Strawberry Cultivars Grown under Protected Structure and Their Susceptibility to Natural Infestation of the Cotton Aphid, *Aphis gossypii* and to Powdery Mildew, *Sphaerotheca macularis* f. sp. *fragarie*

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Abstract

Strawberry (*Fragaria ananassa* Duchesne) cultivars were evaluated to determine their susceptibility to a natural infestation of the cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae), and powdery mildew, *Sphaerotheca macularis* f. sp. *fragarie*, in a passively ventilated greenhouse. Cultivars were planted at a density of 22 plants per m^2. No insecticide and only one fungicide application was made. Bi-weekly releases of *Aphidius colemani* L. at an approximate rate of 10 wasps per m^2 were made to control aphids. Ten strawberry leaflets were selected at random, and the total number of aphids and parasitized aphids per leaflet were counted weekly. The presence of powdery mildew also was recorded. 'Sweet Charlie' and 'Carmine' sustained the greatest average number of aphids per leaflet throughout the growing season, while FL 97-39 and 'Camarosa' had the lowest number. Populations of the aphid continued to rise in all cultivars from late November to mid January; however, 95% control by *A. colemani* was achieved by the end of February. FL 97-39 produced the most fruit and possessed the lowest number of aphids per leaflet throughout the season; however FL 97-39 was the most susceptible to powdery mildew.

INTRODUCTION

Strawberries are grown commercially in Florida on approximately 2,873 ha in open fields, with more than 95 percent of the acreage located in the Plant City area (Hillsborough County) (NASS-USDA, 2001). The mild-winter climate of the region allows Florida growers to produce strawberries while most of the U.S. is too cold to produce them. The Florida strawberry industry seeks to remain competitive during the small window of opportunity existing during mid-November to end of February when market prices are high and the volume from California is low (NASS-USDA, 2003). The ability of Florida producers to enhance early production is constrained by factors such as the loss of methyl bromide (a soil fumigant that controls soil pathogens, nematodes and weeds) unpredictable weather, land and water regulations and pesticide use. Especially important among these is the imminent ban on the use of methyl bromide in the U.S., beginning 1 January 2005 (U.S. EPA, 2002); thus there is an urgent need to develop alternatives that are safe, effective, and economically viable.

Protected agriculture is a technique used worldwide to produce many horticultural crops (Cantliffe et. al, 2001). The use of soilless growing substrates combined with protected culture eliminate the need of methyl bromide (Takeda, 2000) and the effective use of biological pest management techniques can further reduce the use of pesticides, improve fruit quality, and enable growers to market strawberries as "pesticide free" (Paranjpe, 2004). At present, the area of strawberry grown under protected cultivation in Florida is less than 1 ha (NASS-USDA, 2003); however, this is expected to increase as growers look for alternatives in the post-methyl bromide era (Paranjpe, 2004).

From the strawberry growers' perspective, earliness, high fruit yield, fruit firmness, good external appearance, and resistance to arthropods and diseases are the most important characteristics to target for a successful crop. Besides twospotted spider mites, two of the main greenhouse grown strawberry pests are the cotton or melon aphid,

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Aphis gossypii Glover, and powdery mildew, *Sphaerotheca macularis* f. sp. *fragarie.* Moderate to low humidity combined with low light intensity and poor air circulation create a good environment for the proliferation of both pests (Belanger and Labbe, 2002).

The objective of this research was to determine the susceptibility of seven strawberry cultivars grown under protected structure to natural infestation of the cotton aphid, *A. gossypii*, and powdery mildew, *S. macularis.* Results from this investigation will provide a basis for selection of cultivars to use in the greenhouse.

MATERIALS AND METHODS

The experiment was conducted at the University of Florida, Horticulture Unit from 1 October 2002 – 26 March 2003. Polygal® 'Hanging Bed-Pack' troughs, with planting holes spaced 17.5 cm apart, were used as growing containers. Troughs were suspended 1.8 m above the ground and pine bark was used as growing medium. The methodology followed was described in detail by Paranjpe (2004) and Paranjpe et al. (2003).

Strawberry Cultivars

Seven strawberry cultivars were arranged in a randomized complete block design with three replications per treatment (cultivar). Each plot was 1 m long with 9 plants per plot at a density of 22 plants per m^2. The cultivars evaluated were: 'Strawberry Festival', 'Sweet Charlie', 'Earlibrite', 'Carmine', FL 97-39, 'Treasure', and 'Camarosa'. The first five cultivars were developed at the University of Florida Institute of Food and Agricultural Sciences strawberry research center at Dover by Dr. Craig Chandler, 'Treasure' was developed by Dr. Peggy Chang, a private strawberry breeder in Florida, and 'Camarosa' was developed by the University of California.

Biological Control Program

No insecticides or miticides were used throughout the season. Monthly preventive releases of the predatory mite *Neoseiulus californicus* McGregor (Biotactics Inc., Perris, CA) at 4 per m^2 were made for controlling twospotted spider mites. *Aphidius colemani* L. (IPM laboratories, Locke, NY) at 10 per m^2 were released bi-weekly to control aphids. One application of sulphur was made 11 January to control powdery mildew.

Scouting and Harvesting Protocol

Live and parasitized aphids ('mummies') were monitored weekly by counting those on 10 randomly selected leaflets in each plot with the aid of 5X and 14X hand lenses. Presence or absence of powdery mildew was recorded once a week by a random sample of 10 leaflets per plot.

Fruits were harvested at 80% color development at 4 to 5 day intervals to determine total yield per each treatment. Fruits that weighed more than 10 g and were not deformed or diseased were considered marketable.

Data Analysis

Aphid infestation, powdery mildew incidence, and fruit yield were subjected to analysis of variance (ANOVA) and Least Significant Differences (LSD) among treatments using Duncan's multiple range tests. Analysis was conducted using SAS software (SAS Institute Inc., 1999-2001).

RESULTS AND DISCUSSION

Aphid Infestation and Biological Control

Data presented on table 1 are monthly averages. Aphid infestation levels were low at the beginning of the season; however, within 21 days after transplanting, aphid populations started to increase rapidly particularly on 'Sweet Charlie' and 'Carmine', two early-producing cultivars. Aphid populations on all cultivars were highest during mid-

December through early January, with 'Sweet Charlie' and 'Carmine' sustaining as much as 665 ± 23 aphids per leaflet (11 December), and 614 ± 33 aphids per leaflet (4 December), respectively. Mid-season producing cultivars such as 'Strawberry Festival' and 'Treasure' sustained their highest aphid densities on 7 January with 394 ± 24 aphids per leaflet and 417 ± 27 aphids per leaflet, respectively. A late cultivar such as 'Camarosa' sustained the highest aphid densities on 17 December (255 ± 18 aphids per leaflet). Data collected suggested that the later the fruiting of the cultivar the less it was susceptible to aphid infestation. Due to a shipment of sub-standard parasitic wasps and low temperatures during November and December (15 - 20°C daily mean temperatures) the parasitic wasps did not effectively control the aphids early. *A. colemani* densities were very low on all cultivars (less than 1 mummy per leaflet) until 7 January (Table 1). By 21 January, the highest number of mummies was recorded on 'Treasure' (63 ± 13 mummies per leaflet). Despite the initial delay, about 95% control was achieved by the end of the season.

Powdery Mildew

Powdery mildew incidence was observed throughout the season in most cultivars from late October to mid-January. Only one application of sulphur was made on 1 January to control mildew. By 7 January the incidence decreased, however a rapid increase of powdery mildew was observed weeks later (Table 2). FL 97-39 hosted the highest incidence of powdery mildew throughout the season with a peak on late January and early February (97 ± 2 % infestation). 'Carmine" had the least powdery mildew among the cultivars evaluated ($F=3.56$, $df= 6, 41$, $P < 0.05$).

Total Marketable Yield

Total marketable yield from 'Carmine' was significantly greater than from 'Treasure', 'Earlibrite', 'Camarosa', and 'Sweet Charlie', but was not significantly different from FL 97-39 and 'Strawberry Festival' (Table 3). Mean fruit weights for FL 97-39, 'Treasure' and 'Earlibrite' were not significantly different from each other but were significantly greater those of 'Carmine', 'Strawberry Festival', 'Camarosa' and 'Sweet Charlie'. Percentage of marketable yield of 'Treasure' was significantly higher than that of the other six cultivars. Although FL 97-30 and 'Carmine' were among the highest yielding cultivars, FL 97-30 was susceptible to powdery mildew and 'Carmine' sustained one of the highest aphid infestations observed during the season. FL 97-30 likely would not be recommended for greenhouse production since it is very susceptible to powdery mildew.

Cultivars are almost exclusively bred for field production and information regarding their performance under protected culture is limited (Paranjpe, 2004). Since aphids and powdery mildew are important pests in protected strawberry culture future cultivar selections should be made based on both pests. The greenhouse industry would benefit from the identification of cultivars that produce high early yields and possess low susceptibility to cotton aphid and to powdery mildew. If reliability of *A. colemani* as a control agent for cotton aphid can be improved under Florida's winter conditions, 'Carmine' and 'Strawberry Festival' could emerge as a strong candidate for greenhouse production. Nowadays, 'Strawberry Festival' is being largely used in field strawberry production. Additional long term work should be performed to determine if indeed these cultivars and/or others can be relied upon to sustain a protected strawberry industry in a post-methyl bromide era.

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Tables

Table 1. Monthly averages (mean ± SE) of *Aphis gossypii* Glover and *Aphidius colemani* L. on seven cultivars of strawberry grown under protected culture during the 2002 –2003 production.

Strawberry Varieties	Months											
	October		November		December		January		February		March	
	A. g.*	A.c.**	A.g.	A.c.	A.g.	A.c.	A.g.	A.c.	A.g.	A.c.	A.g.	A.c.
FL 97-39	2±0	0±0	55±8	0±0	202±34	3±1	107±6	5±2	2±0	7±2	0±0	10±2
Carmine	4±1	0±0	168±13	0±0	482±42	3±1	206±13	12±3	6±2	22±1	0±0	15±2
Strawberry Festival	1±0	0±0	75±13	0±0	268±36	6±2	168±15	24±3	5±2	16±2	0±0	12±1
Treasure	1±0	0±0	20±5	0±0	220±29	4±1	220±12	28±4	8±2	19±5	0±0	11±3
Earlibrite	1±0	0±0	50±12	0±0	241±32	1±0	173±10	14±2	7±2	17±5	0±0	8±2
Camarosa	3±0	0±0	32±8	0±0	233±33	2±0	104±9	7±2	2±0	10±3	0±0	18±3
Sweet Charlie	1±0	0±0	202±34	0±0	566±46	4±1	285±12	35±3	11±3	25±3	0±0	45±12

* *Aphis gossypii*: A.g. ** *Aphidius colemani*: A.c.

Table 2. Monthly averages rates* (mean ± SE) of *Sphaerotheca macularis* f. sp. *fragarie* infestation on seven cultivars of strawberry grown under protected culture during the 2002 –2003 production.

Strawberry Varieties	Months					
	October	November	December	January	February	March
FL 97-39	0 ± 0	6 ± 2	5 ± 1	8 ± 2	8 ± 2	5 ± 1
Carmine	0 ± 0	1 ± 0	1 ± 0	2 ± 1	3 ± 1	4 ± 1
Strawberry Festival	0 ± 0	2 ± 1	2 ± 1	3 ± 1	3 ± 1	1 ± 0
Treasure	0 ± 0	2 ± 1	2 ± 1	2 ± 1	3 ± 1	1 ± 0
Earlibrite	0 ± 0	3 ± 1	3 ± 1	5 ± 1	5 ± 1	0 ± 0
Camarosa	0 ± 0	5 ± 1	2 ± 1	3 ± 1	1 ± 0	0 ± 0
Sweet Charlie	0 ± 0	3 ± 1	3 ± 1	2 ± 1	3 ± 1	4 ± 1

* rates: 0: no powdery mildew; 5: moderate powdery mildew; 10: high powdery mildew.

Table 3. Total marketable yield for seven strawberry cultivars grown in soilless culture in a passively ventilated greenhouse, Gainesville, Fl 2002-2003.

Cultivar	Marketablefruit yield[y]		Mean fruit weight	Percentage marketable yield[x]	
	fruit.plant^{-1}	g.plant^{-1}	g.fruit^{-1}	% (fruit.plant^{-1})	%(g.plant^{-1})
FL 97-39	24.0 ab[z]	517.2 a	21.5 a	73.2 b	89.8 ab
Carmine	26.2 a	488.5 a	18.6 bc	76.3 b	89.3 b
Strawberry Festival	22.2 abc	483.3 ab	19.7 b	77.3 b	89.9 ab
Treasure	19.4 bc	423.4 ab	21.8 a	85.3 a	94.3 a
Earlibrite	18.0 c	404.5 ab	22.5 a	74.1 b	88.9 b
Camarosa	18.0 c	344.3 b	19.2 b	77.0 b	83.7 bc
Sweet Charlie	18.4 c	325.6 b	17.6 c	63.7 c	80.6 c

[z]Means followed by the same letter within a column are not significantly different based on Duncan's Multiple range Test (alpha=0.05).
[y]Includes fruits that weight more than 10g and were not deformed or diseased.
[x]Statistical analysis performed on arcsine square root transformed data, means presented are not transformed.