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PERFORMANCE OF GREENHOUSE TOMATO CULTIVARS GROWN IN SOILLESS CULTURE IN NORTH CENTRAL FLORIDA

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Abstract. **A greenhouse tomato (*Lycopersicon esculentum* Mill.) cultivar trial was conducted at the University of Florida's Protected Agriculture Project site in Gainesville, Florida during the spring of 1999. The objective of this trial was to evaluate Israeli and Dutch tomato cultivars grown in the greenhouse for yield and fruit quality under the climatic conditions (spring-summer) of north central Florida. Tomato plants were transplanted into white polyethylene bags filled with coarse perlite on 15 Feb. 1999, and were grown for 7 months. Bags were arranged in double rows 20 cm apart and 30 m long. Plants were spaced 36 cm apart. Water and nutrients were supplied through a drip system as needed and adjusted to permit 20 to 30% leachate in a 24-hour cycle. Both cluster and beefsteak varieties were compared in this trial. 'Champion', 'Taverna', and 'FA-593' had greater marketable yields (fruit per plant) than other cluster cultivars. Among the beefsteak cultivars, marketable yields for 'FA-574' and 'Catherine' were higher than 'Trust'. Cultivars with the highest yield had high fruit quality and good disease resistance. Cluster varieties 'Champion' and 'Taverna' and the beefsteak variety 'Catherine', should be considered by growers who wish to compete with product imported from Europe and Canada. When managed with the standard practices for greenhouse tomatoes in Florida (training, pruning, and fertigation) these cultivars could provide growers additional tomato varieties for trial.**

During the 1998-1999 production season, nearly 17,564 ha of tomatoes (*Lycopersicon esculentum* Mill.) were harvested in Florida and were valued at more than $460.9 million (Fla. Agr. Stat. Serv., 1999). Tomatoes are the leading vegetable crop in Florida and, although open field production is still the preferred method of producing tomatoes and other economically important vegetables in the state, greenhouse vegetable production is increasing.

Lucier et al. (2000) reported that consumption of fresh and processed tomatoes (including greenhouse tomatoes) in the United States has significantly increased in the last two decades. In 1999, greenhouse tomatoes comprised approximately 10% of the total U.S tomato consumption; however, growers believe that this figure could increase up to 50% in the next few years (Johnson, 1999). In Florida, greenhouse tomatoes account for an area of approximately 7 ha (Tyson et al., 2001).

Commercial production of greenhouse vegetables is one of the most intense forms of agricultural enterprises, especially when soilless culture is used (Jensen, 1997). Greenhouse vegetable production is initially capital intensive, highly productive, conserves water and land, and can be less environmentally harmful compared with field production (Resh, 1997). In the United States, the primary crop being grown in greenhouses is tomato. Consumption of both fresh and processed tomatoes is not diminishing, but rather increasing, and it is very likely that the volume needed to supply this demand will keep greenhouse tomato production profitable (Brentlinger, 1999).

Greenhouse production of vegetables could alleviate many of the production problems that field growers are currently facing. Growing concern over the use of pesticides and soil fumigants, such as methyl bromide, which is to be completely phased out in 2005, will force many growers to search for production alternatives. New production systems must be able to compete with foreign markets and still obtain a profitable return to the grower's investment. In addition to these problems, urbanization and loss of farmland, increased regulation of pesticides, and severe weather conditions (e.g.

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winds, rain, and freezes) are especially pressing for Florida's tomato growers. The use of protected structures along with new greenhouse vegetable cultivars and the use of soilless techniques could be incorporated into production systems that could overcome these challenges. As reported by Heacox (2001), some experts believe that growing crops under greenhouse structures and using the proven techniques that work for these types of systems can successfully address these problems. Greenhouse tomato production is a good example of how greenhouse and soilless culture systems can be combined to produce high value commodities with increased yields and high quality (Jensen and Malter, 1995).

The Protected Agriculture Project at the University of Florida is conducting research in production of greenhouse vegetables to find the most suitable cultivars and growing techniques for tomatoes, peppers (*Capsicum annuum* L.), cucumbers (*Cucumis sativus* L.), melons (*Cucumis melo* L.), and strawberries (*Fragaria* × *ananassa* Duchesne) (http://www.hos.ufl.edu/protectedag). The objectives of the present research were to identify suitable greenhouse tomato cultivars for the climatic conditions of north central Florida during the spring and summer months and provide tomato growers information on adaptable tomato cultivars.

Materials and Methods

A greenhouse tomato variety trial was conducted in spring 1999 to evaluate the performance (quality and yield) of 15 cultivars. Seeds were sown in rockwool cubes (Grodan, Agrodynamics, Eatontown, N.J.) on 18 Jan. 1999 and grown in an evaporative-pad-and-fan-cooled glasshouse located at the University of Florida, Horticultural Sciences Plant Facilities in Gainesville. Temperatures of 28°C day and 22°C night were maintained for optimal seedling growth for 4 weeks. Seedlings were fertilized twice a week using a 20% N, 8.8% P, and 16.6% K soluble fertilizer (Spectrum Group, Louis, Mo.) to provide 50 mg·L^{-1} (ppm) N, 23 mg L^{-1} P, and 44 mg L^{-1} K for each irrigation, as well as other essential plant nutrients (Mg, B, Cu, Fe, Mn, Mo and Zn). The cluster tomato cultivars were 'Amanda', 'Champion', 'Dynamite', 'Graziella', 'Taverna', and 'VT-906' from Zeraim Gedera (Gedera, Israel); 'Brillante', 'Daniela', 'Shirley', 'FA-593', and 'FA-852' from Hazera Seeds Inc. (Grover Beach, Calif.); and 'Tradiro' from DeRuiter (Columbus, Ohio). In addition, three beefsteak cultivars, 'Catherine' and 'FA-574' from Hazera Seeds and 'Trust' from DeRuiter, also were evaluated in this trial.

The production greenhouse used for this experiment is located at the Horticulture Research Unit in Gainesville, Fla. The structure (7,300 m^2) is a passive-ventilated high-roof Israeli-type greenhouse (Top Greenhouses Ltd., Barkan, Israel) and part of the Florida Protected Agriculture Project at the University of Florida. A double layer polyethylene roof was used to protect against strong winds and provide insulation during cold periods. The sidewalls could be raised or lowered at any time to provide additional air movement during hot summer days, and also, protection against cooler periods. Both sidewalls and roof vents were covered with an ultraviolet 50-mesh insect screen to keep unwanted insect pests from entering and to keep beneficial insects such as bumblebees and natural enemies inside the greenhouse. A pressure compensated drip irrigation system (1.9 L h^{-1}) (Netafim USA, Longwood, Fla.) was installed to provide the plants with water and nutrients as needed. An irrigation timer (Pro-Rain, Antelco, Longwood, Fla.) was used to program all irrigation schedules throughout the season.

The experiment consisted of a randomized complete block design with four blocks, in which each experimental plot consisted of six plants. On 15 Feb. 1999, the seedlings were transplanted into 1 m long × 0.10 m diameter re-sleeving white-on-black polyethylene bags (Agrodynamics) filled with coarse perlite (Airlite Processing Corp. of Florida, Vero Beach, Fla.). Particle sizes for 85% of total weight of coarse perlite is between 1.3 to 5.1 mm. Each bag contained approximately 34 L of perlite. Bags were arranged in double rows (30 m long), on 1.5 m centers (one double row to the next). Plants were spaced 36 cm apart within the row and 20 cm between rows (33,000 ha^{-1}). All plants were individually trellised on a rollerhook twine accessory (Paskal Binding Accessories, Migdal Tefen, Israel) and hooked to a steel cable harnessed at 4 m above each plant row. In addition, plastic vine clips (Paskal Binding Accessories) were placed for added support at different internodes (every 30 cm) below the leaf petiole. Auxiliary shoots or suckers were removed throughout the season to maintain a single main stem.

Daily irrigation schedules were programmed to allow a 20 to 30% leachate of the total irrigation volume per plant per day (24 hours). Plants received a complete nutrient solution that followed the guidelines for hydroponic tomato production described in Recipe 1, of 'Design suggestions and greenhouse management for rockwool vegetable greenhouses in Florida' (Hochmuth, 1998). The fertilizer recipes were mixed and held in two separate concentrated stock tank solutions as recommended by Hochmuth (1998). The complete nutrient solution was proportioned using two Dosatron (DI 16-11 GPM, Dosatron, Clearwater, Fla.) water-driven injectors and delivered to the plants through the drip system each time the plants were irrigated.

Yellow sticky traps (Whitmire Micro-Gen, Research Laboratories, St. Louis, Mo.) were used to monitor whiteflies (*Bemisia argentifolii*) and other common greenhouse pests (i.e., aphids, *Aphis gossypii*). Bumblebees (*Bombus impatiens*; NATUPOL, Koppert Biological Systems, Romulus, Mich.) were used for pollination.

Once fruit had set in each cluster, the clusters were pruned leaving only 3 to 5 fruit of uniform size. Tomatoes were harvested as a cluster and only when all fruit had reached a color grade of 4 or higher, as described by the color classification requirements in the USDA Greenhouse Tomato Standards (USDA, 1997). Fruit size categories for grading all of the cluster and beefsteak varieties were divided into small (<50 mm), medium (60 mm), large (70 mm) and extra large (>80 mm) diameters.

Total marketable yields were determined by combining the four fruit size categories for each plant. Marketable fruit consisted of uniform shape (deep globe, globe and oblate) with no misshapen fruit (i.e. cat-facing), nutritional deficiencies (blossom-end rot), or cracking.

Data were subjected to analysis of variance (SAS Institute, Cary, N.C.). Cultivar means were separated using Duncan's multiple range test, $P < 0.05$.

Results and Discussion

Cluster cultivars were compared separately from beefsteak cultivars. Cluster cultivars generally have smaller size fruit than beefsteak cultivars and are sold with the calyx still

Table 1. Marketable fruit harvested per plant of greenhouse 'cluster' tomato cultivars. Spring/Summer 1999.

	Fruit size categories[z]							
	Small		Medium		Large		X-Large	
Cultivar	no.	wt. (kg)	no.	wt. (kg)	no.	wt. (kg)	no.	wt. (kg)
Amanda	9.8 cd	0.8 cd	16.5	2.1	3.4 bcd	0.6 be	0.0 e	0.1 b
Brillante	5.6 de	0.5 de	13.5	1.9	5.6 ab	1.0 abc	0.9 cde	0.3 b
Champion	27.4 a	2.2 a	9.5	1.2	0.5 d	0.1 e	0.4 de	0.1 b
Daniela	12.9 c	1.0 c	14.9	1.9	2.6 cd	0.5 cde	0.4 de	0.1 b
Dynamite	9.9 cd	0.7 cde	13.6	1.8	3.5 bcd	0.6 b-e	0.4 de	0.1 b
Graziella	7.5 cde	0.6 cde	14.4	2.0	4.0 bc	0.7 bcd	0.5 de	0.2 b
Shirley	11.1 cd	0.9 cd	16.8	2.0	1.8 cd	0.3 de	0.0 e	0.0 b
Taverna	18.4 b	1.6 b	12.1	4.3	1.1 cd	0.2 de	0.0 e	0.0 b
FA-593	10.4 cd	0.9 cd	17.8	2.3	3.3 cd	0.6 b-e	0.5 de	0.2 b
FA-852	8.5 cde	0.8 cd	15.1	1.9	3.5 bcd	0.6b -e	0.1 e	0.03 b
VT-906	3.1 e	0.3 e	9.3	1.3	7.6 a	1.4 a	2.4 bc	0.6 a
Tradiro	7.0 de	0.7 cde	13.9	1.9	6.0 ab	1.1 ab	1.3 cde	0.3 b

[z]Fruit size categories divided into small (<50 mm), medium (60 mm), large (70 mm) and extra large (>80 mm). Fruit were harvested from 4 June to 30 June 1999. Means separation for each column was done using Duncan's multiple range test, $P < 0.05$.

attached to the fruit with 3 to 5 fruit in a cluster. After the clusters are sold, customers can pull individual fruit from the cluster. All cultivars were indeterminate and had a vigorous growth habit. There was no incidence of tobacco mosaic virus or tomato yellow leaf curl virus in any of the cultivars evaluated in this trial. Quadris (Axostrobin, Zeneca Ag. Products, Wilmington, Del.) applied at 68.9 g ha^{-1} and sulfur (Liquid Sulfur Six, Helena Chemical Co., Collierville, Tenn.) applied at 4.1 L ha^{-1} were sprayed as preventive measures against fungal diseases (i.e., powdery mildew; *Erysiphe* sp). Whiteflies, thrips, or leaf miner populations never increased to levels at which any significant economical damage occurred.

In all cases, pruning fruit clusters to 3 to 5 tomatoes resulted in more uniform sized fruit. In the case of cluster types and with the exception of 'Champion' and 'Taverna', the number of medium size (60 mm) fruit was greater than fruit in the small (<50 mm), large (70 mm), and extra-large (>80 mm) grades (Table 1). 'Champion' and 'Taverna' had greater numbers of small fruit per plant than any of the cluster cultivars. The number of medium size fruit per plant did not differ among the cluster types. However, 'Tradiro' and 'VT-906' had a greater number of large and extra-large fruit per plant than the other cultivars (6.0 and 7.6 respectively). Fruit harvested from 'Champion' had a globe shape, good fruit firmness (not soft), and uniform color (no green shoulders). It was observed that fruit from 'Taverna' plants had a more oblate shape and a darker red color.

'Champion', 'FA-593', and 'Taverna' had greater numbers of marketable fruit per plant than any of the other cluster cultivars (Table 2). The average numbers of marketable fruit per plant were 37.8, 31.6, and 32.1, respectively. The total marketable yield per plant did not differ among cluster cultivars. The average fruit weight per plant ranged from 3.3 to 6.0 kg. Marketable fruit yield per square meter did not differ among the cluster types. Marketable yield ranged from 8.1 to 19.8 kg m^{-2}.

Among beefsteak cultivars, 'FA-574' had a greater number of small fruit, but, along with 'Catherine', had greater numbers of large fruit (Table 3). The number of medium size fruit was not significantly different between 'FA-574', 'Catherine', and 'Trust'. 'FA-574' and 'Catherine' had higher marketable fruit weights per plant (3.7 and 4.0 kg, respectively) than 'Trust' (2.4 kg) (Table 4). Thus, the average marketable yield per square meter was 12.2 kg for 'FA-574' and 13.2 kg for 'Catherine'.

The yields obtained in this trial for the best cluster and beefsteak cultivars are higher than those obtained by greenhouse growers in Spain (10 to 12 kg m^{-2}) (Costa and Heuvelink, 2000). Spain is the largest greenhouse tomato producer in Europe with a season that extends from Oct. to June. In our work we had higher marketable yields over a much shorter season, 4 June to 30 June 1999.

In Florida, popular greenhouse cultivars such as 'Tradiro' (cluster) and 'Trust' (beefsteak) can have average yields of 18.0 and 37.6 kg m^{-2}, respectively (Hochmuth, 2001). These yields were obtained when tomatoes were planted in Sept. and harvested over a 5-month period, and were higher than those obtained in our trial (mean yield in the cluster types was 13.2 kg m^{-2} and 10.9 kg m^{-2} for the beefsteak types). In Canada, a strong competitor for Florida tomatoes, cultivars such as

Table 2. Average fruit weight and marketable fruit yield per plant of greenhouse 'cluster' tomato cultivars. Spring/Summer 1999.

		Marketable fruit yield[z]		
Cultivar	Avg. fruit wt. (kg)	no.	wt. (kg)	(kg·m^{-2})
Amanda	0.13	29.9 b	3.6	11.8
Brillante	0.14	25.7 bc	3.6	11.8
Champion	0.09	37.8 a	3.5	11.5
Daniela	0.12	30.9 b	3.5	11.5
Dynamite	0.12	27.5 bc	3.3	10.9
Graziella	0.13	26.5 bc	3.4	11.2
Shirley	0.12	29.6 bc	3.3	10.9
Taverna	0.19	31.6 ab	6.0	19.8
FA-593	0.13	32.12 ab	4.0	13.2
FA-852	013	27.3 bc	3.4	11.2
VT-906	0.19	22.6 c	3.7	12.2
Tradiro	0.14	28.1 bc	4.0	13.2

[z]Marketable fruit yield is the combination of all fruit size categories. Fruit were harvested from 4 June to 30 June 1999. Means separation for each column was done using Duncan's multiple range test, $P < 0.05$.

Table 3. Marketable fruit harvested per plant of greenhouse 'beefsteak' tomato cultivars. Spring/Summer 1999.

	Fruit size categories[z]							
	Small		Medium		Large		X-Large	
Cultivar	no.	wt. (kg)	no.	wt. (kg)	no.	wt. (kg)	no.	wt. (kg)
Trust	1.6 b	0.2	7.5	1.0	3.1 b	0.6 b	1.9 b	0.5 b
FA-574	4.8 a	0.4	9.3	1.3	5.0 ab	0.9 ab	3.8 ab	1.0 ab
Catherine	2.3 b	0.3	7.4	1.0	6.5 a	1.2 a	5.3 a	1.5 a

[z]Fruit size categories divided into small (<50 mm), medium (60 mm), large (70 mm) and extra large (>80 mm). Fruit were harvested from 4 June to 30 June 1999. Means separation for each column was done using Duncan's multiple range test, $P < 0.05$.

'Trust' yield 33 kg m^{-2} (Papadopoulos, 1997). Despite having lower yields than those generally obtained by greenhouse growers, our results were obtained over a 1-month harvest period and thus, a much shorter growing season. Ideally, these yields could be improved when tomatoes are planted in the greenhouse in Sept. and by prolonging the harvest season to 10 months.

Greenhouse tomato is an important commodity in Florida and with the current concern for the use of pesticides and farmland for vegetables being lost to urban development, it is very likely that more growers will consider greenhouse production. When selecting tomato cultivars, growers should consider the market demand (cluster or beefsteak), fruit characteristics (size, shape, and color), as well as the yielding potential and resistance to diseases. Florida growers should contemplate greenhouse tomato cultivars such as the cluster types 'Champion', 'Taverna', and 'Shirley' and the beefsteak cultivar 'Catherine' as potential cultivars. These cultivars had better yields (number of fruit per plant), and also good fruit quality. Results obtained in this experiment could be duplicated and even improved during the spring through summer conditions of north central Florida, especially when grown with strict nutrient and irrigation practices as described in similar trials by Hochmuth (1998) and the management practices mentioned in this report. Further cultivar trials will be needed to evaluate the influence of season, as it relates to temperature, light, humidity, and the effects these factors have on fruit yield and fruit quality for these cultivars.

Table 4. Average fruit weight and marketable fruit yield per plant of greenhouse 'beefsteak' tomato cultivars. Spring/Summer 1999.

		Marketable fruit yield[z]		
Cultivar	Avg. fruit wt. (kg)	no.	wt. (kg)	wt. (kg· m^{-2})
Trust	0.2	14.1 b	2.4 b	7.9 b
FA-574	0.2	22.8 a	3.7 a	12.2 a
Catherine	0.2	21.4 a	4.0 a	13.2 a

[z]Marketable fruit yield is the combination of all fruit size categories. Fruit were harvested from 4 June to 30 June 1999. Means separation for each column was done using Duncan's multiple range test, $P < 0.05$.

Literature Cited

Brentlinger, D. 1999. Status of the commercial hydroponic industry in the United States. Proc. Intl. Symp. Growing Media Hydroponics. Acta Hort. 481: 731-734.

Costa, J. M. and E. Heuvelink. 2000. Greenhouse horticulture in Almeria (Spain): A report in a study tour 24-29 January 2000.

Florida Agricultural Statistics Service. 2001. Florida Agricultural Statistics. Vegetable Summary, 1999-2000. Fla. Agr. Stat. Serv., Orlando.

Heacox, L. 2001. Growing undercover. American Vegetable Grower Magazine. January 2001, Vol. 49, No. 1.

Hochmuth G. 1998. Design suggestions and greenhouse management for rockwool vegetable greenhouses in Florida. Univ. Florida Coop. Ext. Serv. Bull. 327.

Hochmuth, R., L. Davis, and N. Tillman. Evaluation of greenhouse beefsteak and cluster cultivars for north Florida, 1999-2000 Season 2000-02. *http://liveoak.ifas.ufl.edu/2000-02_report.htm.*

Jensen, M. 1997. Food production in greenhouses, p. 1-14. In: Plant Production in Closed Ecosystems: The International Symposium on Plant Production in Closed Ecosystems. Kluwer, Dordrecht, The Netherlands.

Jensen, M. and A. Malter. 1995. Protected agriculture: A global review. World Bank Tech. Paper No. 253. p. 82–87.

Johnson, G. 1999. Greenhouse produce: Specialty designation fades. The Packer. 18 January, p. A1-A3.

Lucier, G., L. Biing-Hwan, J. Allshouse, and L. Kantor. 2000. Factors affecting tomato consumption in the United States, p. 26-32. In: Economic Research Service/USDA, Vegetable and Specialties/ VGS 282.

Papadopoulos, A. P., X. Hao, and J. L. Blackburn. 1997. Tomato production in open rockwool systems with NFT or rockwool feeding solutions, p. 18-21. In: Annual Report to The Harrow Greenhouse Vegetable Research Advisory Committee: Greenhouse & Processing Crops Research Centre, Ontario, Canada.

Resh, H. 1997. Hydroponic Food Production. Woodbridge Press, Santa Barbara, Calif.

Tyson, R.V., B. C. Hochmuth, G. J. Hochmuth, E. M. Lamb, and M. S. Sweat. 2001. A decade of change in Florida's greenhouse vegetable industry: 1991-2000. Proc. Fla. State Hort. Soc. Vol. 114 (In press).

USDA. 1997. United States Standards for Grades of Greenhouse Tomatoes. U.S. Dept. Agr., Agr. Mktg. Serv., Washington, D.C.