Fruit Yield and Quality of Greenhouse-grown Bell Pepper as Influenced by Density, Container, and Trellis System

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SUMMARY. Production and quality of bell pepper (*Capsicum annuum*) fruit were evaluated in a passively ventilated greenhouse, in soilless media trellised to a "V" system (two-stem-pruned plants) or the "Spanish" system (nonpruned plants) in flat bags or nursery pot containers; and densities of 1.5, 1.9, 3.0, and 3.8 plants/m² (0.14, 0.18, 0.28, and 0.35 plants/ft²), in a winter-to-summer crop in Gainesville, Fla. The trellis systems did not affect total marketable fruit yields but production of extra-large fruit was higher (38%) in non-pruned than in pruned plants. Marketable fruit yields were similar in plants grown in bags and pots, and had positive linear responses to increased plant density. Not pruning reduced by half the percentage of fruit with blossom-end rot. Pruned plants produced 50% fewer flower bud supporting nodes than non-pruned plants but had a greater percentage of fruit set. Regardless of trellis systems, fruit set per plant decreased linearly as plant density increased. Overall, the "Spanish" trellis system at a density of 3.8 plants/m² resulted in greater yields of extra-large fruit and required 75% less labor than the "V" system to prune and support the plant canopy.

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Bell peppers are grown in greenhouses to produce high quality colored fruit during an extended season. In Florida, peppers produced in greenhouses are typically grown in containers with soilless media, irrigated with nutrient solution, and their canopies pruned and trained vertically (Jovicich et al., 2003).

Pruning of greenhouse-grown pepper plants restricts the number of branches, thereby improving canopy light interception, fruit set, and fruit quality (Portree, 1996; Resh, 1996). Pepper plants are pruned throughout the production cycle, particularly in northern latitudes, where low solar radiation occurs during the fall and winter. The "V" and the "Spanish" plant trellis systems widely used in greenhouse-grown pepper crops involve different amounts of labor for pruning and training of the plant canopy. The "V" trellis system consists of forming a two-stem plant by removing one of the two shoots that develop at each node. Stems are supported vertically with twine wound around the stems. The "V" trellis system is used by Canadian and Dutch greenhouse growers and has been adopted by many Florida greenhouse growers.

Spanish and Israeli greenhouse growers prune and train pepper plants to the "Spanish" trellis system (Namesny, 1996; Nuez et al., 1996; R. Offenbach and I. Secker, personal communications). In plants trellised to the "Spanish" system, the stems and lateral branches are not pruned, allowing the plant to develop a canopy with two to four main stems with lateral branches in the mature plant (Namesny, 1996; Nuez et al., 1996). In the "Spanish" trellis system, the plant canopies are supported vertically from both sides by horizontal twines tied to poles distributed along the rows of plants.

The canopy structure of plants trellised to the "V" and "Spanish" systems may have different efficiencies in light interception which may affect fruit production differently. In addition, plant densities affect light interception by the crop and, thus, can be used as a strategy for increasing fruit yield per unit area in greenhouse crops (Papadopoulos and Pararajasingham, 1997). Optimum marketable yields per unit area may result from canopy structures created by particular combinations of plant densities and plant trellis systems. In a greenhouse experiment during a short summer pepper crop in Florida, plants pruned to four stems at high plant densities produced greater fruit yields than plants pruned to one or two stems (Jovicich et al., 1999).

In Florida, a peninsula with a subtropical and mild winter climate, greenhouse pepper growers largely have adapted technologies from countries with cool environments, such as Canada and The Netherlands. Production techniques from warm weather countries, such as the "Spanish" trellis system for pepper, normally used with soil-grown plants (Nuez et al., 1996), have not been evaluated in Florida soilless culture systems.

High-roof, passively ventilated greenhouses create an oasis effect in the arid tropical and subtropical regions by reducing high daytime air temperatures and increasing nighttime minimum temperatures (Wittwer and Castilla, 1995). In subtropical regions, this type of greenhouse protects crops from rainfall, wind, and insect pests. In north-central Florida, a high-roof passively ventilated greenhouse is being used to assess fruit production of high value crops, including pepper (Cantliffe et al., 2001; Jovicich, 2001; Jovicich et al., 2003). Two types of containers, bags and pots, are being used in commercially grown pepper plants in Florida. Usually, one plant is grown in each pot while, depending on plant density, two to five plants share the same 1.0-m-long (3.28 ft) bag.

The purpose of this experiment was to evaluate fruit yield, fruit quality, and final plant growth in a winter to summer bell pepper greenhouse-grown crop with the "Spanish" and the "V" trellis systems at several plant densities and in two types of containers (pots and bags).

Materials and methods

The experiment was conducted in a single bay of a seven-bay gutter-connected, passively ventilated polyethylene-covered, north–south oriented greenhouse (Top Greenhouses, Rosh Ha'ayin, Israel) at the Horticultural Sciences Protected Agriculture Center of the University of Florida (Cantliffe, 1999). The experiment was arranged as a split-split plot design, with three blocks. Trellis system ("Spanish" and "V") was the main plot, container type (pot and bag) the subplot, and plant density (1.5, 1.9, 3.0, and 3.8 plants/m^2) the sub-subplot. Analyses of variance (ANOVA) were performed on fruit yield and plant measurements using SAS (SAS Institute, 1999). The main effects of plant density were partitioned into linear, quadratic, and cubic orthogonal contrasts. Plant densities were not equally spaced; therefore, contrast coefficients were calculated using the Interactive Matrix Programming Language (IML) procedure in SAS. Regression analysis was performed to describe the response of extra-large fruit yield to increased plant density. Percentages of fruit with physiological disorders and fruit set data were arcsin-transformed prior to conducting the ANOVA.

Five-week-old commercial hybrid 'HA3378' bell pepper seedlings (Hazera Seeds, Grover Beach, Calif.) were transplanted on 24 Dec. 1999 into two types of containers: 1) 11.36-L (3.0 gal) black polyethylene nursery pots [25.4 cm (10 inches) diameter (model A-30; Lerio Corp., Kissimmee, Fla.)] and 2) 20.4-L (5.39 gal) white polyethylene bags [100 cm (39.4 inches) in length, 26.4 cm (10.39 inches) in width (Agrodynamics, East Brunswick, N.J.)]. Both containers were filled with horticultural coarse grade particle size perlite (Airlite Processing Corp. of Florida, Vero Beach, Fla.). Four plant densities of 1.5, 1.9, 3.0, and 3.8 plants/m^2 were arranged in 2.0-m-long (6.56 ft) plots, spaced 1.33 m (4.364 ft) from center to center of each row. The number of plants per plot corresponded to 4, 5, 8, or 10 depending on the plant density treatment.

Three weeks after transplanting, the crown flower and the flower on the first node of each stem were removed, allowing plants to develop an adequate vegetative frame before fruit set. Starting 4 weeks after transplanting, plants were trained with the "V" or the "Spanish" trellis system. In the "V" trellis system, the lateral shoots (the smaller shoot of the pair that bifurcated on a node) were pruned when they reached 3 to 4 cm (1.2 to 1.6 inches) long, leaving two adjacent source leaves attached to the two main stems of the plant. Polyethylene strings hung from an overhead wire were loosely wound around each of the main stems to support the plants vertically. Pepper plants trellised to the "Spanish" system were allowed to grow without further pruning after two shoots were left at the node of the first branch bifurcation. In this trellis system, pairs of horizontal and vertical twines supported the canopies on both sides of the plant rows. The time used for pruning and/or training plants was recorded.

Plants were drip-irrigated with a complete nutrient solution for periods of 1.0 to 1.8 min per event with pressure-compensated drip emitters [average flow 34 mL·min^{-1} (1.1 fl oz/min) at 137.9 kPa (20 psi); Netafim, Altamonte Springs, Fla.]. Nutrient levels for peppers were adapted from those formulated for hydroponic greenhouse-grown tomatoes (Table 1) (Hochmuth, 1991; Jovicich, 2001). The frequency of irrigation events was based on integrated solar radiation and was increased with plant growth (Jovicich, 2001). Irrigation frequency varied from nine events per day in December, to 50 irrigation events per day at the end of July. The pH of the irrigation solution was maintained between 5.5 and 6.5. The electrical conductivity of the irrigation solution ranged from 1.4 to 2.5 mS·cm^{-1} depending on nutrient concentration levels.

Air temperatures inside and outside the greenhouse were measured using thermocouples (PR-T-24 Omega Engineering, Stamford, Conn.) placed in shade at a height of 1.5 m (4.92 ft). Temperature data were recorded with a data logger (CR10X; Campbell Scientific, Logan, Utah). There were 14 d with frost from 23 Dec. 1999 to 20 July 2000. Outside air temperatures were as low as –4 °C (24.8 °F). Minimum outside air temperatures were below 1 °C (33.8 °F) on 18 d between 23 Dec. 1999 and 10 Feb. 2000. Minimum outside air temperatures were lower than 5 °C (41.0 °F) on 38 d between 23 Dec. 1999 and 10 Apr. 2000 (Fig. 1).

Pepper plants were protected from near freezing temperatures [2 °C (35.6 °F)] inside the greenhouse by three methods including covering the plants early in the season during the night with a polyethylene row cover film, placing thermal tubes (Polyon, Barkai, Israel) along the plant rows, and, later in January, by operating propane burners. These cold protection systems maintained the minimum air temperatures near the plant canopies above 5 °C during most of the crop season (Fig. 1).

Bumblebees [*Bombus impatiens* (NATUPOL; Koppert Biological Systems, Ann Arbor, Mich.)] were used as pollinators (at a rate of about one bee per 100 plants). Bees were observed to be active during most of the days during the experiment, although during cool or very hot weather their foraging activity appeared to diminish and fewer flower visits were perceived.

All fruit from the first set, which originated from flowers that developed under low temperatures, reached their maximum size at the end of Feb. 2000. These flat-shaped, seedless, green colored fruit were harvested on 1 Mar. 2000. Subsequent fruit were harvested with at least 80% red color from the 2.0-m-long plots on 1 May, 15 May, 5 June, 7 July, and 20 July. Marketable fruit were weighed, counted, and graded by size following a diameter scale used

Table 1. Target concentrations of nutrients in the solution delivered to greenhouse-grown bell peppers throughout the cropping season (24 Dec. 1999 to 20 July 2000).

Nutrient[y]	Transplant/vegetative growth[z]	Vegetative growth/ fruit set/1st harvest		Fruit set	2nd to 6th harvest
	Dec.–Jan.	Jan.	Jan.–Mar.	Mar.–Apr.	Apr.–July
	[mg·L^{-1} (ppm)]				
Nitrogen	80	120	140	150	160
Phosphorus	50	50	50	50	50
Potassium	119	148	173	202	215
Calcium	127	135	159	171	182
Magnesium	40	48	48	48	48
Sulfur	56	66	66	66	66

[z]Stages of the crop, fruit harvest number, and months when each nutrient concentration level was used.
[y]Supplied with every drip irrigation event. Levels of micronutrients [mg·L^{-1} (ppm)] were constant throughout the season: iron = 2.8; copper = 0.2; manganese = 0.8; zinc = 0.3; boron = 0.7; molybdenum = 0.06.

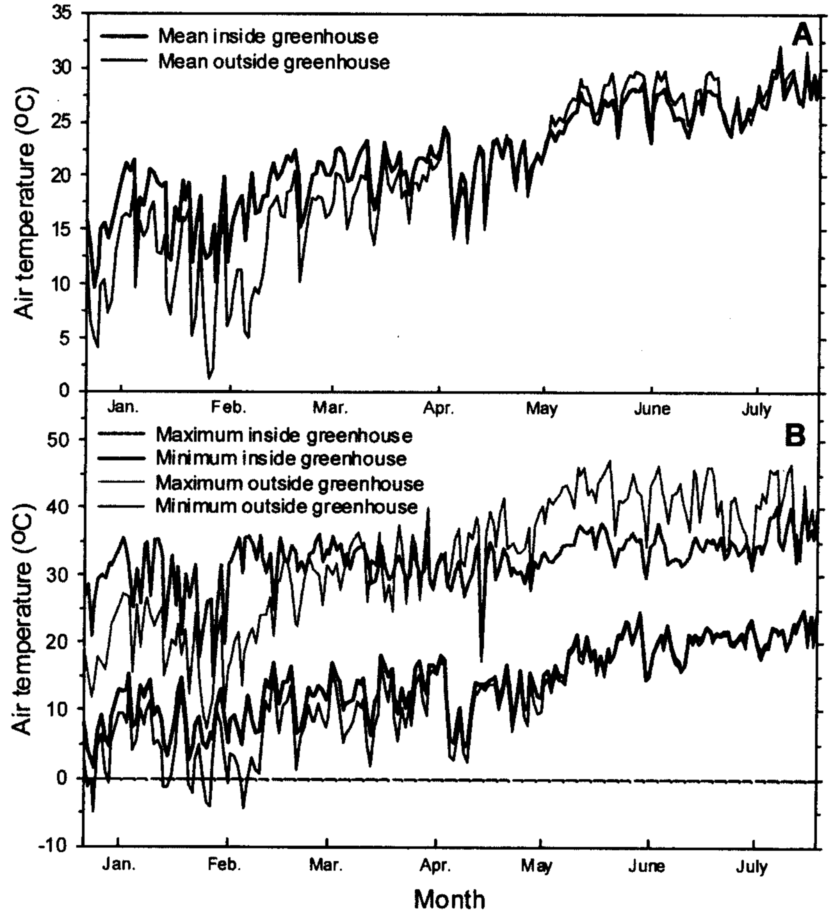

Fig. 1. Daily mean air temperatures (A), and daily maximum and minimum air temperatures (B), measured at a height of 1.5 m (4.92 ft) inside and outside the greenhouse throughout the bell pepper cropping season (24 Dec. 1999 to 20 July 2000) in Gainesville, Fla.; 1.8(°C) + 32 = °F.

for imported greenhouse-grown bell peppers: extra-large [diameter >84.0 mm (3.31 inches)], large [76.0 to 83.9 mm (2.99 to 3.30 inches)], medium [64.0 to 75.9 mm (2.52 to 2.99 inches)], and small [56.0 to 63.9 mm (2.20 to 2.52 inches)]. Unmarketable fruit included fruit with blossom-end rot, flat-shaped fruit, and fruit with a diameter smaller than 55.9 mm (2.20 inches). Fruit with cracking (radial at the blossom-end or russetting) and yellow "color spots" were counted as unmarketable. After the final harvest, plant height (average distance between two of the longest stems, from the top surface of the container media to a node prior to the end of the stem) was measured, leaf nodes were counted, and total fruit set per plant was calculated [fruit set (%) = (number of fruit set × 100)/total number of flower nodes] in two plants at each plot. Yields (weight and number of fruit) were expressed based on a unit of greenhouse floor area that was cropped.

Results and discussion

MARKETABLE FRUIT YIELD. Total yields of extra-large fruit were significantly greater in plants trellised to the "Spanish" system [4.9 kg·m^{-2} (1.00 lb/ft^2) and 21 fruit/m^2 (2.0 fruit/ft^2)] as compared to plants trellised to the "V" system [3.0 kg·m^{-2} (0.61 lb/ft^2) and 13 fruit/m^2 (1.2 fruit/ft^2)] (Table 2). However, total marketable fruit weights and numbers per unit area did not differ among trellis systems (both P=0.06) (Table 2). Yield per plant of extra-large fruit was greater from plants grown with the "Spanish" trellis system at all plant densities and was similar for both container types (Table 2). All interactions between trellis system, plant density, and container type were not significant for any measured fruit yield variables (Table 2).

Total marketable and extra-large fruit yields in weight and number of fruit increased linearly in response to increasing plant densities (Table 2). At 3.8 plants/m^2, extra-large fruit yields averaged 7.3 kg·m^{-2} (1.50 lb/ft^2) in plants with the "Spanish" system and 4.9 kg·m^{-2} in plants with the "V" system (Fig. 2). Extra-large fruit yield per plant was not significantly affected by plant density, but yield per plant of large and medium fruit sizes decreased quadraticaly and linearly, respectively, in response to increasing plant densities (Table 2). Container type did not significantly affect the total marketable or extra-large fruit yield per unit of cropped area or per plant (Table 2). Bags produced a significantly greater amount of small fruit compared to pots.

TOTAL AND UNMARKETABLE FRUIT YIELD. Total number of fruit per unit of cropped area did not differ (P = 0.06) between the two trellis systems (Table 3). Unmarketable fruit were mainly flat and seedless fruit and/or fruit with blossom-end rot (BER). Low temperatures inside the greenhouse during January and February [day mean temperature: 12.0 °C (53.60 °F) and 13.9 °C (57.02 °F), mean minimum: 5.0 °C (41.00 °F) and 6.1 °C (42.98 °F), respectively] (Fig. 1), when the first flowers were developing, may have contributed to the development of a large number of fruit that were flat and seedless (parthenocarpic) (Rylski, 1986). On 1 Mar., the highest percentage of flat seedless fruit was harvested from plants trellised to the "Spanish" system (Table 4). In the subsequent five harvests, there were few fruit with this disorder in any treatment. Plants grown with the "Spanish" trellis had more flowers than plants in the "V" system early in the season and, therefore, early production yielded a larger number of fruit with this disorder. Marketable fruit yield was significantly greater from plants in the "Spanish" trellis system at the third (15 May; P = *0.04*) and fourth (5 June; P = *0.03*) harvests (Table 4) than in the "V" system.

The "V" trellis system produced the highest percentage of fruit with BER (Table 3). Plants at lower densities were more affected with BER than plants at higher densities (Table 3). A high percentage of fruit with BER was harvested on 15 May (Table 4). The 15 May harvest followed a two week period of increased daily mean air temperatures [from 18 °C (64.4 °F) to 27 °C (80.6 °F)] (Fig. 1) and rapid plant growth following the second harvest on 1 May. Between 1 May and

Table 2. The effect of trellis systems, container types, and plant densities in greenhouse-grown plants on marketable fruit yields harvested from 1 Mar. 2000 to 20 July 2000.

	Extra-large[z]		Marketable						
	($kg \cdot m^{-2}$)	(fruit/m²)	($kg \cdot m^{-2}$)	(fruit/m²)	Extra-large[y]	Large	Medium	Small	Total
					(g/plant)				
Trellis system (T)									
"V"	3.0	13	3.9	21	1151	200	157	39.7	1547
"Spanish"	4.9	21	6.2	33	1977	283	245	44.1	2548
	*	*	NS	NS	*	NS	NS	NS	*
Container (C)									
Pot	4.1	18	5.0	26	1620	214	179	29.9	2053
Bag	3.8	16	5.1	28	1507	268	223	53.9	2043
	NS	NS	NS	NS	NS	NS	NS	*	NS
Density (D)									
1.5[w] (plants/m²)	2.5	11	3.5	20	1654	362	262	43.0	2321
1.9	3.0	13	3.9	21	1577	239	212	50.4	2078
3.0	4.4	19	5.5	29	1454	167	163	37.3	1821
3.8	5.9	25	7.4	39	1571	198	166	37.0	1972
	L**	L**	L**	L**	NS	Q*	L*	NS	NS
T × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × D	NS	NS	NS	NS	NS	NS	NS	NS	NS
C × D	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × C × D	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Fruit were graded by diameter: extra-large (diameter >84.0 mm), large (76.0 to 83.9 mm), medium (64.0 to 75.9 mm), and small (56.0 to 63.9 mm); 25.4 mm = 1 inch. Marketable fruit consisted of extra large, large, medium, and small fruit. These fruit were not flat and did not have blossom-end rot, cracking and/or color spots. 1.0 $kg \cdot m^{-2}$ = 0.205 lb/ft². 1.0 fruit/m² = 0.093 fruit/ft².

[y]1.0 g/plant = 0.035 oz/plant.

[x]1.0 plant/m² = 0.093 plant/ft²

NS,*,**Nonsignicant or significant by F test at $P < 0.05$ or 0.01; linear (L) and quadratic (Q) polynomial effects.

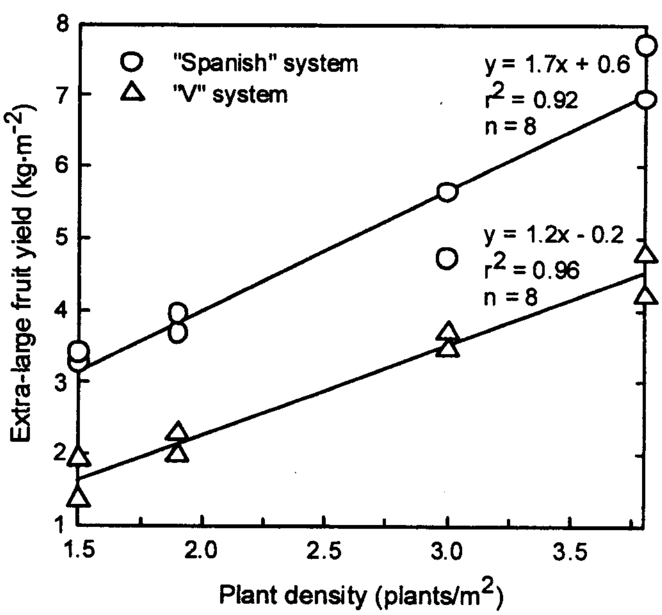

Fig. 2. Response of total extra-large pepper fruit weight [fruit with diameter greater than 84.0 mm (3.31 inches)] to increasing plant density from 1.5 to 3.8 plants/m² (0.14 to 0.35 plants/ft²) in greenhouse-grown plants with the "Spanish" and "V" trellis systems. Plant containers were pots or bags. The two symbols in each trellis system at each level of plant density [1.5, 1.9, 3.0, and 3.8 plants/m² (0.14, 0.18, 0.28, and 0.35 plants/ft²)] represent mean yields from 3 blocks in pots or bags; 1.0 $kg \cdot m^{-2}$ = 0.205 lb/ft², 1.0 plant/m² = 0.093 plant/ft².

15 May, nutrient solution was applied at 2.5 to 3.0 L (0.66 to 0.79 gal) per plant per day. Even with increased irrigation rates, plants still exhibited temporary wilting on the top of the canopies during the afternoon.

Blossom-end rot disorder in pepper fruit has been related to a localized calcium deficiency in the tissue at the base or the sides of the fruit (Marcelis and Ho, 1999). Under environmental conditions with high temperatures, most of the water is drawn to the mature leaves to maintain a functional transpiration rate. As a result, very little calcium reaches the actively growing cells such as those in the young fruit and they become deficient (Marcelis and Ho, 1999). Even temporary water stress can lead to BER in young fruit (Bar-Tal et al., 1999). Plants that were pruned to the "V" system with less number of leaves than those in the "Spanish" system were observed to be more sensitive to temporary wilting during the afternoon hours with high temperatures [>38 °C (100.4 °F)] than non-pruned plants in the "Spanish" system. More leaves in the plants trellised to the "Spanish" system could have resulted in greater transpiration in

Table 3. The effect of trellis system, container type, and plant density in greenhouse-grown plants on total number of pepper fruit, percentage of flat fruit, percentage of fruit with blossom-end rot, plant height, number of nodes per plant, and percentage of fruit set.

	Total fruits[z] (no/m²)	Flat fruit[y] (% by no.)	BER fruit[x] (% by no.)	Plant ht[w] (cm)	Fruit nodes[v] (no./plant)	Fruit set[u] (%)
Trellis system (T)						
"V"	72[t]	5.9	61.6	207[s]	59	50.0
"Spanish"	82	18.9	39.0	190	105	33.7
	NS	**	**	*	**	**
Container (C)						
Pot	74	11.4	50.5	199	82	39.4
Bag	82	13.2	50.1	198	83	44.3
	NS	NS	NS	NS	**	NS
Density (D) (plant/m²)						
1.5[r]	62	13.1	52.0	183	77	54.8
1.9	68	12.0	54.3	192	80	47.5
3.0	80	13.2	47.6	204	85	33.6
3.8	101	11.3	47.6	215	88	31.5
	L**	NS	L**	L*	NS	L**
T × C	NS	NS	NS	NS	**	NS
T × D	NS	NS	NS	NS	**	NS
C × D	NS	NS	NS	NS	**	NS
T × C × D	NS	NS	NS	NS	**	NS

[z]The total number of marketable and nonmarketable fruit harvested from 1 Mar. to 20 July 2000.
[y]Percentage of flat seedless fruit.
[x]Percentage of fruit with blossom-end rot.
[w]Distance from the top surface of the container media to a node prior to the end of the longest stem.
[v]Number of nodes on stems and branches where potentially fruit would have set.
[u]Fruit set were all marketable and nonmarketable fruit removed from the plant. Percentage of fruit set = (no. fruit set × 100)/total no. of flower nodes.
[t]1.0 no./m² = 0.093 no./ft².
[s]1.0 cm = 0.39 inch.
[r]1.0 plant/m² = 0.093 plant/ft².
NS,*,**Nonsignificant or significant by F test at $P \leq 0.05$ or 0.01, respectively; linear (L) polynomial effect.

Table 4. The effect of trellis system used in greenhouse-grown pepper plants on the number of flat seedless fruit, marketable fruit, and fruit with blossom-end rot in six harvest dates.

Harvest date	1 Mar.	1 May	15 May	5 June	7 July	20 July
	(fruit/m²)					
Flat fruit[z]						
"V"	3.9[y]	0.3	0	0	0	0
"Spanish"	15.1	0.3	0	0	0	0
	**	NS	NS	NS	NS	NS
Marketable fruit[x]						
"V"	0	8.0	2.0	2.1	1.7	7.6
"Spanish"	0	8.9	6.9	4.6	3.9	9.0
	NS	NS	*	*	NS	NS
Fruit with BER[w]						
"V"	0	2.1	19.6	14.9	4.6	2.1
"Spanish"	0	0.9	14.0	12.8	3.1	1.1
	NS	NS	**	NS	NS	NS

[z]Flat seedless fruit.
[y]1.0 fruit/m² = 0.093 fruit/ft².
[x]Marketable fruit consisted of extra large, large, medium, and small fruit.
[w]Fruit with blossom-end rot.
NS,*,**Nonsignificant or significant (by F test within harvest dates) at $P \leq 0.05$ or 0.01, respectively.

these plants, and thus, greater calcium uptake by fruit. The shading effect from having more leaves in the plants at the "Spanish" system also could have reduced temperatures inside the canopy allowing more calcium transport into the young fruit (Rylski and Spigelman, 1986).

In addition, plants in both trellis systems at the lowest plant density were observed to be more sensitive to wilting under high temperatures than plants in high-density plots. Plants at lower densities not only were more exposed to solar radiation, which lead to greater transpiration rates, but also had more fruit to be supplied with calcium. With higher plant densities, plants under a greater shading effect from neighbor plants and with less fruit per plant led to a smaller percentage of BER fruit.

Treatments evaluated in this experiment did not affect the number or percentage of fruit with cracking per unit of cropped area. However, up to 26% of fruit in average across treatments (ranging from 24 to 30%) had some degree of cracking.

Plant architecture and size. Plant architecture and size were affected by plant trellis system and by plant density (Fig. 3). Because plants trellised to the "Spanish" system involved little pruning, the number of main stems per plant ranged from two to four. At higher densities, non-pruned plants tended to have two main stems and short lateral branches with two to four nodes. In these plants, fruit set on nodes of the main stems and on the nodes of the smaller lateral branches. Plants in the "V" trellis system were slightly taller than plants under the "Spanish" trellis system (Table 3). In both trellis systems, plant height increased linearly in response to increased plant densities (Table 3).

Fruit set. In all treatments, plants had more nodes than the total number of fruit produced, which indicated that a number of flower buds, flowers, or small fruit had aborted. Pruning lateral shoots to a "V"-shaped plant frame increased the overall fruit set for the season as compared to non-pruned plants trellised to the "Spanish" system (Table 3). Fruit set per plant was less in plants grown at higher densities, where plants had a fewer number of fruit and more nodes per plant (Table 3). Plants trellised to the "Spanish" system had

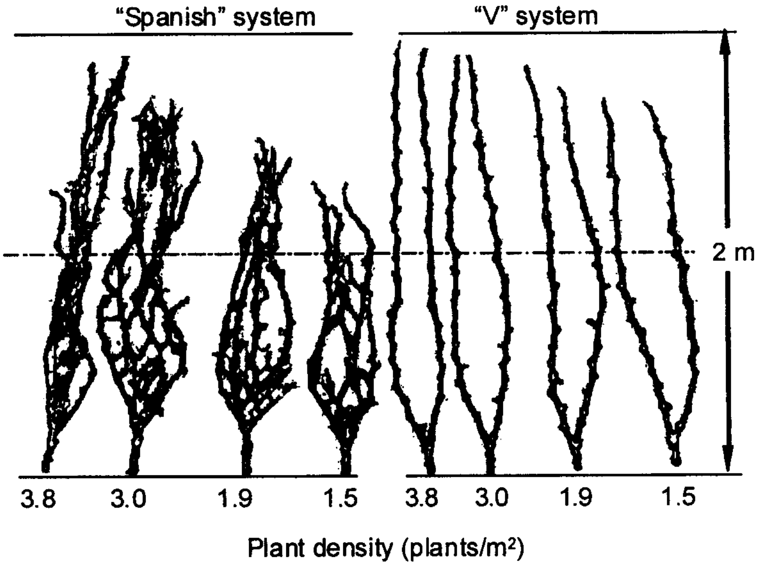

Fig. 3. Plant stems and branches after all leaves and fruit were detached in non-pruned ("Spanish" trellis system) and pruned ("V" trellis system) bell pepper plants 209 d (20 July 2000) after transplant at four plant densities; 1.0 plant/m^2 = 0.093 plant/ft^2, 1.0 m = 3.28 ft.

more nodes at higher densities.

The higher percentage of flower abscission in the non-pruned plants resulted in more leaves per fruit set, which may have contributed to more photo-assimilates for the fruit that set. Also, a more developed canopy in the non-pruned plants may have created an optimum environment (i.e., lower daytime temperatures) for flowers and fruit that developed during the warm season. The types of containers evaluated in this experiment did not affect plant height, total number of fruit, or fruit set (Table 3).

PLANT CONTAINER. With perlite as soilless media and irrigation managed as in this experiment, bags and pots did not affect fruit yield and quality. Pots cost more than bags and with pots at the highest plant density, more soilless medium was required. With 3.8 plants/m^2, the cost of pots and medium per area unit was calculated to be 59% higher than bags (assuming in the container depreciation a durable life of two seasons for bags and six seasons for pots). However, pots contain only one plant root system, reducing the risk of adjacent plant contamination in a case of a root disease outbreak.

LABOR. Plants in the "V" trellis system were pruned and tied 11 times. Plants in the "Spanish" trellis system were pruned only once to ensure two branches after the first flower node and, in addition, six pairs of horizontal strings were extended from both sides of the plant rows throughout the crop season. In the "Spanish" trellis system, plant density did not affect the labor time needed for trellising since the only labor necessary was to extend and tie horizontal twines along both sides of the plant rows and to clip together the parallel pairs of twines. During the 209-d crop for a plant density of 3.8 plants/m^2, trellising rows of pepper plants with the "Spanish" system demanded a total labor time of 3.3 min·m^{-1} (1.01 min/ft) while the time needed with the "V" system was 14.4 min·m^{-1} (4.39 min/ft). With the "Spanish" trellis system, the savings in labor time represented 75% as compared to the "V" system. Savings in labor of similar order and comparable fruit yields were reported by a grower in south Florida who used both growing systems in pepper crops grown in passively ventilated greenhouses.

In north-central Florida, fruit yields from pepper plants grown in a passively ventilated greenhouse through the winter, spring, and summer were affected by the same disorders reported to occur in plants grown in Mediterranean countries with similar production systems (Aloni et al., 1994; Monteiro, 1994; Rylski et al., 1994). Flat fruit, BER, and cracking are common disorders of pepper fruit grown in low-cost greenhouse structures that provide minimal climatic control (Rylski et al., 1994). Nonetheless, under these structures, environmental conditions are improved compared to the open field and can produce an economic yield (Costa and Heuvelink, 2000).

To reduce the percentage of cull fruit, pepper cultivars should be selected for marketable fruit set at low temperatures, low susceptibility to fruit cracking and "color spots" (another disorder noticed in fruit during the late spring), low incidences of BER, and fruit set ability during late spring and summer under Florida's environmental conditions of a mild winter climate (Jovicich, 2001). Greater early fruit yields may be expected from plants if early fruit set can be protected from the low temperatures prevailing from December to February. Heating to minimum levels [night temperatures over 15 °C (59.0 °F)] during these months and using bumblebees for pollination may reduce production of flat fruit, improve plant growth during the winter and lead to more yields of colored fruit during March and April. Improvements in air circulation during the spring and summer and the use of shades (movable horizontal screens) that reduce high temperatures without compromising light requirements by the plants may decrease the incidences of blossom-end rot and cracking disorders (Castilla, 1994; Jovicich, 2001; Monteiro, 1994).

In our experiment, compared to the "V" trellis system, where plants were continuously pruned, the practice of leaving more nodes, flowers, and leaves in the "Spanish" system resulted in similar marketable fruit yields but with more extra-large fruit. Extra large fruit had the same dimensions with all plant densities, containers, and trellis systems used. This fruit grade had a mean diameter of 100 mm (3.9 inches), a mean length of 78 mm (3.1 inches), a mean pericarp thickness of 8.5 mm (0.33 inches), and a mean weight of 233 g (8.2 oz). Using the higher plant density of 3.8 plants/m^2 resulted in greater marketable fruit yields. However, since yields had a linear response to plant density, the yield response to densities higher than 3.8 plants/m^2 should be evaluated.

In Spain, some farmers have experimented trellising pepper plants to the "V" system, leaving two or three main stems per plant (Nuez et al., 1996). Compared to pepper crops grown under the "Spanish" trellis system, the crops under the "V" system resulted with similar or sometimes better fruit quality (uniform fruit size, increased pericarp thickness) (Nuez et al., 1996). However, increased labor demand required for pruning and tying the pepper plants have discouraged Spanish farmers from adopting the "V" trellis system extensively (Namesny, 1996). In addition to labor requirements, Spanish researchers have reported that inside the low-roof greenhouse structures used in the province of Almería (Spain), environment is difficult to control and pruning the soil-grown plants to the "V" system caused greater incidences of blossom-end rot in pepper fruit than in plants trellised to the "Spanish" system (Namesny, 1996; Nuez et al., 1996).

Pepper plants grown at a high plant density, from winter to summer, in a passively ventilated greenhouse in North central Florida, produced greater yields of extra-large fruit and required less labor when trellised to the "Spanish" system compared to the "V" system. With minimum heating used in this experimental crop, fruit yields obtained were similar to those obtained in low cost greenhouses in Spain [in the order of 6 $kg \cdot m^{-2}$ (1.2 lb/ft^2)] (Costa and Heuvelink, 2000) and much lower than that in greenhouses in The Netherlands or Canada (in the order of 25 $kg \cdot m^{-2}$ (5.1 lb/ft^2)] (Costa and Heuvelink, 2000; Mirza, 2003) where the levels of production inputs are higher to cope with the cold and low-light environmental conditions and production season is longer. The "Spanish" system could be used for late fall plantings that will start producing in March and continue during periods of higher temperatures, finishing in June. Further research will be conducted to evaluate the performance, costs, and economic benefits of crops with these two trellis systems in fall plantings.

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