

Effect of Organic and Chemical Fertilizers on Growth and Yield of Hot Pepper, and Insect Pests and Their Natural Enemies

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ABSTRACT

The effects of organic and synthetic chemical fertilizers on crop growth, yield and associated insect pests were studied for two varieties of hot pepper (*Capsicum chinense* Jacquin (Solanaceae)): "Scotch Bonnet" and "Caribbean Red" in north Florida. Hot peppers were grown under three treatments: poultry manure; mushroom compost; or "Growers' Practice", (conventional pesticides and chemical fertilizers), with equivalent amounts of soil nutrients applied to all treatments. The Growers' Practice treatment permitted use of conventional insecticides if insect pests exceeded economic thresholds. Results showed that although plant height and canopy diameter were significantly greater in the mushroom compost treatment for Scotch Bonnet, yields were not significantly affected by treatment or variety. The Growers' practice treatment resulted in lowest plant height in Caribbean Red. Predominant insect pests found were the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (Hemiptera: Aleyrodidae); green peach aphid, *Myzus persicae* (Sulzer) (Hemiptera: Aphidae); bandedwinged whitefly, *Trialeurodes abutilonea* (Haldeman) (Hemiptera: Aleyrodidae); and western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). Significantly more insect pests were found on Caribbean Red than on Scotch Bonnet, but in none of the treatments did pests reach economic injury levels. Therefore, insecticide treatment was not necessary during the seasons tested. Furthermore, the crops may be grown using relatively inexpensive organic fertilizers because the use of synthetic chemical fertilizers does not result in higher yields. Yields realized in the three treatments ranged from average to above average for both varieties of pepper. Findings are consistent with economic reports from other countries. We conclude that organic methods can be profitable for growers in Florida provided pests remain below the economic threshold levels.

Additional Index Words: Scotch Bonnet, Caribbean Red, *Capsicum chinense*.

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Hot peppers in the genus *Capsicum* belong to the nightshade family, Solanaceae. Whereas chile peppers are grown as perennial shrubs in suitable tropical climates of Central America, they are mostly cultivated as annuals in the United States. There are over 20 species of *Capsicum* peppers but most are considered undomesticated. The numerous varieties of domesticated *Capsicum* peppers belong to one of five species, including *Capsicum chinense* Jacquin.

Native to the Caribbean, the Scotch Bonnet

variety of *C. chinense* possesses an apple-cherry tomato flavor; mature fruits measure 2.5 to 3.8 cm in length and 2.5 to 3.8 cm in diameter (Gardner and Queeley 1999). This variety is one of the hottest peppers with reported Scoville Heat Unit (SHU) ratings from 200,000 to 300,000 (ratings above 70,000 are considered extreme). Scotch Bonnet is a renowned export of Jamaica where hot peppers generate >\$1 million per annum in revenue and employ >3000 people (Pollard and Chandler 2000). Key pests of the

Scotch Bonnet variety include gall midges (*Contarinia lycopersici* and *Prodiplosis longifila*), the broad mite (*Polyphagotarsonemus latus*) and aphids (*Aphis gossypii* and *Myzus persicae*). Plant material infested with gall midges is subject to quarantine restrictions in the United States, which is a major market for hot peppers.

As its name implies, the Caribbean Red variety of *C. chinense* also is native to the Caribbean. The variety has bright red, wrinkled fruits about 2.5 cm wide, with a fruity flavor. Like Scotch Bonnet, Caribbean Red is also a very hot pepper, measuring as much as 445,000 SHU in dried samples.

The production of hot *Capsicum* variety peppers is a growing industry in the United States because of increased demand for spicy condiments and hot sauce. These peppers are potentially valuable niche crops for small-scale farmers (Gardner and Queeley 1999). In this paper, we studied the effects of different crop management strategies on plant growth, yield, and insect populations in Scotch Bonnet and Caribbean Red hot pepper varieties in Florida.

MATERIALS AND METHODS

Seedling preparation. Seedlings were prepared in a greenhouse at the Florida A&M University, Tallahassee, FL. Scotch Bonnet and Caribbean Red seeds were obtained from Jamaica and Johnny's Selected Seeds (Albion, ME), respectively. Seeds were sowed in 72 cell plastic flat trays each measuring 61 x 28 cm (Landmark Plastic Corp., Akron, OH). One to three seeds were sowed per tray cell on a commercial growing medium ("Pro-Mix", Premier Horticulture, Quebec, Canada). Seedlings were fertilized once with ammonium nitrate (34-0-0) 3 weeks after germination and watered as needed. To prevent insect damage in the greenhouse, the trays were covered with a poly-organza mesh (Fishman's Fabrics, Inc., Chicago, IL) supported by PVC (61 x 228 x 122 cm) for the first 4 weeks.

Agronomic treatments. The field site was located at the Florida A&M University Research and Extension Center in Quincy, FL. Standard agronomic and management practices for the region were followed. A randomized complete block design was used with three treatments and four blocks for each pepper variety. The field site was divided lengthwise into two equal sections. Each section was planted with four rows each of Scotch Bonnet or Caribbean Red, separated by a 3.7 m buffer. Each row was divided into three sections (7.6 x 1.8 m); each section received one of the following treatments: A) Integrated Pest Management (IPM) – Poultry manure; B) IPM – Mushroom compost; or C) Growers' Practice

(conventional fertilizers and pesticides, Webb et al. 2002). Soil analysis was performed prior to the experiment to determine nutrient availability and to allow calculation of organic or synthetic fertilizer requirements in order that equivalent amounts of soil nutrients would be applied under all treatments.

Soil samples were collected from the field site for nutrient analysis and sent to the University of Florida, Institute of Food and Agriculture Sciences, Extension Soil Testing Laboratory. Soil samples were tested for pH, phosphorous, potassium, magnesium and calcium. Poultry manure and mushroom compost were sent to Waters Agricultural Laboratories, Inc., Camilla, GA and were analyzed for total nitrogen, phosphorous, and potassium, sulfur, boron, zinc, manganese, iron, copper, calcium, magnesium, sodium, aluminum, moisture content, and pH. Based on fertilizer recommendations for pepper (Hochmuth and Hanlon 1998) and nutrient analyses of soil, fertilizer and compost material, the following soil nutrient and fertilizer application rates were calculated (per 7.62 linear m or 25 linear feet): A) IPM – Poultry manure: 14.1 kg; B) IPM – Mushroom compost: 56.7 kg; and C) Growers' Practice: 22.7 kg N synthetic chemical premium fertilizer (10-10-10) plus ammonium nitrate (34-0-0). The Growers' Practice treatment allowed for the use of synthetic insecticides in the event that insect counts exceeded economic threshold limits (Webb et al. 2002).

In May 2003, chemical fertilizer was applied to the Growers' Practice treatment plots. Organic soil nutrients were applied manually. UV reflective mulch was used upon fumigation of the soil with methyl bromide. Weeds were sprayed once during the season using Gramoxone Extra (paraquat dichloride). Hot pepper seedlings were transplanted into the field on May 28th and planted in rows at intervals of 0.9 m.

Plant measurements. Plant height and canopy diameter (cm) were measured every 14 days. We sampled 10 plants per treatment. Mature fruits were sample harvested for each pepper variety at 14-day intervals from September 1 to November 24, 2003. All mature fruits were picked from each of two plants within a plot or replicate and placed in Ziplock[®] plastic bags (S.C. Johnson and Son, Racine, WI). Plants were flagged to continuously sample the same plants throughout the season. The fruits were weighed on a laboratory analytical scale (Sartorius AG, Goettingen, Germany).

Insect sampling. Insect pests and their natural enemies were sampled using yellow sticky cards (7.6 x 12.7 cm) (Olson Products, Median, OH), which were placed on bamboo stakes (1 m high) and secured with twist ties. Four sticky cards were used per treatment and they were replaced every 14 days. Cards were

collected in Ziploc[®] plastic bags (17.8 x 20.3 cm, S.C. Johnson and Son, Racine, WI) and stored in a freezer prior to analysis. For each variety, we recorded the numbers and species of adult insect pests (silverleaf whitefly, bandedwinged whitefly, aphids, thrips) and their natural enemies (ladybugs and syrphids).

Statistical analyses. Plant height and canopy diameter were analyzed using Repeated Measures ANOVA (Zar 1999). When treatment effects were significant, means were separated using the Bonferroni correction method for means separation. Yields were compared by calculating the mean total yield for each treatment in grams of peppers. Cumulative totals at the end of the season were compared using One-Way ANOVA. Total numbers of insect pests were calculated by adding counts of the dominant pests, i.e., whiteflies, aphids, and thrips collected on each trap at each sampling date. Similarly, numbers of key insect natural enemies were obtained by adding ladybugs and syrphids on each trap. Student's t-tests were performed on numbers of pests and natural enemies between the varieties. Insect counts (by species or class) were analyzed using Two-Way ANOVA. Each species or class was analyzed as a dependent factor by sampling date and agronomic treatment, which were independent factors. When treatment effects were found to significantly affect either plant yield or insect counts, means were separated using Tukey's HSD at $P = 0.05$. In all ANOVA tests, the two varieties of hot pepper were analyzed separately. All statistical analyses were performed using Systat 10.2 software (Systat Software, Inc., Point Richmond, CA).

RESULTS

Plant measurements. Plant height during the season is shown for both Scotch Bonnet and Caribbean Red (Fig. 1). In the Scotch Bonnet variety, the treatment effects were highly significant, with increased plant height evident in peppers grown under the mushroom compost treatment ($F = 5.69$; $df = 2, 27$; $P = 0.009$; Bonferroni method, $P < 0.05$; Fig. 1A). In Caribbean Red, plant height was significantly affected by treatment, with declined growth evident in the Growers' practice ($F = 4.99$; $df = 2, 27$; $P = 0.014$; Bonferroni method, $P < 0.05$; Fig. 1B).

Crop canopy measurements during the season are shown for both pepper varieties (Fig. 1). In Scotch Bonnet, treatment significantly affected canopy growth ($F = 7.21$; $df = 2, 27$; $P = 0.003$; Fig. 1C). The mushroom compost treatment produced the largest canopy diameters, followed by the poultry manure; Growers' practice resulted in smallest plant canopies. No statistically significant differences in canopy

diameter were found in Caribbean Red ($F = 2.61$; $df = 2, 27$; $P = 0.092$; Fig. 1D).

Yield was not significantly affected by treatment in either Scotch Bonnet peppers ($F = 0.74$; $df = 2, 9$; $R^2 = 0.14$; $P = 0.51$; Fig. 2A), or Caribbean Red ($F = 1.48$; $df = 2, 9$; $R^2 = 0.25$; $P = 0.277$; Fig. 2B). Total yields of Scotch Bonnet were 2038, 2110, and 3378 g per season in the Growers' practice, poultry manure and mushroom compost treatments, respectively (Fig. 2A inset). Corresponding yields in Caribbean Red were 3111, 4805, and 4594 g in Growers' practice, poultry manure and mushroom compost treatments, respectively (Fig. 2B inset).

In this study, plant height and canopy diameter for Scotch Bonnet were significantly greater in the IPM-mushroom treatment, despite all treatments receiving equivalent amounts of soil nutrients. Furthermore, for Caribbean Red, the Growers' practice treatment resulted in the lowest plant height but there were no treatment effects on canopy diameter. Yields were not significantly affected by treatments in either variety of hot pepper. For both varieties of hot pepper, synthetic fertilizers did not significantly increase plant height, canopy diameter or yield.

Insect sampling. Insect counts in the Growers' Practice treatment never exceeded economic threshold limits, so no insecticides were applied during the experiment. Student's t-tests on aggregate insect counts indicated significantly more insect pests on Caribbean Red than on Scotch Bonnet (Caribbean Red = 28.990 ± 3.361 (mean \pm SE, $n = 96$); Scotch Bonnet = 15.99 ± 1.891 ($n = 96$) ($t = 3.371$; $df = 149.7$; $P = 0.001$). However, there were no significant differences in total counts of natural enemies between the varieties (Caribbean Red = 0.729 ± 0.130 ($n = 96$); Scotch Bonnet = 0.917 ± 0.129 ($n = 96$) ($t = 1.023$; $df = 190$; $P = 0.308$). Insects captured with sticky cards are shown for Scotch Bonnet (Fig. 3) and Caribbean Red (Fig. 4). Predominant pest insects found were: A) the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (Hemiptera: Aleyrodidae); B) aphids, primarily the green peach aphid, *Myzus persicae* (Sulzer) (Hemiptera: Aphidae); C) thrips, primarily the Western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), and D) the bandedwinged whitefly, *Trialeurodes abutilonea* (Haldeman) (Hemiptera: Aleyrodidae). Natural enemies recorded were: E) ladybugs, mostly *Coleomegilla maculata* de Geer and *Hippodamia convergens* Guerin-Meneville (Coleoptera: Coccinellidae), and F) syrphid flies (Diptera: Syrphidae). In both the Scotch Bonnet and Caribbean Red varieties, sampling date often produced a highly significant effect on number of insects recorded.

Fig. 1

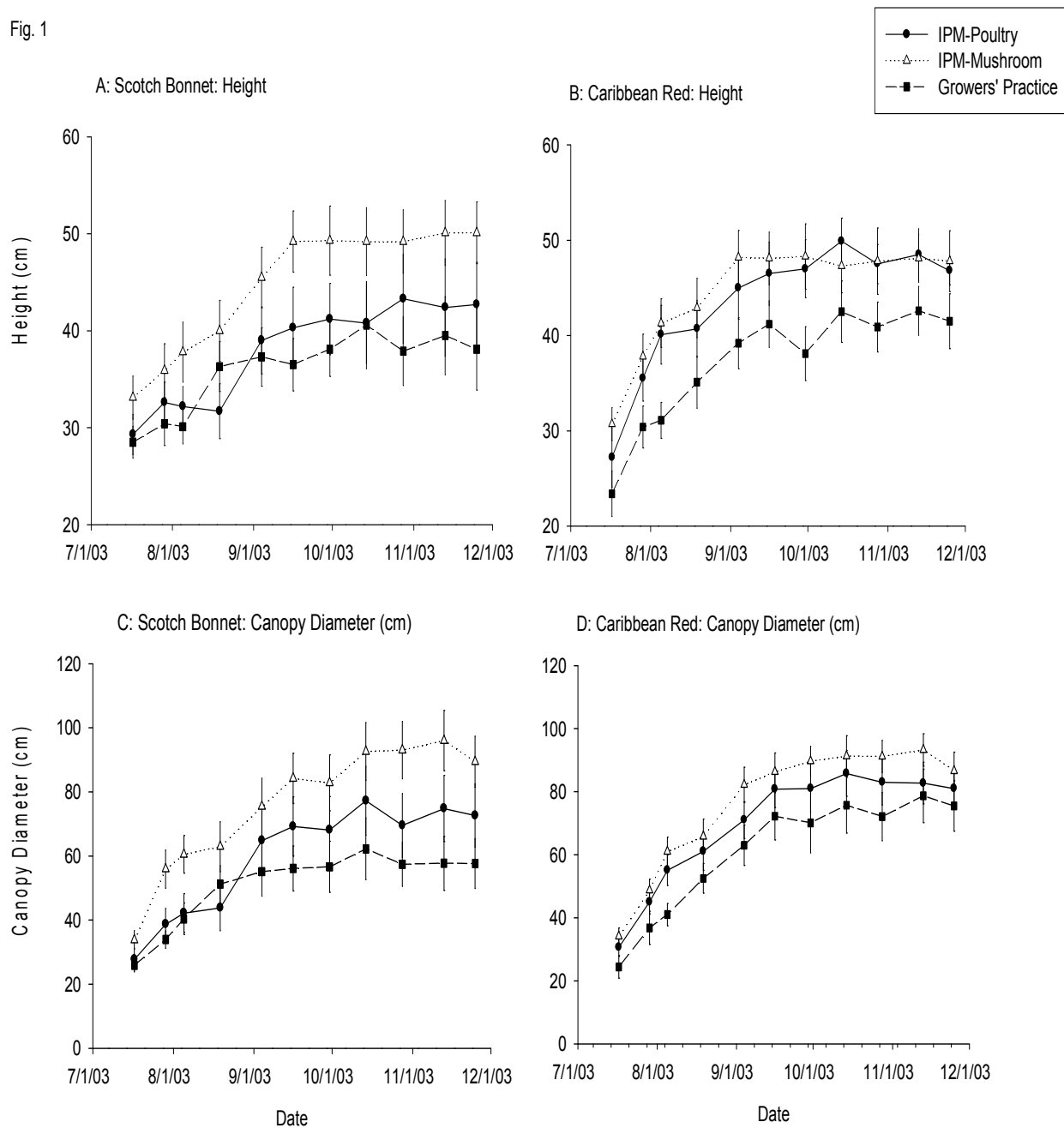


Fig. 1. Plant height (cm, mean \pm SE) and canopy diameter (cm, mean \pm SE) during the growing season of the hot pepper varieties Scotch Bonnet and Caribbean Red using agronomic practices based on poultry manure, mushroom compost and growers' practices. Height measurements for Scotch Bonnet (A) and Caribbean Red (B); Plant canopy diameter of Scotch Bonnet (C) and Caribbean Red (D). Statistical analyses using Repeated Measures ANOVA showed significant differences in crop height and canopy diameter in Scotch Bonnet and in crop height in Caribbean Red.

Fig. 2

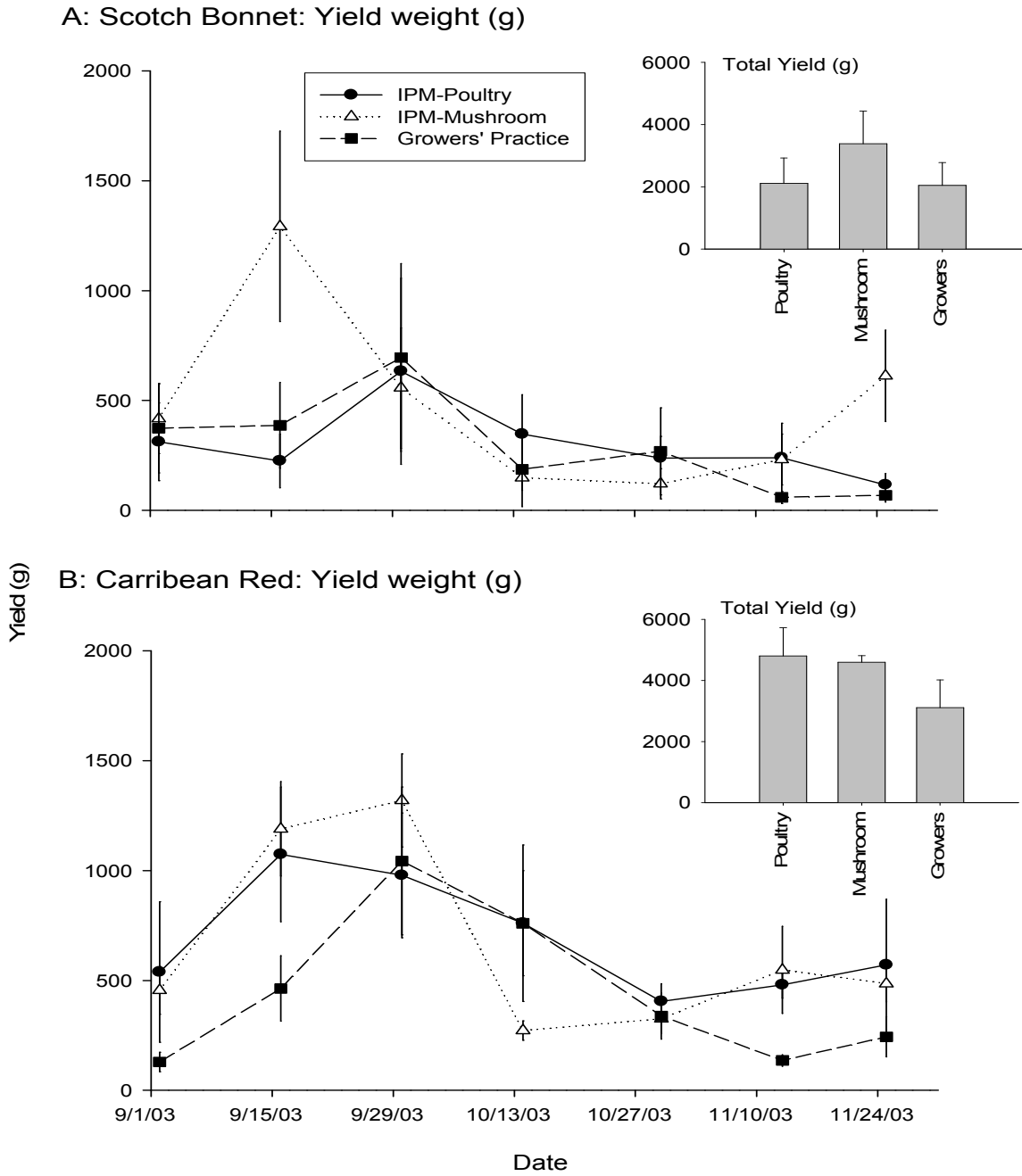


Fig. 2. Fruit yield of A) Scotch Bonnet and B) Carribean Red hot peppers collected during the season. Insets indicate mean total yields for each fertilizer treatment for the entire season. Cumulative yield was not affected by using poultry manure, mushroom compost or Growers' practices in either pepper variety.

Fig. 3

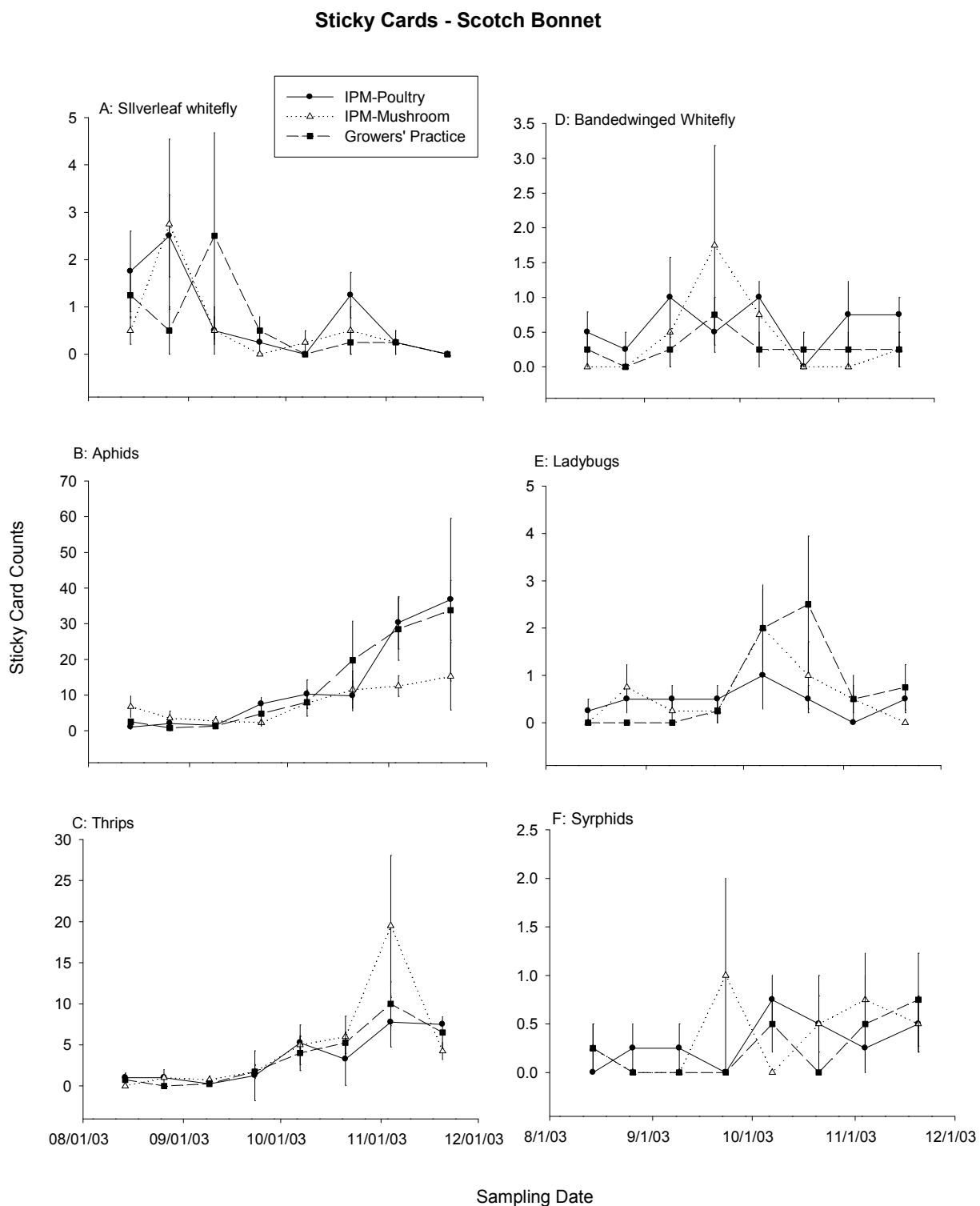


Fig. 3. Sticky card insect counts in Scotch Bonnet according to agronomic treatment and sampling date (mean \pm SE) per sticky card (7.6 x 12.7 cm): A) silverleaf whitefly, *Bemisia argentifolii*; B) aphids, primarily green peach aphid, *Myzus persicae*; C) thrips, primarily Western flower thrips, *Frankliniella occidentalis*; D) bandedwinged whitefly, *Trialeurodes abutilonea*; E) ladybugs, mostly *Coleomegilla maculata* and *Hippodamia convergens*; and F) syrphid flies.

Fig. 4

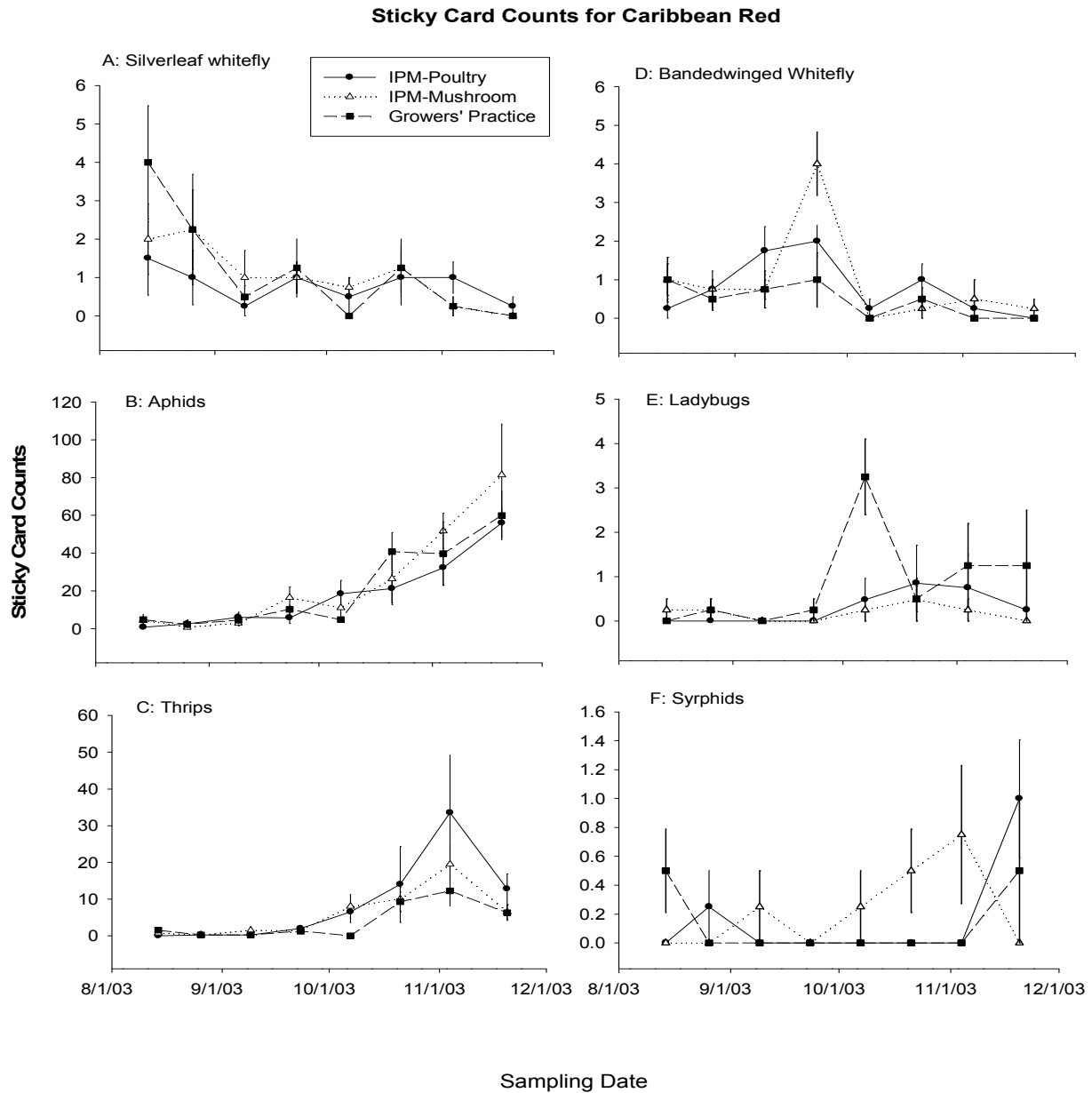


Fig. 4. Sticky card insect counts in Caribbean Red according to agronomic treatment and sampling date (mean \pm SE) per sticky card (7.6 x 12.7 cm): A) silverleaf whitefly, *Bemisia argentifolii*; B) aphids, primarily green peach aphid, *Myzus persicae*; C) thrips, primarily Western flower thrips, *Frankliniella occidentalis*; D) bandedwinged whitefly, *Trialeurodes abutilonea*; E) ladybugs, mostly *Coleomegilla maculata* and *Hippodamia convergens*; and F) syrphid flies.

Table 1. Statistical Analysis of Sticky Card insect data on Scotch Bonnet and Caribbean Red hot pepper varieties.

Insect	R ²	Factor	df	F	P
Scotch Bonnet					
Silverleaf whitefly	0.272	Date	7, 72	1.666	0.131
		Treatment	2, 72	0.240	0.787
		Date x treatment	14, 72	1.056	0.411
Aphids	0.470	Date	7, 72	7.279	<0.001
		Treatment	2, 72	1.298	0.279
		Date x treatment	14, 72	0.731	0.737
Thrips	0.521	Date	7, 72	8.913	<0.001
		Treatment	2, 72	0.800	0.453
		Date x treatment	14, 72	1.018	0.446
Bandedwinged Whitefly	0.264	Date	7, 72	1.813	0.098
		Treatment	2, 72	1.219	0.301
		Date x treatment	14, 72	0.761	0.706
Ladybugs	0.369	Date	7, 72	3.872	0.001
		Treatment	2, 72	0.631	0.535
		Date x treatment	14, 72	0.986	0.477
Syrphids	0.212	Date	7, 72	0.951	0.473
		Treatment	2, 72	0.281	0.756
		Date x treatment	14, 72	0.871	0.593
Caribbean Red					
Silverleaf whitefly	0.365	Date	7, 72	4.203	0.001
		Treatment	2, 72	0.625	0.538
		Date x treatment	14, 72	0.771	0.696
Aphids	0.673	Date	7, 72	19.491	<0.001
		Treatment	2, 72	1.079	0.345
		Date x treatment	14, 72	0.687	0.779
Thrips	0.517	Date	7, 72	8.674	<0.001
		Treatment	2, 72	2.383	0.099
		Date x treatment	14, 72	0.817	0.648
Bandedwinged Whitefly	0.613	Date	7, 72	10.07	<0.001
		Treatment	2, 72	2.949	0.059
		Date x treatment	14, 72	2.468	0.007
Ladybugs	0.461	Date	7, 72	5.176	<0.001
		Treatment	2, 72	2.095	0.130
		Date x treatment	14, 72	1.520	0.126
Syrphids	0.379	Date	7, 72	1.714	0.119
		Treatment	2, 72	0.438	0.647
		Date x treatment	14, 72	2.223	0.015

However, counts of both pests and natural enemy insects were not affected by treatment (Table 1).

DISCUSSION

Hot peppers are important crops in many developing countries. However, improper or inadequate crop management practices can result in poor crop yields and high production costs (Vos and Duriat 1995). In Indonesia where hot peppers (*C. annuum* and *C. frutescens*) are among the highest acreages and values of all low elevation vegetables (Vos and Sumarni 1997), production costs are often high due to the unbalanced application of fertilizers and improper pesticide use against incorrect target pests. Nitrogen application rates can exceed 500 kg/ha, with no application of potassium and phosphorous (Vos and Duriat 1995) despite an optimal application rate of about 150 kg N/ha (Vos and Frinking 1997).

Different nitrogen sources are known to cause differences in plant growth in the hot pepper *C. frutescens*. Owusu et al. (2000) tested four sources of nitrogen: urea, ammonium sulfate, ammonium nitrate and potassium nitrate on four varieties in Ghana. To evaluate the effects of these nitrogen sources, they measured plant height, number of leaves, plant girth, numbers of primary and secondary branches, and leaf greenness. The nitrate sources produced taller and greener plants with larger girths, more fruits and consequently, higher yields. The use of ammonium nitrate resulted in 72 – 101% higher yields than ammonium sulfate, the most common form of nitrogen in Ghana.

In Indonesia, major insect pests reported on hot pepper include thrips (*Thrips parvispinus* Karny) (Thysanoptera: Thripidae), the yellow tea mite (*Polyphagotarsonemus latus* Banks) (Acari: Tarsonemidae), the tropical armyworm (*Spodoptera litura* F.) (Lepidoptera: Noctuidae), Oriental fruit fly (*Bactrocera dorsalis* Hendel) (Diptera: Tephritidae), cotton bollworm (*Heliothis armigera* (Hübner) (Lepidoptera: Noctuidae) and cotton jassid (*Empoasca lybica* de Bergevin and Zanon) (Hemiptera: Cicadellidae) (Vos and Frinking 1997).

In this study, predominant pest insects of hot pepper included the silverleaf and bandedwinged whiteflies, green peach aphid, and western flower thrips. Natural enemies found included ladybugs and syrphid flies. Silverleaf whiteflies occurred early in the crop, whereas aphids and thrips peaked later. Banded winged whitefly populations peaked when the fruit was most abundant. Ladybugs feed on aphids and tended to be abundant when aphid prey was also present in large numbers. Syrphids seemed to be

present continuously in moderate numbers. Significantly more pests were found on Caribbean Red than Scotch Bonnet, but none reached economic injury levels, regardless of treatments. In addition, most of the mature hot peppers were produced during the first 6 weeks from September to October which may have affected the build-up of insect pests. Except for silverleaf whitefly, most of the pests peaked later in the cropping season while the natural enemies continued to increase through most of the season. These results indicate that hot peppers may be grown in Florida without using insecticides when insect pests do not reach economic injury levels. The presence of natural enemies throughout the cropping season may have suppressed the pest populations.

Peppers may be grown using relatively inexpensive organic fertilizers because the use of synthetic chemical fertilizers does not result in higher yields, and treatment yields reported compare favorably against other findings. The average yield realized by Scotch Bonnet farmers in Jamaica who use the standard growers practice (15 - 5 - 35) at 112 kg/ha, ranges from 5000 to 6000 kg/ha. Our findings of 2038 g per season, would translate into 6038 kg/ha, slightly higher than what is realized in Jamaica where the crop is very popular. Our finding of 3111 g per season for Caribbean Red translates into 9287 kg/ha, also higher than the 7000 to 8000 kg/ha we have observed from previous on station trials. For the poultry manure treatment, 2110 g per season for Scotch Bonnet translates to 6299 kg/ha, also rated average to above average. For Caribbean Red, 4805 g per season translates to 14,343 kg/ha, which is relatively high. For the mushroom compost treatment, 3378 g per season translated into 10,083 kg/ha for Scotch Bonnet and 4594 g per season translated into 13,713 kg/ha for Caribbean Red – both yields are relatively high. Therefore, yields obtained here using organic methods compared favorably against reported yields. Organic farming methods for hot peppers can be profitable for growers in Florida provided insect pests remain below economic threshold levels.

ACKNOWLEDGMENTS

We thank Ignacio Baez, Kristen Bowers and Marcus Edwards (USDA, ARS, CMAVE, FAMU-CBC) for technical assistance. Florida A&M University (FAMU) students, Jeffery Head, Elizabeth Aninakwa, Travis Watkins, and FAMU staff, Mohamed Soumare and Frank Chambers, also assisted with this study. We appreciate the generosity of the owners of B & H Poultry Farm, Camilla, GA and Quincy Farms, Greensboro, FL for providing the poultry manure and mushroom compost, respectively,

at no cost. Helpful reviews on the manuscript were provided by Drs. Andrew Rasmussen, Ralph Wills Flowers (Florida A&M University, Tallahassee, FL) and an anonymous reviewer. This research was funded in part by the Center for Cooperative Agricultural Programs jointly administered by University of Florida, Gainesville and FAMU, Tallahassee, FL.

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