrong, with the exception of Tequila. Fruit size was smallest for Tequila, but the other varieties were similar averaging 9.1 oz. at Armstrong and 6.0 oz. at the Horticulture Station (Table 5). Fruit shape tended to be elongated, except for Red Knight. For the Horticulture Station, a mid-May planting produced colored red peppers by August 19, and for the April high tunnel planting, harvest commenced July 6, or 6 weeks earlier. Production of colored fruit with Aristotle was similar to the April planting in the high tunnel, but all other varieties exceeded high tunnel yields because of the longer harvest period, 20 days.

August field plantings. The first of August plantings did not mature to colored fruit at either location. There was heavy flowering at the Horticulture Station on September 10 but cold night temperature aborted fruit development. August and September temperatures were 1.8°F and 0.2°F below normal, respectively.

For more detailed information that includes the second plantings as well as variety photos plus Muscatine Island field station two year pepper variety results go to: http://www.public.iastate.edu/~taber/Extension/Progress%20Rpt%2008/High%20Tunnel%20Colored%20Pepper08.pdf

After two years of study on colored pepper production, some key points:

- Some varieties perform differently under high tunnels compared with field production.
- Select the variety carefully – time to maturity varies greatly under changing weather conditions, fruit shape is not consistent, and shelf life can be short to none.
- Spring high tunnel plantings will advance maturity by almost 6 weeks, compared with traditional field planting date; but yields will not necessarily be greater.
- High tunnel and field plantings cannot be successfully double-cropped. Consider using a greenhouse pepper in the high tunnel environment.

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Table 1. Bell pepper variety characteristics.

Variety	Days to maturity	Disease resistance[1]	Fruit color	Comments
Aristotle	72	BLS 123, PVY,TMV	Red	Smooth shape, blocky, good green or red color
Paladin	72	Phyt, TMV	Red	Elongated, very large fruit, colored production
Red Knight	63	BLS 123, PVY	Red	Blocky, variable yield, good red production
Early Sunsation	72	BLS 123, PVY, TMV	Yellow	Blocky, dark green, sweet when mature yellow, heat setting ability
Orange Grande	76	TMV	Orange	Dark green, large jumbo fruit that retain firmness, tick walls
Tequila	68	TMV	Purple	A 3-4 lobe, slightly elongated type

[1]Indicates resistance or tolerance to: BLS = Bacterial leaf spot; PVY = Potato virus Y; TMV = Tobacco mosaic virus; Phyt = Phytopthora root rot.

Table 2. **High tunnel April planting – full colored yield, as fruit per tunnel, for sweet bell peppers at the Armstrong Farm and Horticulture Station, 2008. Harvest period was 26 days (Armstrong) and 35 days (Hort Station).**

	-------- Armstrong ------			---------- Hort Station ----------				
Variety	DFH[1]	Total yield[2]	Cull, %	DFH	Mkt yield[x]	Cull, %	Fruit shape[3]	Wall thick[4]
Aristotle	91	300	100	81	1770 BC	1.7	1.03	0.25
Paladin	91	360	100	81	2520 B	2.4	1.03	0.23
Red Knight	91	300	100	96	870 CD	39.6	0.83	0.26
Early Sunsation	91	60	100	96	510 D	19.1	0.88	0.26
Orange Grande	91	180	100	96	600 D	16.7	1.03	0.24
Tequila	77	3360	33	74	5820 A	38.3	1.08	0.22

[x]Mean values followed by the same letter within a column are not different, 5% level.
[1]DFH = days to first colored fruit harvest from transplant date of April 16 (Armstrong) and April 17 (Hort Station).
[2]Yield expressed as total fruit/tunnel (1,080 plants) at the Armstrong Farm from July 2 to July 28. Marketable yield at the Horticulture Station from July 1 to August 4.
[3]Fruit shape = length to diameter ratio; ≤ 0.95: very blocky, flattened shape; 1.00: blocky, length equal to diameter; ≥ 1.05: elongated shape with length greater than diameter.
[4]Wall thick = fruit wall thickness, measured in inches, at the equatorial point from stem to blossom end.

Table 3. **High tunnel final harvest – green fruit marketable yield, boxes per tunnel, for sweet bell peppers planted April and harvested from high tunnels at the Armstrong Farm (July 28) and Horticulture Station (August 4), 2008.**

	---------- Armstrong ----------					---------- Hort Station ----------		
Variety	Yield[1]	Cull, %	Fruit size, oz[2]	Fruit shape[3]	Wall thick[4]	Yield	Cull, %	Fruit size, oz.
Aristotle	44	2.3	10.3 AB[x]	1.01	0.26	66	21.4	10.0 A
Paladin	51	16.4	10.6 AB	0.88	0.29	47	30.9	9.6 A
Red Knight	24	17.3	12.3 AB	0.75	0.29	52	32.5	10.5 A
Early Sunsation	25	3.8	9.0 C	1.06	0.32	58	31.0	10.8 A
Orange Grande	48	17.2	7.1 CD	1.00	0.34	57	34.5	9.7 A
Tequila	20	25.9	6.4 D	1.05	0.21	0	100	6.5 B

[x]Mean values followed by the same letter within a column are not different, 5% level.
[1]Yield expressed as marketable boxes fruit/tunnel (1,080 plants) at the Armstrong Farm July 28 and August 4 at the Horticulture Station. One box equals 28 lb.
[2]Fruit size = marketable fruit of colored harvested earlier as well as mature green.
[3]Fruit shape = length to diameter ratio; ≤ 0.95: very blocky, flattened shape; 1.00: blocky, length equal to diameter; ≥ 1.05: elongated shape with length greater than diameter.
[4]Wall thick = fruit wall thickness, measured in inches, at the equatorial point from stem to blossom end.

Table 4. Field May planting – full colored fruit yield of sweet bell peppers at the Armstrong and Horticulture Station locations, 2008. Marketable yield in the field expressed as fruit/tunnel area to be equivalent to high tunnel production. Harvest period at Armstrong was 38 days and the Horticulture Station 56 days (Tequila was 77 days).

	------- Armstrong ---------			--------- Hort Station --------		
Variety	DFH[1]	Mkt yield[2]	Cull, %	DFH	Mkt yield	Cull, %
Aristotle	104	1058 BC	15.7 CD	98	1680 A[x]	72.9
Paladin	139	398 CD	52.4 A	98	718 B	83.8
Red Knight	125	819 BCD	28.0 B	98	2237 A	66.7
Early Sunsation	125	1398 B	9.4 D	98	2080 A	67.3
Orange Grande	139	294 D	28.6 B	98	1768 A	66.4
Tequila	104	8094 A	20.6 BC	65	4617 A	64.8

[x]Mean values followed by the same letter within a column are not different, 5% level.
[1]DFH = days to first colored fruit harvest from transplant date of May 20 (Armstrong) and May 13 (Hort Station).
[2]Yield expressed as marketable fruit/tunnel (1,080 plants) at Armstrong from September 2 to October 10, and the Horticulture Station from July 18 to October 14.

Table 5. Field May planting – fruit characteristics of sweet bell peppers at the Armstrong Farm and Horticulture Station, 2008.

	---------- Armstrong ----------			---------- Hort Station -------		
Variety	Fruit size, oz.	Fruit shape[1]	Wall thick[2]	Fruit size, oz.	Fruit shape	Wall thick
Aristotle	8.9 A[x]	1.08	0.25	6.4 A	1.30	0.24
Paladin	9.0 A	1.09	na	6.3 A	1.26	0.25
Red Knight	9.3 A	1.03	0.26	5.4 AB	1.03	0.24
Early Sunsation	9.3 A	1.12	0.21	5.6 AB	1.12	0.24
Orange Grande	6.1 B	1.03	na	6.1 A	1.26	0.22
Tequila	4.1 C	1.23	0.21	3.0 B	1.13	0.20

[x]Mean values followed by the same letter within a column are not different, 5% level.
[1]Fruit shape = length to diameter ratio; ≤ 0.95: very blocky, flattened shape; 1.00: blocky, length equal to diameter; ≥ 1.05: elongated shape with length greater than diameter.
[2]Wall thick = fruit wall thickness, measured in inches, at the equatorial point from stem to blossom end.

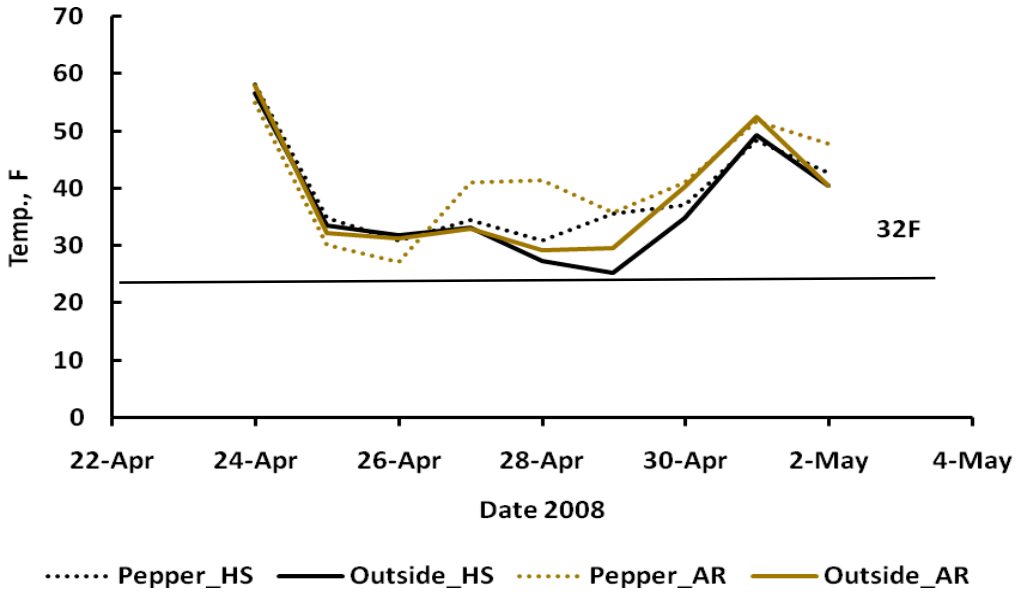

Figure 1. Comparison of minimum temperatures (usually at 6 AM) for Armstrong (AR) and the Horticulture Station (HS) locations. Pepper temperatures taken inside the high tunnel at plant height.