HS1162

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Protected Culture for Vegetable and Small Fruit Crops: High Tunnels for Strawberry Production in Florida[1]

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The United States has the largest planted strawberry area in the world with about 55,000 acres, and Florida accounts for 15% of the planted area. There are two main production systems for strawberry throughout the world: open field and protected culture. Protected culture includes structures such as greenhouses, high tunnels, and mini tunnels. High tunnels are unheated, plastic-covered, solar structures with passive ventilation through roll-up side walls. Height might vary from 6 ft to more than 17 ft. Crops are usually grown in soil. However, pot, trough, and sack culture could be used, along with various growing media such as peat, perlite, and vermiculite, depending on availability, prices, and crops.

Open-field production is the main system used in the U.S. and Australia, while protected culture is widely used in Europe. In Florida and California, strawberry transplants are planted in raised beds and covered with plastic mulch. The crop is drip irrigated and safeguarded from frost by using row covers or sprinkler irrigation. However, if protected culture were used instead of open-field production, sprinkler irrigation might not be required for freeze protection.

While the use of high tunnels and protected agriculture is popular in other countries, it was necessary to investigate their effects on Florida strawberry production due to the differences in climate, cultivars, and production systems. This research sought to compare the effects of high-tunnel and open-field production on the growth, fruit earliness, and yield of strawberry cultivars.

Two studies were conducted at the University of Florida's Gulf Coast Research and Education Center in Balm, Florida, over the course of two growing seasons. The soil used for the experiment was a fine, sandy spodosol with < 1.5% organic matter and a pH of 7.2. Bare-root transplants were placed in fumigated beds the second week in October each year. The experimental area was equipped with sprinklers for frost protection and crop establishment. Both high-tunnel and open-field production systems were used. The cultivars were 'Strawberry Festival', 'Winter Dawn', and 'Florida Elyana'. The high-tunnel units were 16 ft tall, 28 ft wide, and 300 ft long. They were covered with a single layer of clear polyethylene film. For freeze protection, the ends and sides of the units were covered 24 hours before the forecast freeze with a single layer of the same film

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used on the high-tunnel roofs. The units were ventilated by lowering the sides and ends of each unit as soon as the air temperature reached 50°F, provided that another freeze event was not forecast for the following night.

Marketable fruit yield was collected twice per week for a total of 30 harvests each season. Marketable strawberry fruit had the following characteristics: attached calyx, a minimum of 80% red surface, over 10 g in weight, and free of mechanical defects, insects, and diseases. Early and total yield consisted of the marketable fruit weight from the first 6 harvests and from all 30 harvests, respectively. After freeze events, fruit yield data on the following 6 harvests were also recorded and analyzed to assess the effect of cold temperatures on fruit yields inside the high tunnel and in the open field.

Production systems and cultivars affected both early and total yields for strawberries. During the first season, early yields were 54% higher inside high tunnels than in open fields, and 16% higher in the second season (Figure 1). 'Strawberry Festival' had the highest early yields, followed by 'Winter Dawn' and 'Florida Elyana'. Strawberry total marketable yields maximized inside high tunnels in comparison with open fields, with 63% and 50% increments during each respective season (Figure 2). Among the cultivars, 'Strawberry Festival' produced the highest total marketable yields, followed by 'Winter Dawn' and 'Florida Elyana'. These findings indicate that the protective environment improved strawberry fruit earliness and total yield under West Central Florida conditions.

Fruit marketable yields after freezing were recorded during both seasons. Both growing seasons had different temperature patterns from October to March of each year. During the first season, there was a single freeze in the early hours of 3 January 2008, during which the air temperature outside the high tunnels was as low as 27°F; the air temperature inside the high tunnels at that time was 43°F. The production systems and cultivars influenced the accumulated marketable yield of the six harvests made immediately after the freeze. The cumulative yield of those harvests resulted in a marketable yield difference of 74% higher fruit weight from plots inside high tunnels in comparison with open-field plots. 'Strawberry Festival' marketable yield was less affected by low temperatures than 'Winter Dawn' and 'Florida Elyana'. The following year, there were three freezes: from 21 to 23 January, and on 5 and 21 February 2009. The minimum air temperatures outside the high tunnels were 27°F, 21°F, and 23°F (from 21 to 23 January); 27°F (5 February); and 30°F (21 February), whereas the lowest minimum air temperature inside the high tunnels was 34°F during all three freeze events. During most freezes, 'Strawberry Festival' growing inside high tunnels had the highest marketable yield among all treatment cultivars. The results indicated that 'Florida Elyana' and 'Winter Dawn' were the most sensitive cultivars to freezing temperatures outside the high tunnels, whereas 'Strawberry Festival' was the most tolerant to low air temperatures, regardless of the production system used.

The use of high tunnels improved early and total marketable yields by 29% and 56%, respectively, across all the tested cultivars. Furthermore, the marketable yields of the next six harvests after freezing increased by 75% in the 2007–2008 season and by 64% in the 2008–2009 season (Tables 1 and 2). Several environmental factors likely influenced these responses. First, high tunnels protected the flowers and small fruit from the effects of hard freezes during both seasons. Second, flowers and fruit were not exposed to sprinkler irrigation damage during freeze events because sprinkler irrigation was not necessary inside the high tunnels to protect the crop. An approximate water volume of 60,000 gal/acre per 10 hours of freeze protection is normally used in Florida during the strawberry season. Assuming four freeze events per season, which is common based on temperature records for West Central Florida, using the high tunnels would save approximately 260,000 gal/acre of water per season, which might have a significant environmental impact in the crop production areas. Lastly, high tunnels protected fruit against rainfall, which causes reduced fruit number and quality. During the first season, there were 5 rains of 1 in. or more each (19 and 23 January, 12 and 23 February, and 7 March 2008), whereas in the second season, there were 2 significant rains of 1 in. or more each (30 November and 11 December 2008). Plants growing in plots inside high

tunnels were not exposed to rain; therefore, fruit quality did not suffer.

Although a detailed economic analysis is needed, the use of high tunnels in Florida for strawberry production might benefit growers by improving earliness and providing a competitive edge in the market. For instance, if additional early yields of 0.3 ton/acre (Table 2) and a price per 12-lb. strawberry tray of $30/tray (the average December price for Florida strawberries) are assumed, an additional gross income of $1563/acre should be expected. Furthermore, if an additional 2.1 ton/acre of fruit were produced during the whole season in high tunnels, and assuming that the average 12-lb. tray price was $10/tray, then the additional gross income would be $3500/acre per season.

Prevailing conditions on individual farms should influence growers' interest in this alternative production system. Care should be exercised to avoid broad generalizations as to the suitability of these protective structures.

In summary, high tunnels improved fruit earliness and may also open the following opportunities for Florida strawberry growers: a) minimal use of sprinkler irrigation for freeze protection, thus reducing fruit damage and fuel or electricity costs for pumping water; b) decreased incidence of foliar and fruit diseases, such as anthracnose fruit rot (*Colletotrichum acutatum*), botrytis fruit rot (*Botrytis cinerea*), and bacterial angular leaf spot (*Xanthomonas fragariae*), which are disseminated by rain drops, leading to fewer fungicide applications; and c) alternative production systems, such as intense intercropping and soilless culture to reduce fumigation practices.

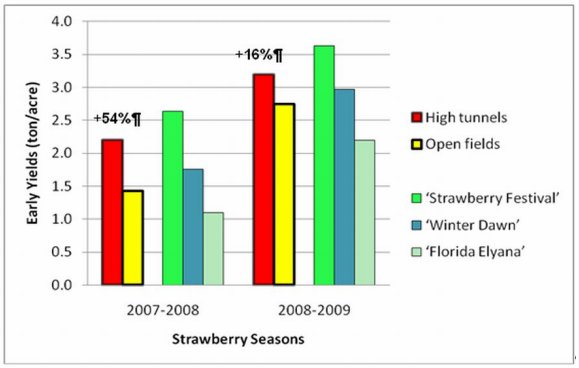

Figure 1. Effects of production systems and strawberry cultivars on early marketable yield, Balm, Florida, 2007–2008 and 2008–2009 seasons.

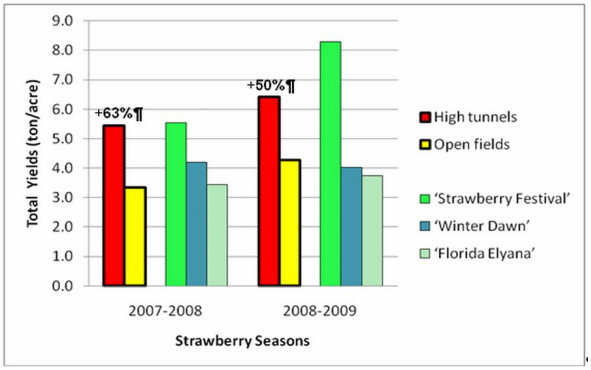

Figure 2. Effects of production systems and strawberry cultivars on total marketable yield, Balm, Florida, 2007-2008 and 2008-2009 seasons.

Table 1. Effects of production systems and strawberry cultivars on marketable yield in 2007–2008 season

Production systems	Market table yield after freeze [y], [z] (ton / acre)
High tunnels	1.23 a
Open fields	0.70 b
Cultivars	
'Strawberry Festival'	1.32 a
'Winter Dawn'	1.14 b
'Florida Elyana'	0.62 c

Note: Data resulting from the six harvests immediately following freezing temperatures in Balm, Florida.
[y]Mean separation within columns by Fisher's protected least significant difference test ($P < 0.05$). Values followed by the same letter do not differ statistically.
[z]The minimum air temperature registered in the open fields was 27°F (3 January 2008).

Table 2. Effects of the interaction between production systems and strawberry cultivars on marketable yield in the 2008–2009 season.

		Marketable yield after freeze [y], [z]		
Production system	Cultivars	21 to 23 Jan.	5 Feb.	21 Feb.
		(ton / acre)		
High tunnels	'Strawberry Festival'	4.6 a	4.4 a	5.4 a
High tunnels	'Winter Dawn'	3.0 bc	3.0 b	2.7 c
High tunnels	'Florida Elyana'	2.4 c	2.6 b	2.7 cd
Open fields	'Strawberry Festival'	3.3 b	3.1 b	3.7 b
Open fields	'Winter Dawn'	0.8 d	0.9 c	1.1 e
Open fields	'Florida Elyana'	1.3 d	1.2 c	1.7 de

Note: Data resulting from the six harvests immediately following freezing temperatures in Balm, Florida.
[y]Mean separation within columns by Fisher's protected least significant difference test ($P < 0.05$). Values followed by the same letter do not differ statistically.
[z]The minimum air temperatures registered in the open fields were 27°F, 21°F, and 23°F (from 21 to 23 January), 27°F (5 February), and 30°F (21 February).