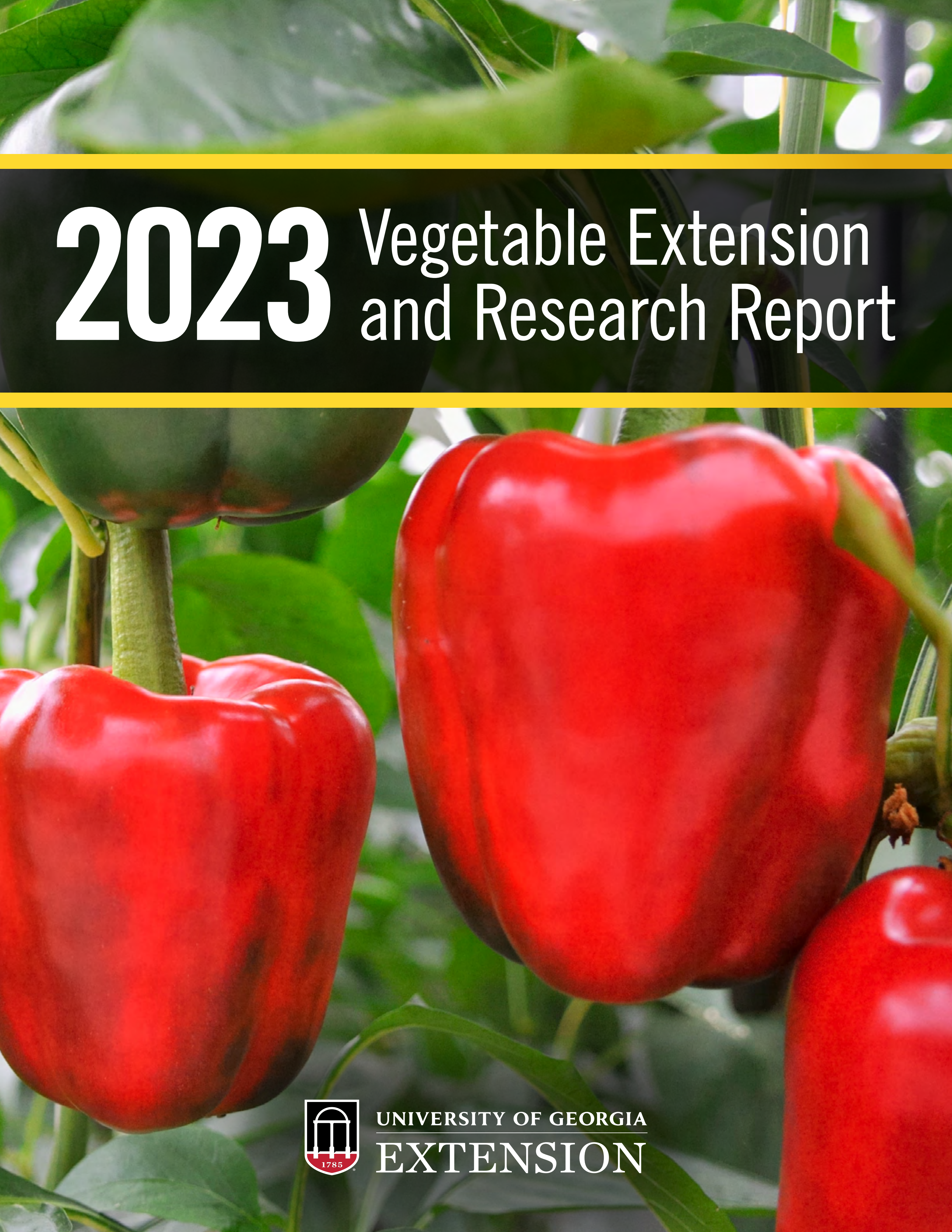

2023 Vegetable Extension and Research Report

UNIVERSITY OF GEORGIA
EXTENSION

Letter from Commodity Commission Chair

The Georgia Commodity Commission for Vegetables (GACCV) is pleased to submit this annual report to the vegetable growers of Georgia outlining the accomplishments made during 2023.

In the year covered in this report, GACCV supported 16 research projects with more than $173,000. These projects focused specifically on benefiting and educating producers that grow the following commodities:

- Beans
- Beets
- Bell peppers
- Broccoli
- Cabbage
- Cantaloupes
- Carrots
- Cucumbers
- Eggplant
- Greens
- Specialty peppers
- Squash
- Sweet potatoes
- Tomatoes

With grower assessment funds, these researchers have evaluated control of overwintering pepper weevils, studied packing and pallet efficiencies in forced-air cooling operations, researched alternative substrates for leafy green production in greenhouses, evaluated tomato varieties for tomato yellow leaf curl virus resistance, continued research in whitefly management in vegetable crops, evaluated various cultivars for phytophthora resistance, and much more.

Grower assessment funds also supported activities at the Tifton Vegetable Park and the Plant Pathology Diagnostic Lab on the University of Georgia Tifton campus. By working collaboratively, researchers were able to broaden their research efforts and maximize the available funds.

The research performed for these projects has provided growers with the opportunity to reduce production costs, increase yields, and improve profitability. If you are interested in serving on any committees or the commission, please let us know.

We look forward to continuing to serve the vegetable growers of Georgia.

Sincerely,

Dick Minor, *Chair*

Commission Members

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Americus, Georgia

Tyler Harper
Georgia Department of Agriculture, Commissioner
Atlanta, Georgia

Tom McCall
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Ty Torrence
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Lowndes County

Efforts in Education

County Extension Agent Continuing Education

In 2023, the Commission provided funding for 11 Georgia county Extension agents to pursue continuing education opportunities.

Faces of Georgia Grown

To help promote Georgia-grown products, the Commission provided funding to the Georgia Grown Pavilion at the Georgia National Fair.

Georgia Farm Monitor

The Commission gave $4,000 to the Georgia Farm Monitor in 2023. This TV show is produced by Georgia Farm Bureau and works to tell the story of Georgia farmers.

Southeast Fruit and Vegetable Conference Education Supporter

Through our support of the Southeast Regional Fruit and Vegetable Conference, farmers are presented with the latest in vegetable research. The Commission gave $6,000 to the conference in 2023.

Vegetable Commodity Fund Financials, Fiscal Year 2023 (July 1, 2022, to June 30, 2023)

Item	***Amount***
Assessment received	$210,569
Bank account balance (as of June 30, 2022)	$198,809
Liabilities	$136,890
Uncommitted funds to carry forward to fiscal year 2024	$61,919
Items Paid in Fiscal Year 2023	
Bank charges	$82
Miscellaneous	$111
Sponsorship for SE Regional Fruit and Vegetable Conference	$6,000
Preparation and printing of annual report	$3,897
County agent support for SE Regional Fruit and Vegetable Conference	$5,059
Georgia Grown — support of Georgia National Fair Building	$3,000
Administrative cost to Georgia Department of Ag.	$8,006
Georgia Farm Bureau — Farm Monitor show sponsor	$4,000
UGA research projects	$148,692
Total Expenses	**$178,847**

2023 University of Georgia Vegetable Extension and Research Report

Timothy Coolong and Theodore McAvoy, *Editors*

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Funds from the Georgia Commodity Commission for Vegetables were used to support all of the research outlined in this report. Without the continued support of the farmers who contribute to the commission, this research would not be possible. In addition to outlined research, commodity grant funds are used to support activities at the Tifton Vegetable Park and the Plant Pathology Diagnostic Lab at the UGA Tifton campus.

GEORGIA
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COMMISSION FOR VEGETABLES

2023 University of Georgia Vegetable Extension and Research Report

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Evaluation of *Phytophthora* Resistant Bell Pepper Cultivars in South Georgia

T. McAvoy, T. Coolong, A. Deltsidis, B. Dutta, T. Torrance, J. Shealey, J. Dawson

Introduction

Phytophthora capsici (PCap) is the most destructive soilborne disease of bell pepper production in Georgia. Extremely high persistence of inoculum in the soil and lack of effective chemical control methods make this disease particularly difficult to manage. Therefore, resistant cultivars offer the best practical solution to manage phytophthora in affected bell pepper fields. This research aimed to screen commercial bell pepper varieties for resistance to *phytophthora*, adaptability within various areas of Georgia, and select varieties with the highest yields, optimum fruit size distribution, and most desirable fruit characteristics.

Material and Methods

The trials compared 15 varieties (Table 1). Thirteen varieties had PCap resistance with varying levels of bacteria leaf spot (BLS) race resistances (Races 1–10) and tomato spotted wilt virus (TSWV) resistance. Two varieties that are susceptible to PCap ('Antebellum' and 'Aristotle') and are widely grown in Georgia were included for comparison. Trials were transplanted on April 4 in growers' fields at two locations (Moultrie and Valdosta) in the spring of 2022. Each plot consisted of 20 plants, was replicated four times, and was arranged in a randomized complete block design. Plants were managed according to grower standards. At the end, we harvested the fruit twice, 1 week apart, from 10 plants per plot. Harvested fruit was graded to remove and classify culls. Marketable fruit was sized into medium, large, extra-large, and jumbo-sized fruits. Data were analyzed using SAS software with analysis of variance to determine differences and least significant differences means separation.

Results

We did not have PCap incidence at either location. However, there were significant differences in yields at both locations. In Moultrie, 'Mercer' (2005 boxes/acre), 'Paladin' (1874 boxes/acre), 'Galileo' (1861 boxes/acre), 'Antebellum' (1829 boxes/acre), and '1819' (1699 boxes/acre) had the highest yields (Table 2). These all yielded higher than 'Intruder' and 'Remarkabelle'.

In Valdosta, the highest yields were obtained with 'Galileo' (1604 boxes/acre), Paladin (1553 boxes/acre), '1819' (1452 boxes/acre), 'Tarpon' (1446 boxes/acre), 'Mercer' (1376 boxes/acre), 'Turnpike' (1284 boxes/acre), 'Aristotle' (1280 boxes/acre), 'Revolution' (1278 boxes/acre), 'Intruder' (1209 boxes/acre), 'Antebellum' (1189 boxes/acre), and 'Nitro' (1155 boxes/acre). 'Galileo', 'Paladin', and '1819' performed significantly better than 'Playmaker', 'Vanguard', 'Remarkabelle', and 'Currier'.

Conclusion

Based on these results, we would recommend 'Mercer', 'Paladin', 'Galileo', and '1819' bell pepper varieties for spring production in South Georgia to growers seeking PCap resistance. These varieties performed similarly to 'Antebellum', the current grower standard; BLS 1-10 variety; and 'Aristotle', the most widely grown BLS 1-3 variety in our region. For growers seeking varieties resistant to PCap and BLS 1-10, they may consider growing 'Playmaker', 'Tarpon', or 'Nitro'. 'Nitro' also has resistance to TSWV. However, the varieties resistant to PCap and BLS 1-10 did not perform consistently between locations.

Table 1. Bell pepper varieties included in spring 2022 *phytophthora* variety trials.

PCap	PCap BLS 1–3	PCap BLS 1–5	PCap BLS 1–10	PCap BLS 1–10 TSWV	BLS 1–10 TSWV	BLS 1–3, 7–8
Paladin	Currier	1819 (7,9)	Playmaker	Nitro	Antebellum	Aristotle
	Galileo	Turnpike (7,9)	Tarpon			
	Intruder	Vanguard				
	Mercer (7, 8)					
	Remarkabelle (7,8)					
	Revolution (5)					

Note: The table indicates if the variety is resistant to phytophthora, bacteria leaf spot, and tomato spotted wilt virus. Numbers following BLS indicate grouping based on resistance to broad categories of different races of BLS 1–3, 1–5, or 1–10. Additional numbers in parenthesis after the variety indicate additional BLS race resistances.

Table 2. Spring bell pepper yields in boxes/acre at Moultrie and Valdosta, GA.

Variety	Boxes/acre Moultrie	Boxes/acre Valdosta
Mercer	2005 a	1376 abc
Paladin	1874 ab	1553 a
Galileo	1861 ab	1604 a
Antebellum	1829 abc	1189 abcd
PS09941819	1699 abcd	1452 a
Aristotle	1573 bcde	1280 abcd
Revolution	1568 bcde	1452 a
Turnpike	1517 bcde	1284 abcd
Playmaker	1214 bcde	1030 bcd
Nitro	1440 cde	1155 abcd
Currier	1434 cde	838 d
Vanguard	1420 cde	1004 bcd
Tarpon	1365 de	1446 ab
Intruder	1272 e	1209 abcd
Remarkabelle	1227 e	959 cd

Note: Values followed by letters that are similar within each column are not significantly different.

Bell Pepper Cultivar Screening for Bacterial Leaf Spot Resistance

T. McAvoy, T. Coolong, A. Deltsidis, B. Dutta, T. Torrance, J. Shealey, J. Dawson

Introduction

Bacterial leaf spot (BLS) is the most prevalent and problematic foliar disease of bell peppers in Georgia. Humid environmental conditions in southern Georgia are ideal for disease development. Resistant cultivars offer the best practical solution to manage BLS in bell peppers. This research aimed to screen commercial bell pepper varieties for resistance to BLS, evaluate production performance within various areas of Georgia, and select resistant varieties with the most desirable fruit characteristics.

Material and Methods

Studies were conducted during the spring of 2022 in a grower's field in Lake Park, GA. As reported in Table 1, 23 entries were evaluated for BLS resistance, marketable yields, fruit size distribution, and fruit quality. All test varieties were resistant to BLS races 1–10. These were compared to a widely grown susceptible control variety, 'Aristotle'.

Each plot consisted of 20 plants, was replicated four times, and was arranged in a randomized complete block design. Plants were managed according to grower standards. At the end we harvested fruit twice, 1 week apart, from 10 plants per plot. Harvested fruit was graded to remove and classify culls. Marketable fruit was sized into medium, large, extra-large, and jumbo-sized fruits. Detrimental fruit flaws resulting in choice fruit (purpling, silvering, crowding, pancaking, tapering) and cull fruit (sunscald, suntan, blossom end rot, soft rot, fruit cracking) were recorded and categorized. Data were analyzed using SAS software with analysis of variance to determine differences and least significant differences means separation.

Results

We did not have BLS disease incidence in our trials. Based on our yield results from spring 2022 in Lake Park, we would recommend growers plant the BLS Race 1–10 resistant varieties 'Prowler' (1657 boxes/acre), 'Standout' (1537 boxes/acre), and 'SV3255' (1500 boxes/acre; Table 2). These varieties have similar yields to 'Aristotle' (1876 boxes/acre) but offer complete protection against BLS. 'Aristotle' was historically the most widely grown variety. Currently, many growers still choose to grow this variety because it has cheaper seed than the BLS 1–10 resistant varieties and, as shown in our trials, offers the highest level of yields when there is no BLS disease presence.

Lastly, 'Antebellum' (1424 boxes/acre), 'Green Machine' (1377 boxes/acre), and 'Autry' (1355 boxes/acre) performed similarly to the highest performing BLS 1–10 varieties, are widely grown in Georgia and have a proven track record among growers. The varieties with the highest quality fruit or least amount of choice and cull fruits were 'SV3255', 'Boca', and 'Tarpon', indicating that they will perform consistently under harsh environmental conditions.

Conclusion

Growers in Georgia have many available BLS Race 1–10 resistant varieties that produce similar yields to older varieties without resistance ('Aristotle'). Planting resistant varieties is a guarantee against BLS disease. Furthermore, these varieties often have tomato spotted wilt virus resistance, which is more prevalent in the spring season in Georgia.

Table 1. Bell pepper varieties included in spring 2022 bacteria leaf spot variety trials.

BLS 1–10	BSL 1–10 TSWV	PCap BLS 1–10	PCap BLS 1–10 TSWV	BLS 1–3, 7–8
LaBelle	Antebellum	Playmaker	Nitro	Aristotle
Ninja	Autry	Tarpon		
Placepack	Boca			
Provider	Delray			
PS09979325	Green Machine			
Raven	Outsider			
Samurai	Prowler			
Speedway 48	Shogun			
Skyhawk	Standout			
SV3255				

Note: The table indicates if the variety is resistant to bacteria leaf spot, phytophthora, and tomato spotted wilt virus. Numbers following BLS indicate which races of BLS the variety is resistant to.

Table 2. 2022 bell pepper yields in boxes/acre in Lake Park, GA.

Variety	Boxes/acre	Choice fruit/plot	Cull fruit/plot
Aristotle	1876 a	14.0 abcd	5.8 defg
Prowler	1657 ab	16.8 ab	2.3 fg
Standout	1537 abc	9.5 cdefg	5.0 efg
SV3255	1500 abcd	4.7 g	7.3 bcdefg
Antebellum	1424 bcde	7.3 defg	8.5 abcdef
Green Machine	1377 bcdef	11.3 abcdefg	7.5 bcdefg
Autry	1355 bcdefg	11.0 bcdefg	14.0 a
Skyhawk	1300 bcdefgh	18.0 a	6 cdefg
Ninja	1266 bcdefgh	9.3 cdefg	12.0 abcd
Boca	1237 bcdefgh	5.5 fg	1.5 g
Shogun	1225 bcdefgh	8.5 cdefg	4.3 efg
PS09979325	1206 cdefgh	12.5 abcde	10.3 abcde
Nitro	1193 cdefgh	15.0 abc	6.5 cdefg
Playmaker	1174 cdefgh	12.3 abcdef	5.0 efg
Tarpon	1130 cdefgh	6.5 efg	3.3 fg
Outsider	1124 cdefgh	7.3 defg	13.5 ab
Raven	1088 defgh	14.3 abc	5.3 efg
Samurai	1037 efgh	7.3 defg	2.8 fg
Placepack	1002 efgh	13.0 abcde	6.8 cdefg
Delray	982 gh	16.8 ab	3.0 fg
Provider	965 gh	8.8 cdefg	9.8 abcde
Seedway 48	924 gh	6.8 efg	12.3 abc
Labelle	907 h	11.8 abcdef	7.5 bcdefg

Note: Values followed by letters that are similar within each column are not significantly different.

Evalutation of Biological and Chemical Products on Managing Bacterial Leaf Spot in Bell Peppers in Georgia

B. Dutta

Introduction

We previously reported a new *Pseudomonas* species, *P. capsici*, that caused typical bacterial symptoms on pepper foliage (leaf spots and blights) under greenhouse conditions (Zhao et al., 2021). The pathogen was also able to cause lesions on fruit that turned necrotic and eventually resulted in fruit rot in pepper. *Pseudomonas capsici* is closely related to *P. cichorii*, and strains from pepper could also rot potatoes (Zhao et al., 2021). In this research we aimed to investigate if biological and chemical antimicrobial products would reduce disease severity under field conditions.

Material and Methods

Bell peppers ('Aristotle' variety) were transplanted into two row beds covered with 18 in. white plastic mulch on April 3. Beds were on 6 ft centers with 1 ft plant spacing within rows. Plots were 20 ft long with 10 ft planted borders between plots. The trial was arranged in a randomized complete block design. Four plots with 40 plants per plot (20 plants per row) were used for each treatment.

Plots were drip irrigated as necessary using a drip tape irrigation system. Fertility and insecticide treatments were applied according to the University of Georgia Extension recommendations. Natural inoculum was relied upon for initial infection. Treatments were applied using a backpack sprayer calibrated to deliver 36 gallons/acre at 48 psi through TX-18 hollow cone nozzles. Treatment applications were made on September 9, September 17, September 23, September 30, October 14, and October 21.

Disease severity was assessed on October 13, October 20, and October 27 as percentage leaf area with symptoms per plot. Area under disease progress curve (AUDPC) was calculated using disease severity ratings from the four assessment periods. Data were analyzed in the ARM software using the Fisher's protected LSD test at $P \leq 0.05$. The mean rainfall received during September and October was 3.5 in. and 5.8 in., respectively. The average high and low temperatures for the month of September were 92 °F and 72 °F, respectively, and for the month of October were 85 °F and 68 °F, respectively.

Results

Bacterial leaf spot symptoms were first observed on October 13 with disease severity significantly higher in the nontreated control plots (68.8%) than in the biological or chemical-treated plots; however, significant differences among the treated plots were not observed (Table 1). Disease progressed gradually over a period of 3 weeks and final severity rating was taken on October 27. Based on final disease severity and AUDPC, significant differences among the biological and chemical products were not observed except for the Kocide 3000 and Manzate Pro-Stik spray program that had a significantly lower AUDPC value compared to other treatments (Table 1). Phytotoxicity was not observed with any of the products evaluated.

Table 1. Summary of treatments, fungicide application frequency, disease severity, and area under disease progress curve (AUDPC).

Treatment and rate of product/acre	Application number[z]	Initial disease severity (%) on Oct. 13[y,x]	Final disease severity (%) on Oct. 27[y,x]	AUDPC[w,x]
Serenade ASO 4 quarts	1–6	35.0 b	63.8 b	739.4 bc
Serifel 16.0 fluid oz	1–6	25.0 b	71.3 bc	756.8 bc
Nordox 1.0 lb	1–6	23.8 b	56.3 b	560.0 bc
LifeGuard 2.0 fluid oz	1–6	20.0 b	53.8 b	616.8 bc
Double Nickel 6.0 quarts	1–6	33.8 b	65.0 b	713.2 bc
Stargus 4.0 fluid oz	1–6	27.5 b	65.5 b	630.0 bc
Oxidate 5.0 0.5 fluid oz/gallon	1–6	37.5 b	62.5 b	726.2 bc
Forticept 1.28 fluid oz/gallon	1–6	38.8 b	68.8 b	822.5 b
Regalia 4.0 quarts	1–6	32.5 b	68.8 b	765.6 bc
Vacciplant 22.0 fluid oz	1–6	26.3 b	60.0 b	669.4 bc
Kocide 3000 1.5 lb	1–6	7.5 b	42.5 b	385.5 c
Manzate Pro-Stik 2.0 lb	1–6			
Forticept 0.9 fluid oz/gallon	1–6	40.0 b	68.8 b	826.8 bc
Nontreated check	—	68.8 a	100.0 a	1238.2 a
P-values		0.0006	0.0312	0.0024

[z] Application dates were: 1 = September 9, 2 = September 17, 3 = September 23, 4 = September 30, 5 = October 14, and 6 = October 21.

[y] Disease severity was rated on a 0–100 scale (0 = no infection and 100 = 100% of leaf area infected) on October 13, October 20, and October 27.

[x] Means followed by the same letter within each column are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$.

[w] AUDPC was calculated from ratings taken on October 13, October 20, and October 27.

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Pepper Anthracnose: Evaluation of Pathogen Biology and Fungicide Sensitivity

B. Dutta, N. Kaur

Introduction

Outbreaks of pepper anthracnose have been on the rise in Georgia in specialty peppers, including bell, cubanelle, and jalapeno. In some cases, commonly used fungicides (FRAC 11: Quadris and Cabrio) were not effective in reducing disease severity. Previous reports in the United States indicated that there are four different species of Colletotrichum responsible for anthracnose in peppers, which include *C. acutatum, C. capsici, C. coccodes*, and *C. gloeosporioides* (Hadden et al., 1989; Marvel et al., 2003; Roy et al., 1997; Harp, 2008). In Georgia only two species were observed earlier; however, we hypothesize that the recent outbreaks could be an outcome of the introduction of other species, development of resistance against FRAC 11 fungicides (Quadris and Cabrio), or both.

Figure 1. Symptons of anthracnose on a bell pepper (left) and cubanelle pepper (right).

Material and Methods

Collection of isolates from commercial fields: A total of 108 fungal isolates from five commercial pepper fields were collected and isolated on culture medium. Single-spore cultures were later made. The isolates included nine from cubanelle peppers, three from jalapeno peppers, and 96 from bell peppers.

Identification of* Colletotrichum *species complex: DNA from each isolate was extracted and ITS gene was amplified and sequenced (White et al., 1990). A phylogenetic tree was constructed using these sequences and interpretations were made.

Pathogenicity of* Colletotrichum *spp.: Pathogenicity assay was conducted on bell peppers and jalapeno peppers using a whole fruit inoculation assay where a conidial suspension of 1×105 conidia/ml was dispensed on a fruit surface. Fruits inoculated with sterile water served as a negative control. A known *C. acutatum* isolate was used as a positive control. A representative set of isolates from *C. acutatum* (n = 17) was screened. Assessment of symptoms was conducted after a week of incubation at room temperature.

Results

Identification of* Colletotrichum *species complex: Our study indicates that a *Colletotrichum* species complex could be involved in recent pepper anthracnose outbreaks in Georgia. The species *C. acutatum* and *C. gloeosporioides* are mainly associated with bell peppers, while *C. acutatum* was only associated with anthracnose on cubanelle peppers. Anthracnose on jalapeno peppers was associated with *C. truncatum* and *C. gloeosporioides*. Another minor species, such as *C. coccodes*, has also been found (Figure 2).

Pathogenicity of* Colletotrichum *spp.: A whole fruit assay was used for the pathogenicity assay. Screening of 17 *C. acutatum* isolates resulted in symptoms on both jalapeno and bell peppers. The symptoms include sunken spots with orange sporulation in the middle (Figure 1). The positive control displayed symptoms similar to the test isolates (Figure 3). Fruit symptoms were not observed on fruit inoculated with sterile water.

Conclusion

There is an involvement of *Colletotrichum* species complex in the recent anthracnose disease outbreaks in bell and specialty peppers in Georgia. The species include *C. acutatum, C. gloeosporioides,* and *C. truncatum*. We also observed a host association with *Colletotrichum* species complex indicating a potential host preference with some *Colletotrichum* species. We also observed that these isolates could cause symptoms on bell and jalapeno peppers. Together, these observations suggest that *Colletotrichum* species complex that cause anthracnose on peppers remain unchanged. However, a new *Colletotrichum* species (*C. truncatum*) seemed to be a recent introduction in this pathogen complex.

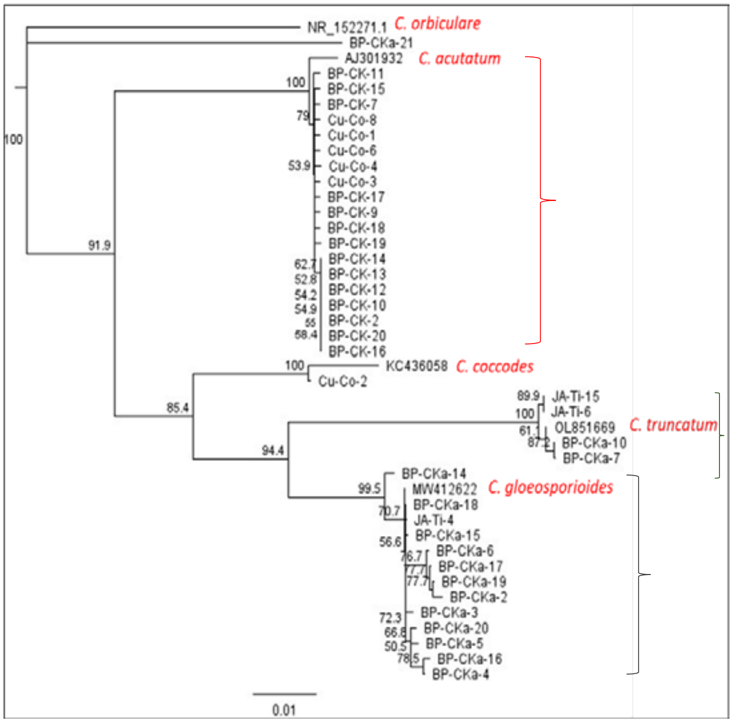

Figure 2. This phylogenetic tree of *Colletotrichum* species infecting bell, jalapeno, and cubanelle peppers was prepared by aligning ITS gene with the reference *Colletotrichum* species. This figure indicates *Colletotrichum* spp. from bell, jalapeno, and cubanelle peppers in Georgia.

Figure 3. Pathogenicity of *Colletotrichum acutatum* on jalapeno and bell peppers determined using whole fruit inoculation. A typical sunken lesion with orange color spore mass was produced on the inoculated fruits. Panel A represents pathogenocity of *Colletotrichum* spp. on jalapeno peppers. Panel B includes representative pathogenic *Colletotrichum* spp. on bell peppers.

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Season Exploration of Alternative Substrates for Optimized Arugula and Lettuce Production in Hydroponics

R. S. Ferrarezi, K. Qin, L. X. Nguyen,
S. D. Poole, J. S. Cardenas, M. J. Housley

Introduction

Rockwool and peat moss are commonly used substrates in the greenhouse industry due to their quality, stable pH, and exceptional water retention properties. However, the unsustainable disposal of rockwool and peat mining have caused several economic and environmental concerns. In anticipation of deep sustainable production changes with a massive impact on greenhouse operations in North America, there is a need to study other substrates for vegetable production due to the constraints of using rockwool and peat.

Substrate evaluation is essential to determine the optimal substrate for vegetable hydroponic production. We hypothesized that substrates with materials other than rockwool and peat, or with portion substitutes for peat (especially coir), could provide similar growth for leafy greens. In this study, we aimed to identify alternative substrates for leafy green production in greenhouses for three consecutive growing seasons.

Materials and Methods

Study Location and Environmental Conditions. This study was conducted in a greenhouse at the University of Georgia in Athens, GA, for three consecutive growing seasons. Environmental parameters inside the greenhouse were measured to determine air temperature and relative humidity, CO_2 concentration, and photosynthetic photon flux density.

Growth Conditions, Plant Materials, and Treatments. Two leafy greens, 'Slow Bolt' arugula and 'Summer Crisp' lettuce, were sown in 13 substrates (Table 1) and placed inside a vertical farm with an automated ebb-and-flow irrigation system. After 2 weeks, seedlings were transferred to a greenhouse, placed inside a net cup, and then transplanted in a deep-water culture hydroponics system. The system used 243.8 × 121.9 × 20.3 cm (L × W × H) trays covered with polystyrene foam insulation boards with 12 × 6 holes (3.8 cm diameter) for a total of 72 plants per tray. The plants located at the edge of the tray were used as a border, and each experimental unit had three plants per substrate tested. Each tray was aerated by four air stones connected by clear extruded acrylic tubes to a 3.75 L/s at 0.048 MPa aeration pump with a 1.27 cm outlet. The system was filled with a fertilizer solution prepared using calcium nitrate, potassium sulfate, monoammonium phosphate, potassium nitrate, magnesium nitrate, magnesium sulfate, boric acid, copper sulfate, manganese sulfate, ammonium molybdate, chelated iron, and zinc sulfate, resulting in a fertilizer solution described on Table 2.

Arugula plants were grown for 3, 4, and 4 weeks after transplanting, respectively, during summer, early fall, and late fall trials, while lettuce plants were grown for 4, 5, and 5 weeks after transplanting during the three trial seasons.

Substrate Physical Properties. The substrate's physical properties largely determine the growth and quality of plants. We measured the bulk density, air porosity, water porosity, and total porosity of the 13 substrates following the method described by Huang and Fisher (2013). The measurements were repeated three times.

Measurements. During the plant growth periods, weekly measurements were taken for height, width, chlorophyll and anthocyanin content, solution pH, electrical conductivity, and dissolved oxygen. When harvested, leaf area was measured using an area meter, and soluble solids content (SSC) was determined using a digital refractometer. Shoot fresh weight was determined by a separate set of plants, and the dry biomass was determined after oven drying at 80 °C for 3 days. After drying, leaf samples were collected and shipped to Waters Agricultural Laboratories (Camilla, GA) for tissue mineral concentration analysis. After plants were removed from the system, total water use was recorded. The solution samples were sent to Waters Agricultural Laboratories for water mineral concentration analysis. Use efficiencies and nutrients consumed were estimated for N, P, K, and Ca at the tray level.

Experimental Design and Statistical Analysis. For each crop, the study was arranged as a randomized complete block design with 13 substrate treatments and conducted for three growing seasons (summer, early fall, and late fall). Each treatment had three replications, with three plants per replication. Results were analyzed using Rand, and the mean comparison was conducted using Tukey's HSD test at 5% probability. Heatmaps with clustering were created for arugula and lettuce using R to visualize the significant interaction effects between substrates and trial seasons.

Results

Cultural control: Mulch efficacy. Arugula plants grown using Jiffy 75% peat and 25% coir Jiffy Preforma HP (JiHPC) overall had the greatest height and width regardless of season, while Riococo coir PCM Coco (RiC) had the worst results; Ellepot 100% Coir Universal 6-9 paper (EIC) and Ellepot 100% Coir Organic 2.0 paper (EIOC) substrates limited arugula height and width development, especially during summer and early fall, while other substrates showed similar effects on arugula growth (Figure 1). The effects of substrates on arugula chlorophyll and anthocyanin contents were more challenging to understand during the summertime. EIOC had more positive effects of increasing plant chlorophyll and anthocyanin content during summer, while during early and late fall, substrates had similar effects, except plants grown using RiC tended to have less chlorophyll and anthocyanin content in early fall (Figure 1). JiHPC substrate also induced the highest arugula leaf area, yield (fresh weight), and shoot dry weight, while plants on Jiffy 98% Peat Horticulture Peat Pellet (JiPP) had the highest SSC and Jiffy 98% Peat Pellet (JiP) had the highest K concentrations (Table 3).

Seasonal variations also existed: plants grown in early fall had the highest leaf area, shoot fresh and dry weight, and K and Ca concentrations, while plants grown in the late fall had the least canopy, biomass, and SSC but the highest N and P concentrations (Table 3). Significant interaction effects were found between season and substrates on arugula leaf area, biomass, and SSC. During summer, arugula on RiC had the lowest canopy and biomass but the highest SSC, which had been clustered together with EIC, JiPP, and EIOC with similar high SSC and low biomass, while plants grown using JiHPC substrate had the highest biomass but lowest SSC. During early and late fall, the high SSC caused by the RiC substrate disappeared. Instead, JiPP became the best substrate to increase arugula SSC.

The manifestation of benefits or disadvantages from different substrates was less evident in lettuce. Plants grown using JiP, Jiffy 98% Peat Horticulture Pellet (JiH), JiHPC, and JiPP substrates performed better in height, width, chlorophyll, and anthocyanin content than other substrates (Figure 1). JiHPC also had the most pronounced effects on improving lettuce leaf area, shoot fresh and dry weights, and RiC resulted in the lowest leaf area and shoot fresh weight of lettuce, while plants on Oasis phenolic foam single seed dibble (OaS) and Oasis phenolic foam multiseed dibble (OaM) substrates had the least shoot dry biomass. No differences were found in nutrients among different substrates (Table 4).

Unlike arugula, lettuce grown in summer had the highest leaf area, fresh weight, and SSC, while plants grown in late fall had the lowest canopy, biomass, and SSC but the highest N, P, K, and Ca concentrations (Table 4). Interactions between seasons and substrates were reduced in lettuce growth, mainly reflected in canopy and biomass. During summer, JiHPC, Ellepot Peat & Coir Mix Organic 2.0 paper (EIOPC), EIPC, JiP, and JiPP had beneficial effects of increased lettuce growth. Plants grown using RiC showed higher shoot dry weight than other substrates, while during the early and late fall seasons, EIOPC dropped from the beneficial top-performer groups. The positive effect of RiC on shoot dry biomass accumulation was not presented.

Conclusion

In this study, substrates made from peat had overall higher benefits for plant growth, while the highest plant performances were achieved using the 75% peat and 25% coir mixture substrate. Except for 100% coir, other materials (phenolic foam, peat) and the mixed use of peat and coir can be used as alternatives to replace rockwool in hydroponic leafy greens production.

In addition, arugula was found to have a higher production and resource use efficiency during summer when temperature and light intensity were higher, while lettuce favored the cooler season to achieve its maximum production potential.

Acknowledgements

This project was funded by the GACCV (Award ID# AWD00014421) and received substrate donations from Oasis, Grodan, Jiffy, Ellepot, and RioCoco.

We appreciate the strong support from Georgia growers by funding this research project. We are also thankful for the donation received from the substrate companies: Oasis (Dr. Vijay Rapaka), Grodan (Phil Johnson and Austin Smith), Jiffy (Freeman Agnew), Ellepot (Lars Jensen, David Dobos, and Dr. Bill Argo), and RioCoco (Rico), and for the technical support received by the Ferrarezi Lab members (George Hutchinson, Christopher Nieters, Husnain Rauf, Thiago Gastaldo, Alan Huber, and Hannah Chaffe).

Table 1. List of substrates used products and their physical properties.

#	Code	Product	Substrate type	Company	Bulk density (gallon/lm)	Total porosity (%)	Air porosity (%)	Water porosity (%)
1	OaS	Horticubes® Aeromax single seed dibble	Phenolic foam	Oasis Grower Solutions Kent, OH	0.02	91.44	8.29	83.15
2	OaM	Horticubes® Aeromax multiseed dibble	Phenolic foam	Oasis Grower Solutions Kent, OH	0.01	64.73	5.94	58.79
3	Gr25	AO 25/40 Plug	Rockwool	Grodan, Roermond, The Netherlands	0.07	76.15	2.55	75.59
4	Gr36	AO 36/40 Plug	Rockwool	Grodan, Roermond, The Netherlands	0.07	73.04	3.43	69.61
5	JiP	Jiffy 7 Organic Peat Pellet	98% peat	Jiffy Group, Zwijndrecht, The Netherlands	0.14	93.30	2.62	90.68
6	JiH	Jiffy 7 Horticulture Pellet	98% peat	Jiffy Group, Zwijndrecht, The Netherlands	0.16	91.87	6.13	85.75
7	JiHPC	Preforma *HP* DJ	75% peat, 25% coir	Jiffy Group, Zwijndrecht, The Netherlands	0.10	61.66	3.16	58.50
8	JiPP	Jiffy 7 Horticulture Peat Pellet	98% peat	Jiffy Group, Zwijndrecht, The Netherlands	0.14	85.37	4.23	81.13
9	E1C	Universal 6-9 paper	100% coir	Ellepot, Esbjerg, Denmark	0.20	77.72	1.54	76.18
10	E1PC	Universal 6-9 paper	Peat & coir mix	Ellepot, Esbjerg, Denmark	0.21	92.65	2.29	90.36
11	E1OC	Organic 2.0 paper	100% coir	Ellepot, Esbjerg, Denmark	0.20	88.05	2.82	85.23
12	E1OPC	Organic 2.0 paper	Peat & coir mix	Ellepot, Esbjerg, Denmark	0.20	90.09	2.66	87.44
13	RiC	PCM Coco	Coconut coir	Riococo, Irving, TX	0.14	80.34	5.57	74.78

Table 2. Detailed nutrient concentrations of fertilizer solution used in this study.

Nutrients	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Mo	Zn
(mg/L)	150	31	210	90	24	32	0.250	0.023	1.800	0.130	0.020	0.160

Table 3. Plant growth performance and mineral concentration of arugula cultivated for three seasons.

	Source	**Leaf area (cm^2)**	**SFW (g)**	**SDW (g)**	**SSC (%)**	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**
Substrates (Sub)	OaS	1269 bcd	77.84 bc	9.11 cde	2.99 abc	6.92	0.75	8.02 ab	2.60
	OaM	1143 cd	71.24 cd	9.87 bcd	2.68 bc	6.87	0.69	7.83 abc	2.70
	Gr25	1244 bcd	78.87 bc	10.15 bc	3.01 abc	6.78	0.70	7.48 abc	2.79
	Gr36	1192 bcd	80.02 bc	9.48 cde	2.71 bc	6.90	0.73	7.37 abc	2.66
	JiP	1485 bc	100.37 b	11.81 bc	2.64 c	6.78	0.75	8.05 a	2.65
	JiH	1218 bcd	79.69 bc	9.53 cde	2.74 abc	6.69	0.72	7.67 abc	2.74
	JiHPC	2655 a	190.70 a	25.03 a	2.94 abc	6.62	0.73	7.64 abc	2.77
	JiPP	1572 b	102.20 b	13.94 b	3.76 a	6.61	0.74	7.55 abc	2.89
	EIC	703 e	73.70 d	5.44 ef	3.12 abc	6.80	0.70	7.15 abc	2.94
	EIPC	1345 bcd	88.92 bc	11.60 bc	3.11 abc	6.65	0.73	7.18 abc	2.86
	EIOC	727 e	44.04 d	5.74 de	3.21 abc	6.27	0.67	6.89 c	2.81
	EIOPC	1026 de	67.71 cd	9.79 bcd	2.97 abc	6.52	0.73	7.34 abc	2.78
	RiC	239 f	12.54 e	1.33 f	3.70 ab	6.29	0.65	6.90 abc	2.50
Trial Seasons	Summer	1073 b	72.97 b	11.23 b	3.68 a	5.81 c	0.65 b	6.13 b	2.78 a
	Early fall	1622 a	112.28 a	14.02 a	3.09 b	6.94 b	0.74 a	8.18 a	2.88 a
	Late fall	956 b	54.25 c	5.39 c	2.36 c	7.25 a	0.75 a	8.09 a	2.57 b
P-values									
Substrates		***	***	***	**	NS	NS	**	NS
Trial Seasons		***	***	***	***	***	***	***	***
Substrates * Trial Seasons		***	***	***	**	NS	NS	NS	**

Note: The 13 commercial substrates tested are OaS: Oasis phenolic foam single seed dibble; OaM: Oasis phenolic foam multiseed dibble; Gr25: Grodan Rockwool AO 25/40 Plug; Gr36: Grodan Rockwool AO 36/40 Plug; JiP: Jiffy 98% Peat Pellet; JiH: Jiffy 98% Peat Horticulture Pellet; JiHPC: Jiffy 75% peat and 25% coir Preforma HP; JiPP: Jiffy 98% Peat Horticulture Peat Pellet; EIC: Ellepot 100% Coir Universal 6-9 paper; EIPC: Ellepot Peat & Coir Mix Universal 6-9 paper; EIOC: Ellepot 100% Coir Organic 2.0 paper; EIOPC: Ellepot Peat & Coir Mix Organic 2.0 paper; RiC: Riococo coir PCM Coco. Shoot fresh weight, SFW; shoot dry weight, SDW; soluble solids content, SSC.

According to Tukey's HSD test, different letters within a column indicate significant differences at $\alpha = 0.05$.

NS = nonsignificant

*, **, *** indicate significant at $P < 0.05$, 0.01, or 0.001, respectively.

Table 4. Plant growth performance and mineral concentration of lettuce cultivated for three seasons.

	Source	Leaf area (cm^2)	SFW (g)	SDW (g)	SSC (% Brix)	N (%)	P (%)	K (%)	Ca (%)
Substrates (Sub)	OaS	1613 de	105.14 de	3.55 e	1.78	6.35	1.16	9.32	1.53
	OaM	2005 cd	138.17 cd	3.54 e	1.60	6.04	1.07	9.05	1.43
	Gr25	1836 cde	126.19 cde	5.13 de	1.48	6.30	1.06	9.00	1.41
	Gr36	1572 de	103.81 de	6.74 cd	1.63	6.29	1.11	9.02	1.47
	JiP	3040 ab	216.88 b	8.72 bc	1.84	6.17	1.11	9.53	1.53
	JiH	2237 c	159.97 c	6.58 d	1.59	6.29	1.13	9.20	1.53
	JiHPC	3584 a	264.79 a	10.90 a	1.70	6.26	1.20	9.75	1.64
	JiPP	3243 ab	231.09 ab	10.81 ab	1.69	6.34	1.19	9.84	1.57
	ElC	1555 de	106.09 de	5.36 de	1.57	6.30	1.15	9.56	1.54
	ElPC	2932 b	212.49 b	8.75 bc	1.70	6.07	1.18	9.37	1.59
	ElOC	1439 de	97.37 e	6.01 d	1.44	6.38	1.08	9.32	1.39
	ElOPC	2285 c	154.76 c	6.06 d	1.54	6.27	1.07	9.15	1.42
	RiC	1384 e	88.69 e	6.12 d	1.67	6.30	1.11	9.21	1.44
Trial Seasons	Summer	3055 a	211.06 a	8.19 b	1.91 a	5.39 b	0.80 c	7.37 b	1.36 b
	Early fall	2501 b	191.71 b	9.02 a	1.72 b	6.59 a	1.19 b	10.11 a	1.43 b
	Late fall	1073 c	60.02 c	3.16 c	1.27 c	6.79 a	1.38 a	10.51 a	1.71 a
P-values									
Substrates		***	***	***	NS	NS	NS	NS	*
Trial Seasons		***	***	***	***	***	***	***	***
Substrates * Trial Seasons		***	***	***	NS	NS	NS	NS	NS

Note. The 13 commercial substrates tested are OaS: Oasis phenolic foam single seed dibble; OaM: Oasis phenolic foam multiseed dibble; Gr25: Grodan Rockwool AO 25/40 Plug; Gr36: Grodan Rockwool AO 36/40 Plug; JiP: Jiffy 98% Peat Pellet; JiH: Jiffy 98% Peat Horticulture Pellet; JiHPC: Jiffy 75% peat and 25% coir Preforma HP; JiPP: Jiffy 98% Peat Horticulture Peat Pellet; ElC: Ellepot 100% Coir Universal 6-9 paper; ElPC: Ellepot Peat & Coir Mix Universal 6-9 paper; ElOC: Ellepot 100% Coir Organic 2.0 paper; ElOPC: Ellepot Peat & Coir Mix Organic 2.0 paper; RiC: Riococo coir PCM Coco. Leaf area, LA; shoot fresh weight, SFW; shoot dry weight, SDW; soluble solids content, SSC.

According to Tukey's HSD test, different letters within a column indicate significant differences at $\alpha = 0.05$.

NS = nonsignificant

*, **, *** indicate significant at $P < 0.05$, 0.01, or 0.001, respectively.

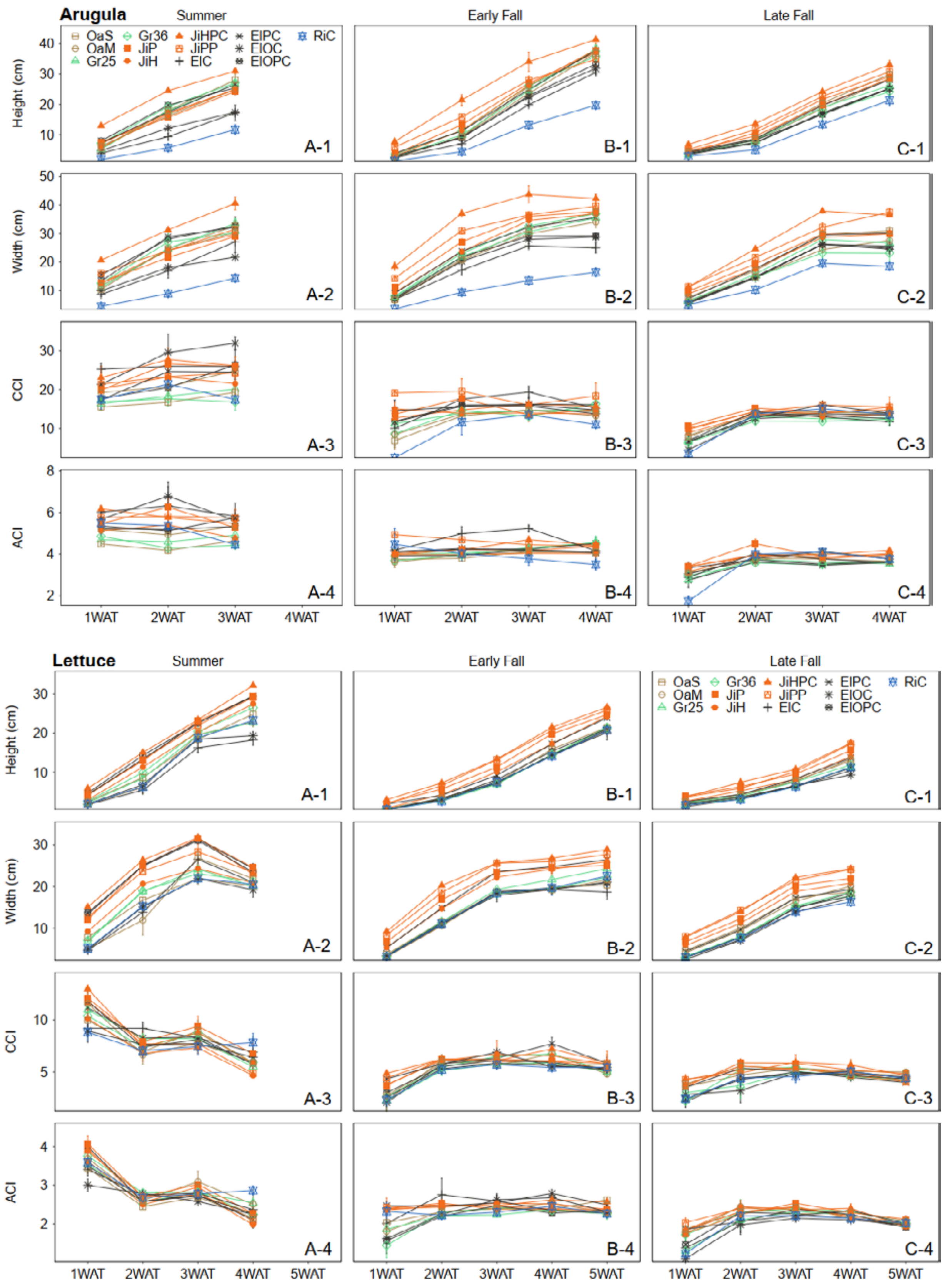

Figure 1. Plant height, width, chlorophyll content index (CCI), and anthocyanin content index (ACI) of arugula (top) and lettuce (bottom) cultivated for three seasons, summer (A-1 to A-4), early fall (B-1 to B-4), and late fall (C-1 to C-4). The 13 commercial substrates tested are OaS: Oasis phenolic foam single seed dibble; OaM: Oasis phenolic foam multiseed dibble; Gr25: Grodan Rockwool AO 25/40 Plug; Gr36: Grodan Rockwool AO 36/40 Plug; JiP: Jiffy 98% Peat Pellet; JiH: Jiffy 98% Peat Horticulture Pellet; JiHPC: Jiffy 75% peat and 25% coir Preforma HP; JiPP: Jiffy 98% Peat Horticulture Peat Pellet; EIC: Ellepot 100% Coir Universal 6-9 paper; EIPC: Ellepot Peat & Coir Mix Universal 6-9 paper; EIOC: Ellepot 100% Coir Organic 2.0 paper; EIOPC: Ellepot Peat & Coir Mix Organic 2.0 paper; RiC: Riococo coir PCM Coco. Arugula plants were grown in the deep water culture system for 3, 4, and 4 weeks after transplanting (WAT) in summer, early fall, and late fall.

Rely Herbicide Approved for Use in Several Fruiting and Cucurbit Vegetables in Georgia

S. Culpepper, J. Vance, T. Randell-Singleton

Introduction

Improving the number of tools that a vegetable farmer has in their weed management toolbox is a priority for the University of Georgia's Extension Weed Science program. During 2023, the herbicide Rely (glufosinate) received supplemental labeling for weed control in two fruiting vegetables, including tomato and pepper (bell and non-bell), and four cucurbits, including cantaloupe, cucumber, summer squash, and watermelon. Rely can be extremely effective in controlling morningglory, ragweed parthenium, cocklebur, sicklepod, small pigweeds, and lambsquarters. Control of Florida pusley, purslane, goosegrass, spiderwort, and wild radish are often not acceptable. Historically, the assumption was that Rely has little to no residual activity, which is not correct. In fact, the residual activity from this herbicide poses significant consequences to vegetable crops if it is not understood.

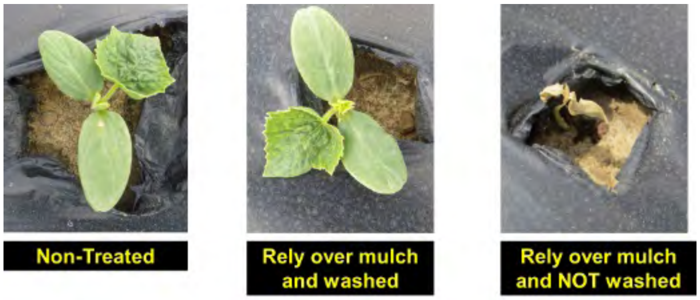

Figure 1. Cucumber response to Rely applied preplant over mulch.

Research

More than 20 studies, supported by the Georgia Commodity Commission for Vegetables, were conducted in fruiting vegetables and cucurbits to assist in the development of Rely herbicide labels for vegetable producers. Each of these studies focused on maximizing weed control while most importantly minimizing crop injury. This research was among the first conducted in vegetables to document that Rely could be removed from plastic mulch with irrigation/rainfall (Figure 1). Additionally, these efforts were the first to document how sensitive some vegetable crops are to the residual activity of Rely (Figure 2).

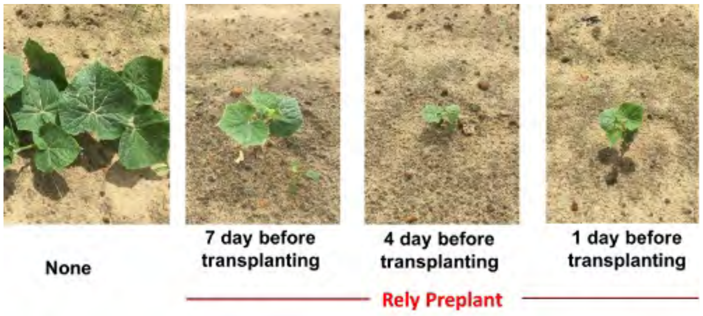

Figure 2. Rely applied just prior to transplanting cucumbers in bareground causes unacceptable injury.

Results

After compiling experimental results from Georgia, along with results of other studies conducted by the manufacturer and IR-4 (Interregional Project #4), two supplemental Rely labels have been developed: one for fruiting vegetables and one for cucurbit vegetables. Applicators must refer to the labels for specific application uses, recommendations, and restrictions; however, Tables 1 and 2 provide a brief summary.

Conclusions

1. Rely is a new tool available for some vegetable growers to improve their weed management program.

2. As the vegetable weed management toolbox expands, growers are encouraged to implement sound programs in each of their fields. Starting clean (no weeds at planting), overlapping residual herbicides throughout the season when feasible, applying postemergence/row middle herbicides and/or tillage in a timely fashion, and then removing the crop and weeds as soon as harvest is complete (hopefully before weed seed maturity) are critical to success. Also remember success of a weed control program is influenced greatly by the commitment of managing the weed seedbank, a job that requires work 365 days a year.

Table 1. Rely uses and rates for cantaloupe, cucumber, summer squash, and watermelon.

Use Pattern	Herbicide	Amount of Formulation	lb Active Ingredient	Remarks
Preplant burndown in plasticulture only; not for preplant use in bareground production	*glufosinate* Rely 2.34S	29–43 oz/acre	0.53–0.79	Can make up to two applications not to exceed 64 fl oz/acre. *At least a 3 day interval between application and transplanting PLUS a rain/irrigation event of at least 0.5 in. in a single event must occur between application and transplanting to remove herbicide from mulch.* DO NOT punch holes until after washing mulch, and transplants must not land within 6 in. of any holes/tears in mulch at time of application.
Precision row middle applications avoiding crop contact (hood)	*glufosinate* Rely 2.34S	29–62 oz/acre	0.53–1.14	Make one or two hooded applications not to exceed a total use of 62 fl oz/acre. Allow at least 14 days between sequential applications. Do not spray within 6 in. of running vines. *When including preplant burndown and row middle applications do not exceed three applications and 87 fl oz/acre.*

Table 2. Rely uses and rates for tomato and pepper (bell and non-bell).

Use Pattern	Herbicide	Amount of Formulation	lb Active Ingredient	Remarks	
For burndown of emerged weeds prior to transplanting	*glufosinate* Rely 2.34S	29–43 oz/acre	0.53–0.79	**Bareground production**: Up to three applications are approved not to exceed 87 oz/acre. The interval between application and planting is 14 days plus a 0.5 in. rainfall/irrigation in a single event.	**Mulch production:** Up to two applications are approved not to exceed 64 oz/acre. Beds must be shaped such that water and herbicide runoff into the row middle. *At least a 3-day interval between application and transplanting PLUS a rain/irrigation event of at least an 0.5 in. in a single event must occur between application and transplanting to remove herbicide from mulch.* DO NOT punch holes until after washing mulch and transplants must not land within 6 in. of any holes/tears in mulch at time of application.
Precision row middle applications avoiding crop contact (hood)	*glufosinate* Rely 2.34S	29–62 oz/acre	0.53–1.14	Make one or two hooded applications not to exceed a total use of 62 fl oz/acre. Allow at least 14 days between sequential applications. Do not spray within 6 in. of running vines. *When including preplant burndown and row middle applications do not exceed three applications and 87 fl oz/acre.*	

Monitoring of Overwintering Pepper Weevil in Southern Georgia

A. N. Sparks

Introduction

Pepper weevil, *Anthonomus eugenii* Cano, is the key pest of peppers wherever the crop and pest coexist. In Georgia, pepper weevil was historically considered an occasional pest, with infestations generally attributed to man-aided movement. Recent monitoring of overwintering in populations with pheromone traps clearly demonstrated that pepper weevil now overwinters throughout southern Georgia, including all our primary pepper production areas. To monitor this situation and make growers aware of the issue, pheromone traps were established and monitored throughout the winter of 2022–2023. Traps were established in the primary pepper growing counties. In general, traps were established in early December to determine population levels entering winter and monitored into the following spring planting season to determine if weevils successfully overwintered.

Material and Methods

Fields were monitored in Brooks, Echols, Lowndes, Grady, Tift, and Worth counties. In general, traps were established in fields that had been planted to pepper during the fall. Four pepper weevil traps were established in each field. Traps were baited with the standard two-part pepper weevil pheromone from Trece Corporation (Pepper Weevil 4-Station Kit, Trece Corp., Adair, OK). Traps were run for 2 weeks each month from December through February and weekly during March. In total, pepper weevil traps were run in 17 fields.

Results

The overall trends were similar to previous years, with large populations entering early winter and obvious survival of low populations well into late winter (Figures 1 and 2). Very high numbers can be captured during the winter, particularly during warmer periods with individual traps occasionally catching more than 1,000 adults in a single week.

As the weather warms and planting season approaches, the majority of the weevils appear to die. However, even one weevil per trap is too many at planting time, as adults can utilize pepper foliage as a food source and survive until fruit are available for reproduction. Although this obviously occurred in multiple fields (Figure 2, last two sample dates), a majority of fields had no weevils captured in late March. This is unlike previous years trapping when weevils were captured in all fields in late March.

While the cause of the low captures in March is unknown, we can speculate on the cause. Southern Georgia experienced an extended freeze event in mid-December 2022. Minimum temperatures approached 15 °F, temperatures were continuously below freezing for 24–36 hr, and they dipped below freezing for 6 nights consecutively. While none of these events are adequate to cause extensive mortality in pepper weevil adults, they would likely kill potential host plants. Thus, we did not see an elimination of weevils from the event, as indicated by significant trap captures in January, but likely impacted longevity of adults, resulting in reduced numbers of weevils surviving in late March 2023.

Conclusion

As in previous years, our research indicates that the majority of weevils entering the winter do not survive to spring planting (suggesting that attempts to control weevils during the winter are likely unwarranted); however, low numbers do survive and infest the spring crop. The extended freeze experienced in December 2022 likely further reduced the population of weevils surviving to infest the spring crop, but it did not eliminate all weevils in southern Georgia.

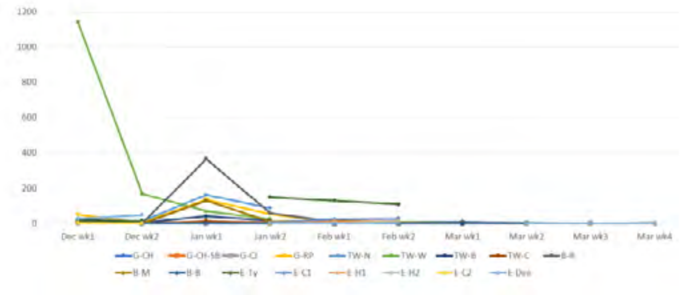

Figure 1. Average weevil captures per trap, 2022–2023.

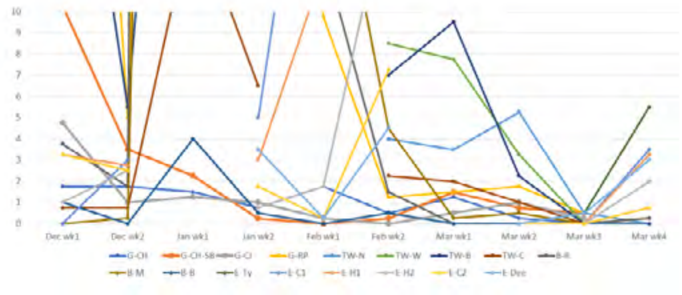

Figure 2. Weevil captures per trap, 2022–2023. Emphasis on lack of zero capture dates.

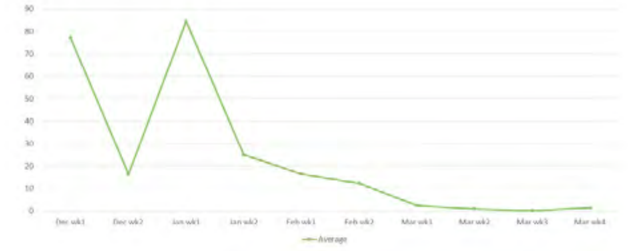

Figure 3. Weevil captures per trap, 2022–2023, averaged across all fields.

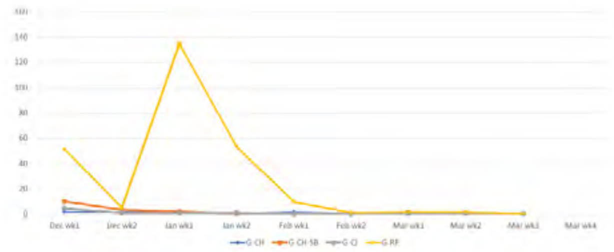

Figure 4. Average weevil captures per trap, 2022–2023, Grady County.

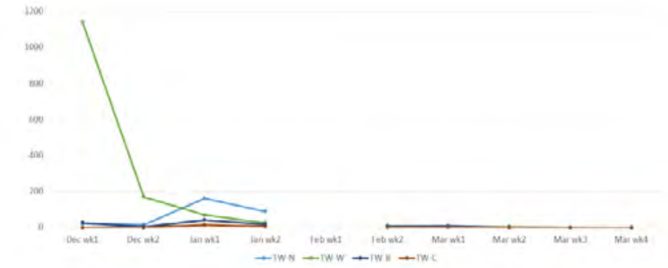

Figure 5. Average weevil captures per trap, 2022–2023, Tift and Worth counties.

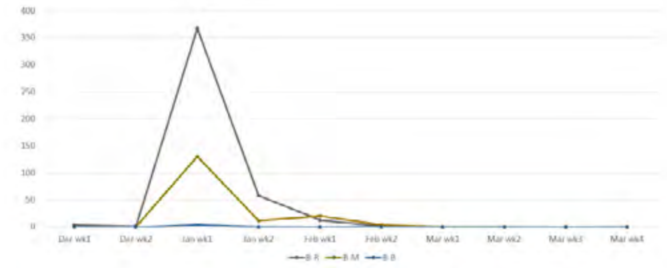

Figure 6. Average weevil captures per trap, 2022–2023, Brooks County.

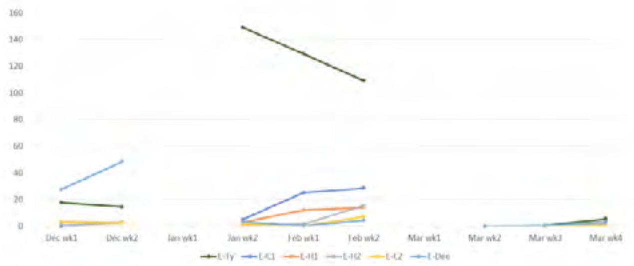

Figure 7. Average weevil captures per trap, 2022–2023, Echols and Lowndes counties.

Bioassay of Diamondback Moth with *Bacillus thuringiensis* and Baculovirus Inseciticide Mixtures

T. Dunn, P. Cremonez, W. Brown, D. Riley, D. Champagne

Introduction

In 2022, the Tifton Entomology Vegetable Research Lab conducted several bioassays to assess the efficacy of *Bacillus thuringiensis* (Bt) and Baculovirus (AcMNPV) insecticides for the control of diamondback moth (DBM), *Plutella xylostella*. The insecticides tested were XenTari (*Bacillus thuringiensis* subsp. *aizaiwai*), DiPel (*Bacillus thuringiensis* subsp. *kurstaki*), and Lepigen (*Autographa californica* Multiple Nucleopolyhedrovirus strain R3). Bt insecticides are applied consistently for DBM control in Georgia, and the recent registration of Lepigen has provided another product for potential insecticide rotations. Interestingly, both antagonism and synergism have been observed when mixing Bt insecticides with different NPV products for control of other lepidopteran pests (Pingel & Lewis, 1999; Raymond et al., 2006; Dader et al., 2020). Therefore, assessment of these effects for DBM via bioassay is the logical first step to explore potential concerns.

Figure 1. Damage to a collard leaf in Grady County, GA from diamondback moth larvae. Photo: T. Dunn and W. Brown.

Material and Methods

Throughout the 2022 growing season, larvae were collected from two commercial collard field sites in Cook and Worth (SMN) counties in Georgia, as well as a test plot at the Vidalia Onion and Vegetable Research Center in Toombs County. Larvae were transported to the Coastal Plains Experiment Station in Tifton and reared to the first generation for toxicological characterization. Additionally, a susceptible population, maintained by Frontier Genomics (FRT), was used as a control population.

The leaf-dip bioassay method was utilized for toxicological assessment of the field-collected colonies for Bt insecticides individually (doses tested were equivalent to these rates: XenTari 1.5 lb/acre, DiPel 1.0 lb/acre), as well as in mixture with the AcMNPV product Lepigen. For the FRT colony, the same maximum doses were used in bioassay (high), as well as 10-fold dilutions of the maximum labelled doses of the Bt products (low). The dose of Lepigen was consistent for every mixture (equivalent to a rate of 1.5 fl oz/acre) throughout all bioassays. These were completed using untreated collard leaf discs as the bioassay substrate and 0.1% v/v of Kinetic adjuvant.

Each treatment had a minimum of three replicates, with 10 larvae per replicate. Replicates were checked every 24 hr until the 72-hr mark, and live, down, dead, and pupated larvae were recorded. Mortality data, represented as percent mortality, was then analyzed using PROC GLM and Tukey HSD.

Results

Bioassay of the field-collected populations revealed no synergistic effects of Bt and Lepigen mixtures (Figure 2). When comparing the Bt insecticides to their corresponding mixtures, no significant differences were recorded. However, a marginal reduction was recorded for DiPel and Lepigen in the SMN bioassay, suggesting the mixture slightly reduced mortality in comparison to the individual DiPel treatment (Figure 2A). Similar results were recorded for the susceptible FRT population. While the high doses and their respective mixtures were not significantly different from each other, the mortalities of the low doses of both Bt products were significantly higher than their respective low dose mixtures (Figure 3).

Conclusion

The data suggests that XenTari and DiPel experienced no synergistic effects in terms of DBM mortality when mixed with Lepigen for control of these colonies. Additionally, potential antagonism was experienced with two of these colonies. While the data seems to indicate that there is no benefit from mixing these products for application, further field studies may be required to confirm these effects alongside other environmental factors. We must also acknowledge that Lepigen efficacy was not assessed individually in these experiments.

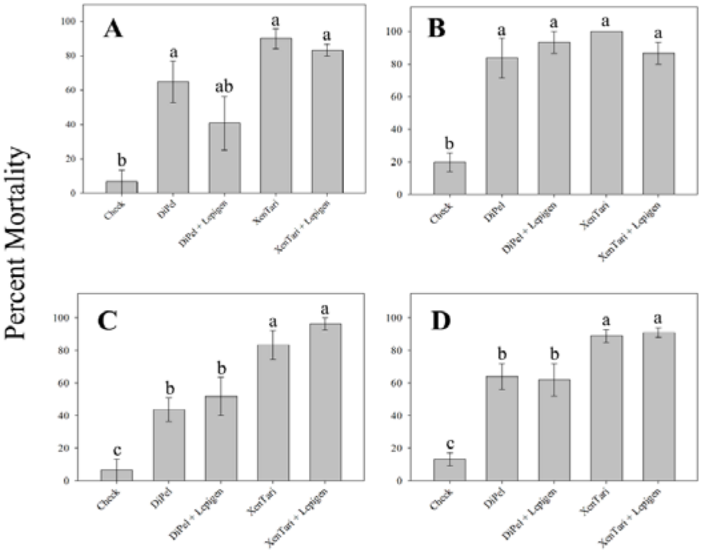

Figure 2. Bioassay results (72 hr) of (A) Worth County (SMN), (B) Toombs County (TMB), (C) Cook County (CKC), and (D) a composite of all three colonies of diamondback moth populations collected during the 2022 growing seasons. Comparisons and means separation analysis were completed via GLM (Tukey HSD).

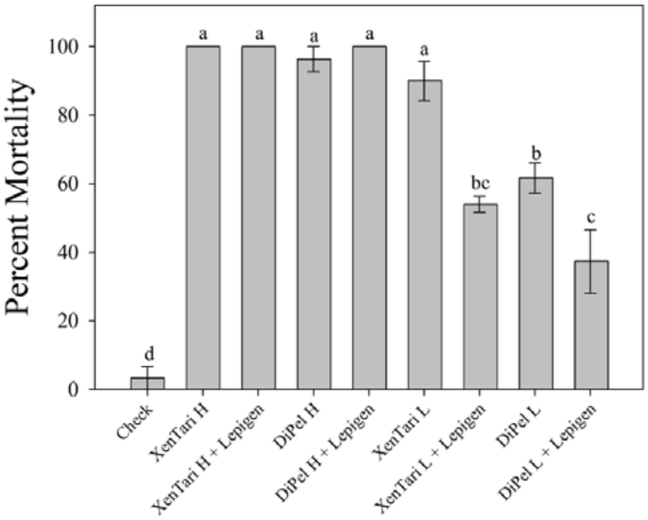

Figure 3. Bioassay results (72 hr) of the Frontier (FRT) diamondback moth population. H represents the maximum labelled dose of the associated product, while L represents a 10-fold dilution of the maximum labelled dose. Comparisons and means separation analysis were completed via GLM (Tukey HSD).

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Host Plant Resistance to the Diamondback Moth in Laboratory and Field Tests

D. Riley, W. Brown

Introduction

The literature on host plant resistance in cabbage to diamondback moth (DBM), *Plutella xylostella*, can best be summarized by three main reports. Eigenbrode and Shelton (1992) stated that "reduction in leaf waxes is the basis of resistance to *P. xylostell*a in genetically glossy plants." A follow-up paper by Hariprasad and van Emden (2010) stated that "leaf toughness and surface wax load" under field conditions appear to be most important factors associated with resistance to DBM. Thus, most of the factors contributing host plant resistance to DBM appeared to be physical. However, Sun et al. (2009) stated that "nonvolatile indole glucosinolates and volatile aliphatic glucosinolate breakdown products both appear to play important roles as host recognition cues for *P. xylostella* oviposition."

In 2021, a cabbage variety trial in Colquitt County, GA, indicated that one of the cultivars being tested, 'Green Challenger', was visibly more resistant to diamondback moth than all of the other cabbage hybrids being evaluated. The significantly reduced damage and DBM infestation compared to standard cultivars in adjacent plots suggested that either the cultivar was not preferred for egg-laying by DBM adults (nonpreference) or that there was some quality of the plant that was detrimental to DBM larval feeding and development resulting in greater mortality, similar to the Hariprasad and van Emden (2010) report. We investigated two specific cabbage traits, plant volatiles and plant age, that could be used for reducing the damage impact of diamondback moth in cabbage based on field observations and previous reports on cabbage resistance to DBM.

Material and Methods

Objective 1: Olfactometry study. An A10 olfactometer was set up with a factory-tanked, ultra-clean, or "zero," air source and maintained in a filtered, laminar flow hood for maximum air purity during data collection. One study consisted of one of the glass closed volatile collection chambers (VCC) loaded with a five-leaf seedling of each variety versus an empty VCC to observe a choice between the cabbage volatile and no cabbage volatile for each variety. The other olfactometer study compared the preference for volatiles of 'Green Challenger' to 'Cheers' by loading a five-leaf seedling of 'Green Challenger' in one VCC and 'Cheers' in a separate VCC in different runs. The moving behavior of the DBM adult toward the preferred air source was recorded.

Objective 2: Choice tunnel study. Five cabbage cultivars, including 'Green Challenger' and 'Cheers', were transplanted (10 plants each) into plastic mulched beds and immediately covered with floating row cover tunnels in four replicates. A rate of four moths/10 plants was released at each end of each tunnel. DBM reproduction and damage were assessed after two DBM generations under the tunnel or approximately 1 month. After the first month assessment from transplant to precupping growth stages, the test was uncovered for 1 month and a second pest and damage assessment was made. Then the whole test was sprayed with the insecticide combination of spinetoram (Radiant 1SC at 10 fluid oz/acre) and bifenthrin (Bifenture EC 6.4 at fluid oz/acre). At that point a fresh tunnel was pulled over the maturing cabbage plants and another release of DBM adults at the same rate was introduced into each tunnel 1 week after treatment.

After a 3 month period, we uncovered the plants, sampled DBM (and other insects), and did a final cabbage weight and damage assessment. The test was conducted in the spring season when DBM were prevalent. We also conducted a choice study without the tunnels, just relying on the natural DBM population to infest the cabbage plots. Cabbage yield data from this and the following no-choice test were contrasted to see if similar yield differences could be seen in tunneled versus nontunneled or open cabbage plots.

Objective 3: No-choice tunnel study. The same five cabbage cultivars were transplanted (20 plants each) into the same tunnels described above, but with only a single cultivar in each tunnel. The same rate of four moths/10 plants used under Objective 1 were released per tunnel. DBM reproduction and damage were assessed after two DBM generations under the tunnel or 1 month. We used the same "1 month uncovered, sample, spray, recover, re-release DBM and take the final data" protocol as under Objective 1.

Results

The olfactometer results (Objective 1) presented in Figure 4 demonstrated a significant choice effect overall ($F = 83.4$, df = 2, 375, $P < 0.0001$), but not when just considering clean air versus cabbage volatile ($F = 1.55$, df = 1, 250, $P = 0.21$). When you grouped the more resistant 'Green Challenger' and 'Cairo', there was a marginally significant effect in favor of clean air ($F = 3.23$, df = 1, 56, $P < 0.077$) suggesting strong nonpreference, possible repellency, but mostly confirming no attraction of these cabbage lines for DBM adults. The average no-choice selection for these resistance lines was 86%, whereas that selection was 65% in the other susceptible lines combined, suggesting that there was just more adult activity around the volatiles of the susceptible cabbage lines (Figure 1). When we compared just the susceptible 'Cheers' line to the resistant 'Green Challenger' line compared to a no-choice, the average choice for each was 0.13 ± 0.063, 0.07 ± 0.046, and 0.80 ± 0.074 ($n = 30$), respectively, showing that 'Cheers' was preferred about twice as much as 'Green Challenger'.

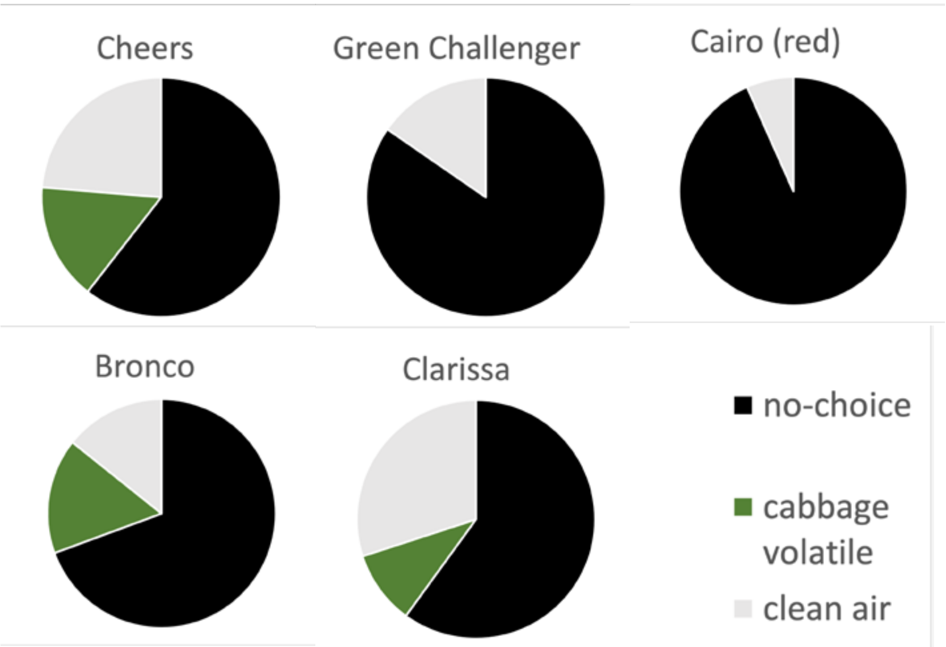

Figure 1. Olfactometer study showing a majority of no-choice moths remaining in central tube.

In the choice experiment (Objective 2) under the row cover tunnel, 'Clarissa' appeared to be preferred more prominently than the other varieties 1 month after planting, as seen in Figure 2, but the numbers decreased dramatically on the next two sample dates, after the tunnel was removed and after the late season tunnel with a new infestation was re-applied. 'Green Challenger' and 'Cheers' seemed less preferred initially; however, due to a large amount of variation between replicates, there were no significant differences in number of DBM between varieties on any date. The only consistent effect was that all DBM numbers declined at harvest dramatically across all varieties, suggesting that there may be some mature plant resistance to DBM. Overall, the tunnel choice study suggested that there was no clear preference of DBM for the five cabbage cultivars tested. The floating row cover (Agribon+ AG-30 70% light transmission) with reduced sunlight could have affected the wax surface of the cabbage leaves.

Just as there was no clear choice of DBM in the choice experiment under the row cover tunnel, there was also no significant difference in foliar damage, based on the 0–5 damage rating system. The open study provided some evidence that it was not just a lack of effect due to the tunnel. Naturally occurring DBM, in the open study, tended to prefer 'Green Challenger' the least compared to the other cultivars 1 month after planting but did not result in a significant difference from 'Cheers'. The only data that supports the 2021 field observation that 'Green Challenger' was resistant to DBM was just in the crop yield response, and even

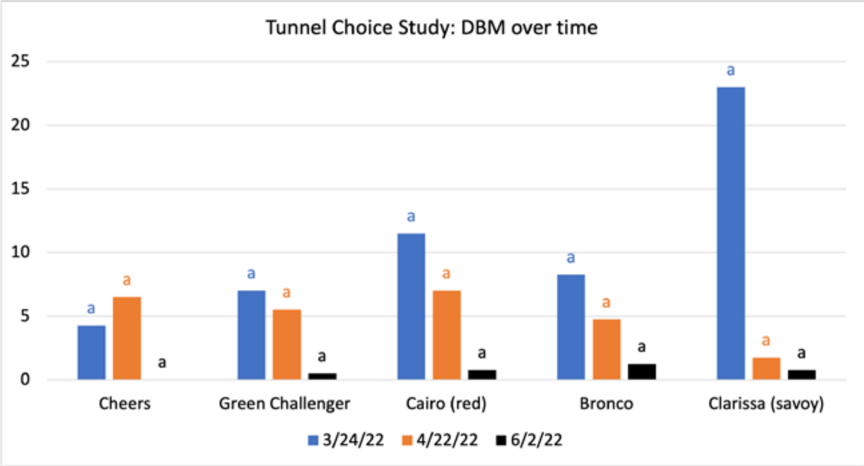

Figure 2. Choice experiment under tunnel, average number of DBM larvae plus pupae per cabbage cultivar near the end of the 1st, 2nd, and 3rd month of the growing season [same color bars with different letters are significantly different ($P < 0.05$, LSD)].

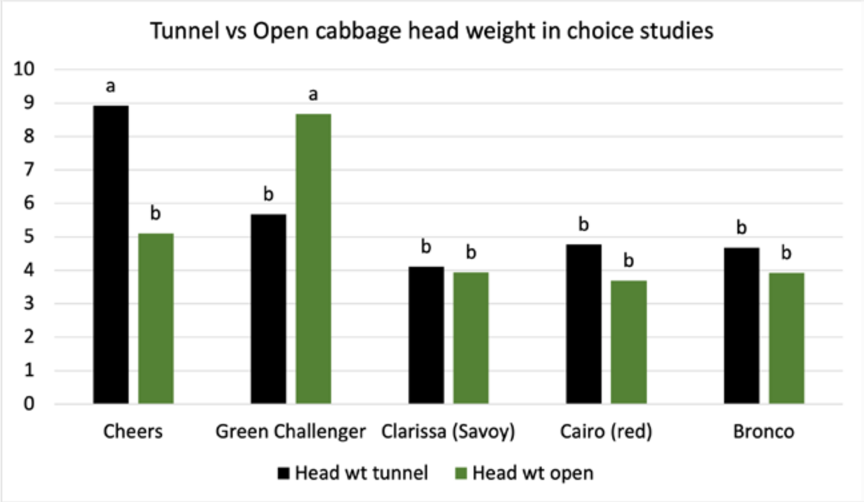

Figure 3. Cabbage head weight by cultivar comparing the no-choice experiment under tunnel versus the open nontunnel choice test [same color bars with different letters are significantly different ($P < 0.05$, LSD)].

this varied depending on whether you grew the cabbage under a row cover tunnel or in the open sun (Figure 3). Under the tunnel, 'Cheers' outperformed 'Green Challenger' in terms of head weight (Figure 3). However, outside of the tunnels, in open sunlight conditions with heavy initial DBM populations, the 'Green Challenger' line outperformed Cheers (Figure 3). Thus, there did seem to be a plant response, like tolerance to DBM infestation in field conditions. The question remained, did 'Green Challenger' negatively influence DBM in the no-choice test?

Unfortunately, in the no-choice experiment under tunnel (Objective 3), 1 month after planting, 'Green Challenger' and 'Cheers' supported DBM reproduction greater than the other varieties, i.e., the greatest amount of DBM larvae and pupae (Figure 4).

The damage did decrease in the no-choice experiment for 'Green Challenger' and 'Cairo' once the tunnel was removed; specifically, lepidopteran damage decreased on 'Green Challenger' but increased on 'Cheers' 2 months after planting (Figure 5). Like in the choice experiment under tunnel, the population of DBM declined across all plots at the end of the growing season, although the amount of DBM on 'Cheers' remained higher (Figure 4).

Conclusion

To summarize the results, the olfactometry data suggested that 'Green Challenger' was one of the cabbage varieties to which DBM adults were not attracted. The choice studies, both the tunnel and open experiments, did not show a clear attraction or repellency of any of the five cabbage lines tested, especially when plants were young. Even so, in the open study, 'Green Challenger' did produce more head weight than the other lines suggesting that it was more tolerant to DBM damage than the other varieties tested by the end of the season when the plant was mature. In the no-choice tunnel study, 'Cheers' had the highest number of DBM on the last date, suggesting that it was the most preferred for DBM reproduction by the end of the field test. In other words, 'Cheers' seems to have the least amount of resistance to DBM immatures on the mature plant, and 'Green Challenger' has a greater amount of mature plant resistance.

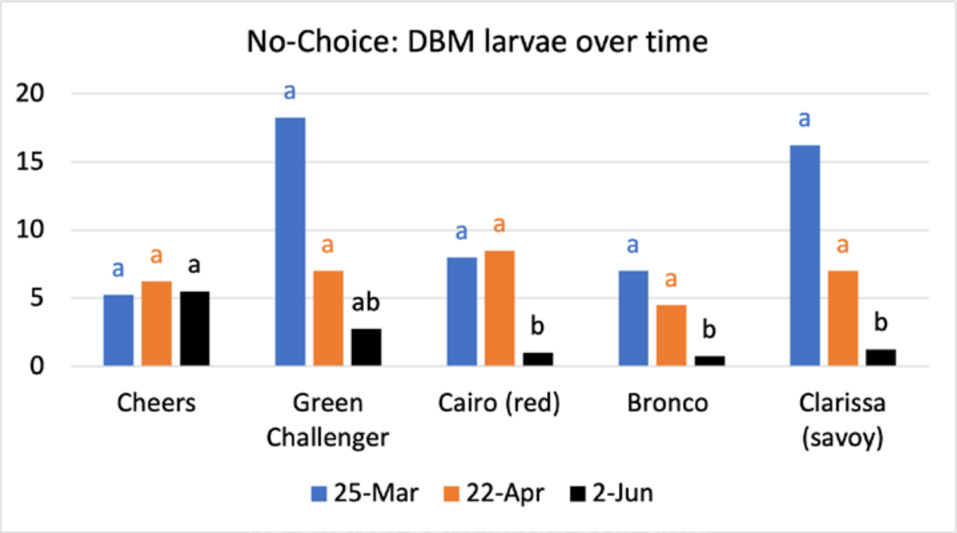

Figure 4. No-choice experiment under tunnel, showing average number of DBM larvae plus pupae per cabbage line near the end of the 1st, 2nd, and 3rd month of the growing season [same color bars with different letters are significantly different ($P < 0.05$, LSD)].

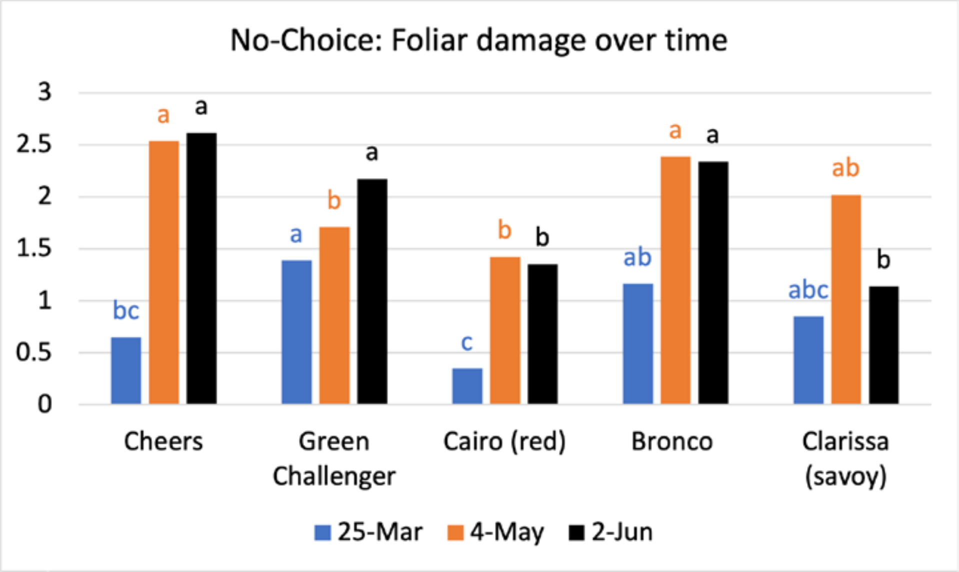

Figure 5. No-choice experiment under tunnel, showing average rated damage per cabbage line near the end of the 1st, 2nd, and 3rd month of the growing season [same color bars with different letters are significantly different ($P < 0.05$, LSD)].

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Evaluation of Commercial Tomato Varieties for Resistance-Break Against Insect-Transmitted Viruses Under Natural Disease Incidence in Georgia

M. Kumar, S. R. Kavalappara, T. McAvoy,
T. Torrance, C. Cloud, S. Bag

Introduction

Tomato (*Solanum lycopersicum* L.) production in the United States has been severely impacted by tomato yellow leaf curl virus (TYLCV). Furthermore, a complex association of whitefly-transmitted TYLCV and tomato chlorosis virus (ToCV) were recently identified in tomato. Several tomato cultivars were developed and commercialized with intermediate resistance against TYLCV-IL (Israel), the predominant strain of TYLCV found in Georgia. TYLCV-resistant cultivars were tested in open field conditions against multiple whitefly-transmitted viruses in Georgia under natural disease pressure during the fall of 2022. The area under disease progress curve over time showed a steady increase in disease severity among all cultivars from 30 days to 60 days after tomato transplantation. Further analysis of infected samples using molecular techniques revealed the presence of TYLCV and ToCV in symptomatic leaves. A mixed infection of both viruses (TYLCV and ToCV) resulted in severe disease development which may enhance the commercial tomato plants to break resistance and lead to decreased fruit quality and marketable yields.

Material and Methods

Plant materials: In the fall of 2022, seven commercially available slicer tomato cultivars with different combinations of Ty (resistance) genes were evaluated under natural incidence in Tift County and a commercial field in Colquitt and Grady counties (Table 1). Ten plants of each variety were transplanted on the first week of August 2022 in four replications. The plots were maintained as per standard Georgia tomato production guidelines.

Disease observation and sample collections: Research symptom severity was visually observed, and disease incidence was monitored every 2 weeks after transplantation. A disease severity scale ranging from 1–5 was utilized, where 1 = no symptoms; 2 = very mild yellowing; 3 = mild yellowing and downward or upward leaf curling; 4 = severe yellowing, leaf rolling, yellowing (in lower leaves), and leaf chlorosis; and 5 = severe leaf curling and stunted growth. Symptomatic leaves were collected from five plants of each cultivar from each replication at 45 days and 60 days posttransplanting (DPT).

Virus quantification and detection: To ensure the presence of virus in the samples, symptomatic tissues were homogenized using extraction buffer by mechanical disruption in a Bead Mill Homogenizer (Thermo Fisher Scientific, Waltham, MA). Virus segment specific primers were used for the amplification of the target genome using polymerase chain reaction. Since very little information is known about ToCV from Georgia, symptomatic tomato samples collected from the UGA Research Farm in Tifton in 2021 were also used for advanced high throughput sequencing for detailed analysis.

Figure 1. Symptoms observed on tomato plants infected with tomato yellow leaf curl disease caused by tomato yellow leaf curl virus (TYLCV) and tomato chlorosis virus (ToCV) in Georgia. Symptoms observed are (A, B) upward curling of leaves, ywllow margin; (C) dwarfism; and (D) leaf curling on the upper foliage and interveinal chlorosis of lower leaves.

Results

Tomato yellow leaf curl disease (TYLCD) is a serious threat to tomato production worldwide. TYLCV epidemics have posed a major threat to tomato production in the southeastern U.S. Several cultivars carrying resistance genes against TYLCV are commercially available in the United States. Seven such cultivars with different combinations of resistance genes were evaluated under field conditions in different locations in South Georgia during the fall of 2022; this is when whiteflies and TYLCV incidences were the highest during each year. Symptom severity was measured until 60 DPT. In Grady County, the symptoms of TYLCD started after 30 DPT, whereas the symptoms started appearing after 45 DPT in Colquitt County. The symptoms were more severe in Tift County as compared to Colquitt and Grady counties. Due to the lower disease incidence, cultivars evaluated in Grady County expressed less severe symptoms. However, in Tift County after 45 DPT, all seven cultivars evaluated had greater than a 50% incidence of TYLCD, and by 60 DPT, there was 100% TYLCD incidence. The high incidence of the disease in these genotypes was not unexpected because they are not immune and get systemically infected. However, all test lines carrying resistance genes showed severe symptoms typical of those produced on susceptible cultivars, contrary to the milder symptoms expected.

The susceptible cultivar 'Myrtle' supported significantly higher TYLCV virus concentration (titer) counts compared to the test cultivars at 60 DPT in all infected plant samples (Figure 2). Additionally, a significant increase in viral count has been observed in 'Myrtle' and 'STM2255' over time when comparing 45 versus 60 DPT (Figure 2A). In contrast, there was no significant difference in either symptom severity or disease progression among the selected tomato cultivars. This indicated that there is some contributing factor to the symptoms observed other than TYLCV.

To further confirm our hypothesis, we did high throughput sequencing, resulted in confirmation of another RNA genome containing virus, ToCV. Typical symptoms of ToCV include interveinal yellowing of leaves, leaf thickening, leaf rolling, and infected leaves that are brittle and crispy on the lower canopy of the plant. Often, these symptoms are misdiagnosed as abiotic stress including nutritional deficiencies or heat stress. In Georgia, ToCV was first reported in field-grown tomato in research trials conducted in 2009 and 2010. However, there had been no further reports of the incidence or spread of ToCV in the region. ToCV was mixed-infected with TYLCV and detected in all the tomato cultivars after 8 weeks of transplantation. The presence of ToCV at significant levels in the symptomatic plants mix-infected with TYLCV might boost the breakdown of TYLCV-mediated resistance/tolerance in tomato plants.

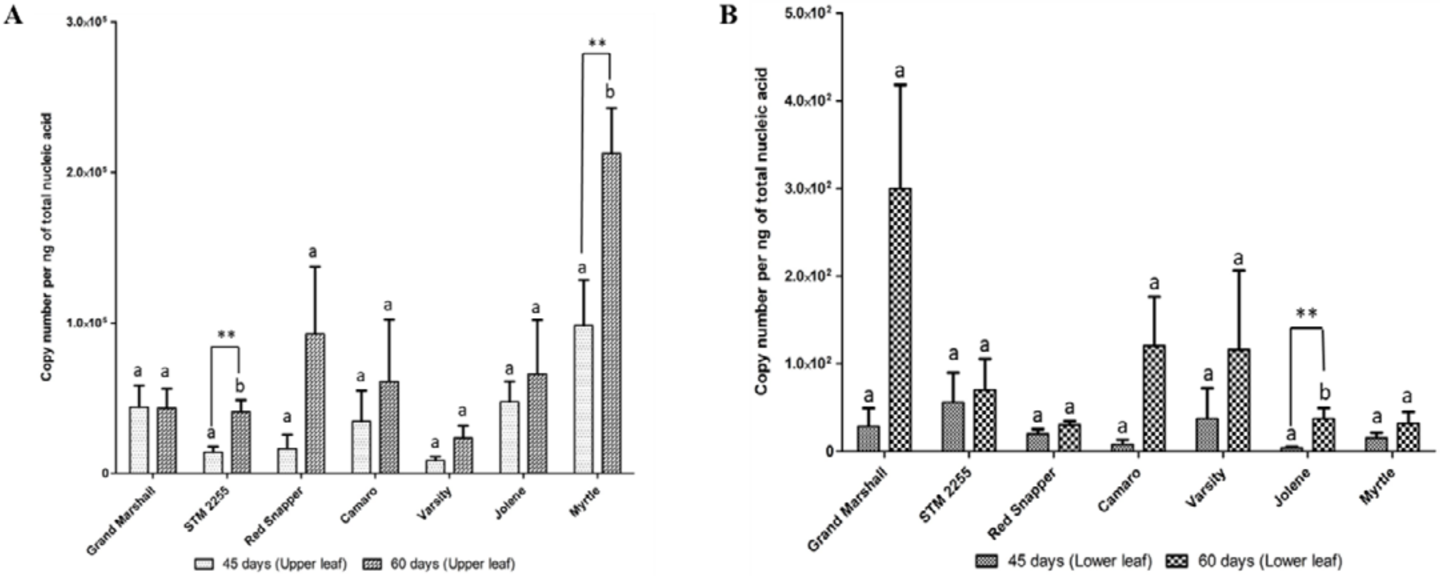

Figure 2. Quantification of virus titer in symptomatic tomato plants with tomato yellow leaf curl virus (TYLCV) and tomato chlorosis virus (ToCV) at 45 and 60 DPT. TYLCV copy numbers were quantified in the latter from the top symptomatic tissues (A), while for ToCV (B) it was in the lower foliage from pooled samples from at least five plants. The graphs represent an average of four replicates from each cultivar. The y-axis represents virus copy number per ng of total nucleic acid; the x-axis shows tomato cultivars used in this study.

Conclusion

Detection of ToCV on all samples tested and in three different counties supports that ToCV is now widely prevalent in Georgia. Coinfection of ToCV and TYLCV in tomato has been recently reported in China and Spain as well. Tomato plants coinfected with TYLCV and ToCV showed more severe symptoms at late stages compared to single infections. Mixed infection resulted in increased accumulation of both the viruses in tomato plants and induced severe symptoms, resulting in decreased plant height and weight. We are speculating that susceptible varieties, such as 'Versity', 'Myrtle' (with single or no resistance gene), and others, such as 'Jolene', 'STM2255', and 'Red Snapper' (with more than one resistance gene) are getting infected with TYLCV and ToCV, regardless of the presence of plant tolerance/resistance factors against TYLCV in these cultivars. Further investigation is needed to determine the mechanism of ToCV in TYLCV-mediated resistance breakdown and the potential chance of the emergence of a new viral strain in intermediate or resistant tomato varieties.

Table 1. Comparison of cumulative symptom severity (on symptomatic tomato varieties) of tomato yellow leaf curl virus and tomato chlorosis virus.

Sl. No.	Tomato Cultivar	Source Used (*Solanum lycopersicum* cv.)	*Ty*-Gene (resistance)	AUSPC (mean)†	Standard Error	Multiple Mean Comparison*
1	Grand Marshall	Sakata Seeds, Morgan Hill, CA	*Ty3* and *Ty6*	1593.75	242.03	a
2	STM 2255	Sakata Seeds, Morgan Hill, CA	*Ty3* and *Ty6*	2018.75	184.67	a
3	Red Snapper	Sakata Seeds, Morgan Hill, CA	*Ty3* and *Ty6*	1868.75	149.09	a
4	Camaro	Sakata Seeds, Morgan Hill, CA	*Ty3* and *Ty6*	1850	200.78	a
5	Varsity	Syngenta Vegetable Seeds, Greensboro, NC	*Ty1*	2231.25	187.47	a
6	Jolene	Bejo Seeds, Inc., Oceano, CA	*Ty3* and *Ty6*	1700	195.52	a
7	Myrtle	Bayer Crop Science, Creve Coeur, MO	None	2431.25	79.3	a
8	SkyWay687**	Enza Zeda, Enkhuizen, Netherlands	*Ty3* and *Ty6*	225	159.1	a
9	HM 8148**	HM Clause, Halls, NY	*Ty3* and *Ty6*	112.5	64.95	a
10	Saybrook**	Bayer Crop Science, USA	None	ND	ND	a

Note. Symptom severity is measured as area under symptom progress curve (AUSPC).

† AUSPC is calculated using mean of 10 individual plants with four replications (10 × 4 = 40 plants), measured at 0, 15, 30, 45, and 60 days posttransplantation. AUSPC was performed as described earlier by Simko et al., 2021.

* Mean comparisons of 10 individual plants with four replications (10 × 4 = 40 plants) in each cultivar were performed using the ANOVA statistical test followed by multiple mean comparisons with Tukey's (HSD) test using XLSTAT, 2023.

** These varieties were only used in Grady County.

ND = Not determined.

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Support of the UGA Georgia Weather Network

P. Knox

Introduction

The Georgia Weather Network provides 15-min interval weather data and monitors soil conditions at 89 locations around the state, mainly in agricultural areas. Support from the Georgia Commodity Commission for Vegetables helps maintain weather stations, store archived data, and calibrate instruments, as well as work with Extension agents to monitor crop conditions and environmental data that can be used to predict pest and disease pressures on vegetable crops. This funding has allowed us to explore expansion of the network.

Material and Methods

Our network of 89 Campbell Scientific automated stations is maintained by one full-time and one part-time technician, an electronics engineer who provides IT support and manages the network, and a quality control specialist who monitors the data for errors and makes appropriate corrections. The technicians visit the stations every 4–6 weeks to clean and repair equipment and ensure that the quality of the site locations is maintained. Instruments are rotated out and calibrated on a regular schedule. The IT specialist maintains the network and is working on moving the historical data files from a Griffin-based service to online cloud storage for improved access. In 2022, we added stations at Gray and Townsend. In 2023, we moved the Brunswick station to Jekyll Island to provide weather data to the airport there. We are still looking for an additional site near Columbus to fill a gap in our network.

Results

In 2022, our network maintained nearly continuous availability of current high-quality weather data, other than some temporary delays due to cell network outages. We are proud that our data were available nearly 100% of the time due to our comprehensive maintenance program, which the Vegetable Commission helps fund. Our maintenance schedule is the envy of some weather networks in other states, where they visit their stations much less frequently.

In 2022, the work of moving the network data storage from server-based text files to a cloud-based database was continued. The migration has been delayed due to the lack of a suitable applicant to take over that task. As a result, in 2023 we contracted with a web development team at UGA-Tifton to assist us in finishing this project. We have created a full database with the help of a graduate student in the statistics department and are working to link it to our website.

Conclusion

Thanks to the support from the Vegetable Commission, as well as other commodity commissions in Georgia, the network performed well and consistently provided continuous and current high-quality data to Extension agents and producers around the state on demand. We provided additional archived data to scientists and students for specialized studies of disease and pest management on request. We hope to continue this service to vegetable producers and to expand our range of tools in the coming years.

Funding for UGA-Tifton Vegetable Park Research Farm

T. McAvoy, J. C. Diaz-Perez, B. Dutta, A. N. Sparks, S. Culpepper

Introduction

The University of Georgia Tifton campus is ideally located in the heart of the southern Georgia vegetable production regions. Tifton Vegetable Park (TVP) is the primary research farm at UGA-Tifton used by the vegetable team faculty to conduct trials in various disciplines including horticulture, plant pathology, entomology, and weed science. This research site is important for conducting high quality research that cannot be performed in commercial vegetable production fields.

The TVP allows researchers to apply experimental chemistries, control fertilizer and irrigation rates, inoculate with diseases, and leave control plots weedy, insect-infested, or full of pathogens. Infrastructure and equipment at TVP allow plasticulture (raised beds covered with plastic mulch using drip irrigation/fertigation), bare ground, or small greenhouse experiments to be conducted at the highest levels. Funding for TVP is critical to continue valuable research that positively impacts the vegetable industry.

Material and Methods

Funding in 2022 was used to procure various supplies including crop maintenance chemicals (fertilizer, fungicides, insecticides, and herbicides), plastic mulch, irrigation supplies (poly hose, timers, drip tape, connectors, and flush valves), vegetable seeds, cover crop seeds, sprayer tips, picking bins, seedling trays, wooden stakes, twine, labels, flags, marking tape, and spray paint.

Results

Impactful vegetable research was conducted at TVP under controlled parameters in similar climatic conditions to the surrounding vegetable production regions of southern Georgia to provide high quality data for making meaningful recommendations.

Conclusion

Funding for recurring supplies and equipment maintenance benefits all research at TVP, every department, and ultimately the entire vegetable industry in Georgia.

Managing Whitefly-Transmitted Viruses in Important Vegetable Crops of Georgia

R. Srinivasan, B. Dutta, C. McGregor, A. N. Sparks

Objective

Whiteflies and the impact of whitefly-transmitted viruses have become endemic to Georgia and manifest themselves regularly in the fall season each year. The roster of viruses found in 2022 and 2023 was similar to the previous years. The viruses included the tomato yellow leaf curl virus (TYLCV) and tomato chlorosis virus (ToCV) in tomato; cucurbit leaf crumple virus (CuLCrV), cucurbit yellow stunting disorder virus (CYSDV), and cucurbit chlorotic yellow virus (CCYV) in squash; and CuLCrV and sida golden mosaic virus (SiGMV) in snap bean. CCYV in squash was first identified in GA in 2020. CuLCrV and CYSDV/CCYV were often found as a mixed infection in squash. Similarly, CuLCrV and SiGMV were found as a mixed infection in snap bean. The mixed-infected plants are typically more symptomatic than plants infected with one virus and suffer heavy yield losses.

Our laboratory continues to spend considerable amounts of time and resources to understand how these viruses are transmitted by whiteflies, specificity in transmission, whitefly population dynamics, and virus epidemics. This research is continuous mainly because each of these questions requires a multitude of experiments to be precisely addressed. Our goal is to exploit the knowledge gained to better manage whiteflies and viruses in vegetable crops. Management has centred on host plant resistance (when available) and on cultural and chemical tactics. Host plant resistance is lacking against viruses especially in squash and snap bean. Our recent research has focused on evaluation for host resistance against one or multiple viruses and/or insects. Last year's research focused on resistance against cucurbit viruses in squash and against CuLCrV and SiGMV in snap bean.

Material and Methods

Squash breeding materials including PIs, bridge lines, and other species besides *Cucurbita pepo* were obtained from McGregor's program. A number of these materials were evaluated through whitefly-mediated inoculation in insect proof cages using a protocol optimized in our laboratory (Gautam et al., 2020). Similarly, the amount of virus accumulation in these materials also was evaluated for at least two of the viruses commonly found in squash, CuLCrV and CYSDV. Evaluations were also conducted for CCYV. We have essentially developed a high throughput screening platform to evaluate resistance.

Snap bean materials were obtained from Dutta's program based on previous evaluations. The selected materials were also evaluated using whitefly-mediated inoculation in insect proof cages using the protocol optimized in our laboratory (Gautam et al., 2023). Additionally, virus accumulation in these materials were also evaluated for two commonly occurring viruses, CuLCrV and SiGMV.

Results

Squash

Whitefly-mediated transmission assays indicated that *C. pepo* materials displayed more severe symptoms than other Cucurbita species (Figure 1). This reiterated

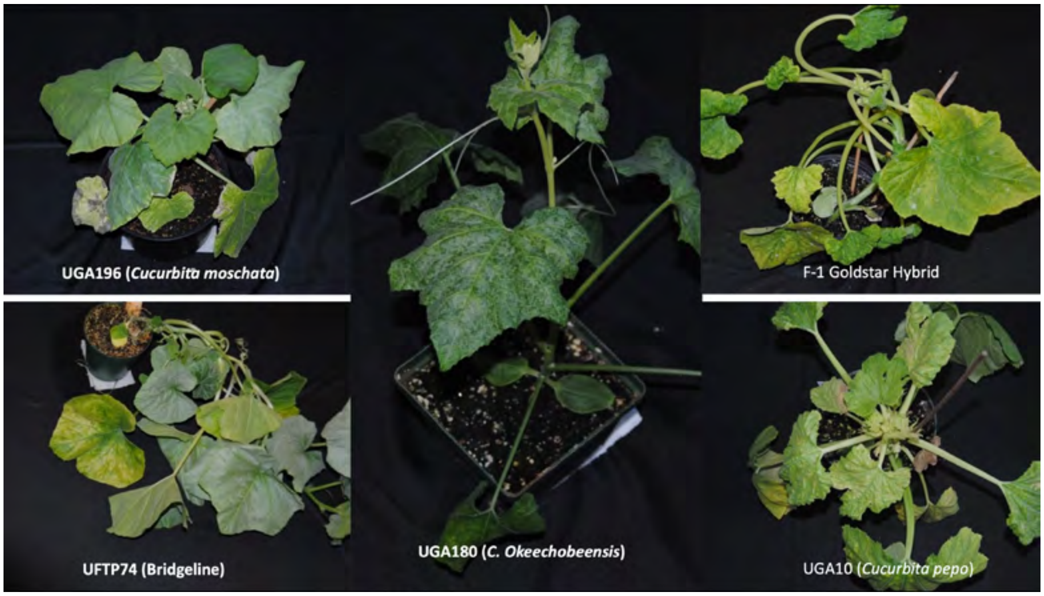

Figure 1. Cucurbita material showing varying symptoms of virus infection following whitefly-mediated inoculation.

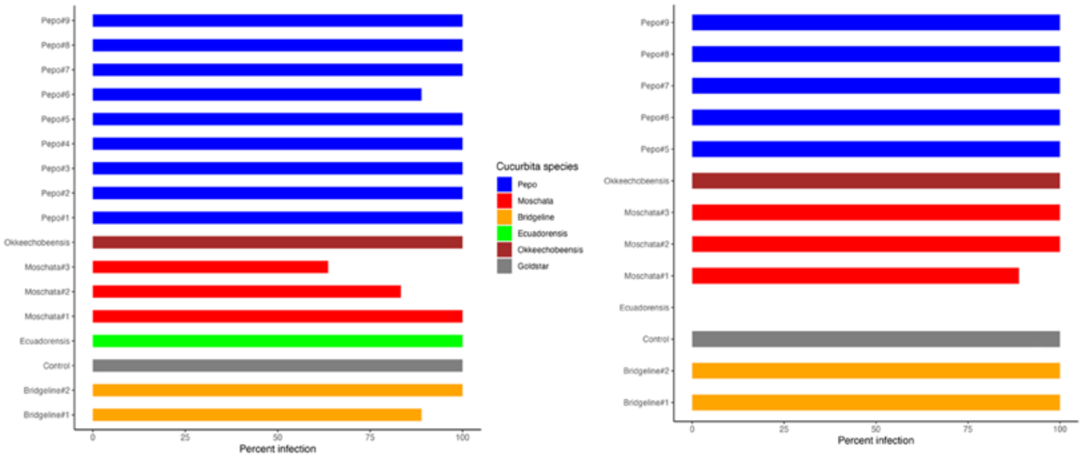

Figure 2. CuLCrV (left) and CYSDV (right) infection percentages in squash materials.

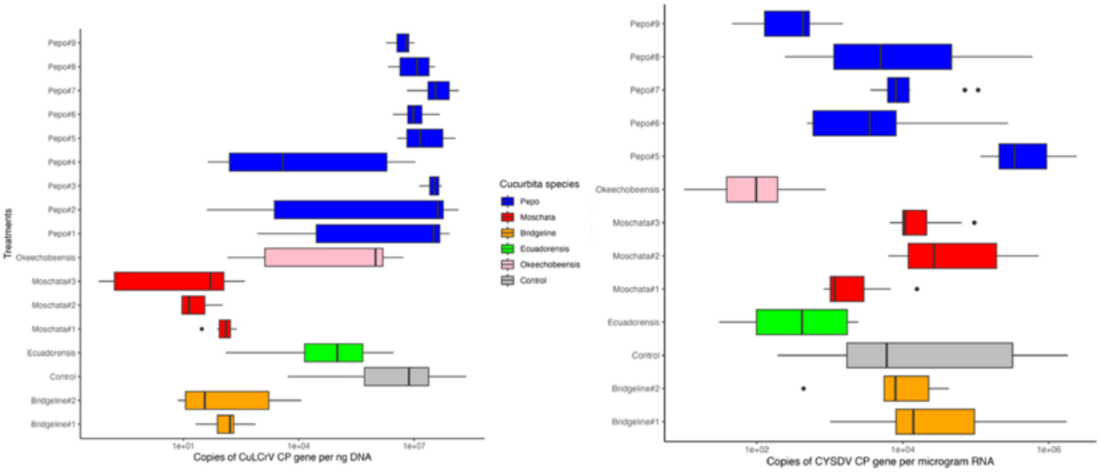

Figure 3. CuLCrV (left and CYSDV (right) copies in squash materials.

that *C. pepo* materials were extremely susceptible than other Cucurbita species. However, some of the bridge materials were promising and need to be evaluated further. In addition to evaluating virus-induced symptoms, virus infection percentages (Figure 2) and virus loads (accumulation; Figure 3) were determined.

Snap Bean

Whitefly-mediated inoculation of CuLCrV and/or SiGMV resulted in differential symptom expression. The results indicated that some materials tested were indeed tolerant/resistant to CuLCrV but the differences were not so legible in the case of SiGMV. The mixed infection of both viruses compromised CuLCrV resistance to a degree. Overall, no accession was immune to virus infection, and the results are explained in Figure 6. Numerous accessions were tolerant/resistant to CuLCrV but not SiGMV.

As explained with infection percentages, CuLCrV accumulation was reduced in several snap bean accessions evaluated. However, a lot of those accessions accumulated substantial amounts of SiGMV in comparison with the susceptible standard. Nevertheless, there were some accessions that displayed tolerance to both CuLCrV and SiGMV.

CuLCrV-infected Mixed-infected SiGMV-infected

Figure 4. CuLCrV and/or SiGMV infection in a susceptible snap bean cultivar.

SiGMV-infected Mixed-infected CuLCrV-infected

Figure 5. CuLCrV and/or SiGMV infection in a relatively resistant/tolerant snap bean accession.

Discussion

Host plant resistance (resistant cultivars) is the most convincing management option for whitefly-transmitted viruses. Our laboratory has been engaged in evaluating breeding materials for squash and snap bean for common whitefly-transmitted viruses. This work was conducted in conjunction with plant breeders and plant pathologists.

In squash, numerous *C. pepo* accessions evaluated were susceptible to CuLCrV and CYSDV. However, resistance/tolerance seems to be present in other Cucurbita species. Introgression of that resistance into *C. pepo* has been the challenge. Bridge lines of *C. pepo* hybridized with other species have shown promise in our evaluations and will be examined further.

In snap bean, numerous accessions have shown resistance/tolerance to CuLCrV and some in the case of SiGMV. This information is critical, as our research has clearly shown that more often than not both viruses occur as mixed infection/coinfection. However, some accessions seem to be tolerant to both viruses and show promise.

Meanwhile, research continues in our lab on whitefly-virus interactions aimed at developing long-term and sustainable management options.

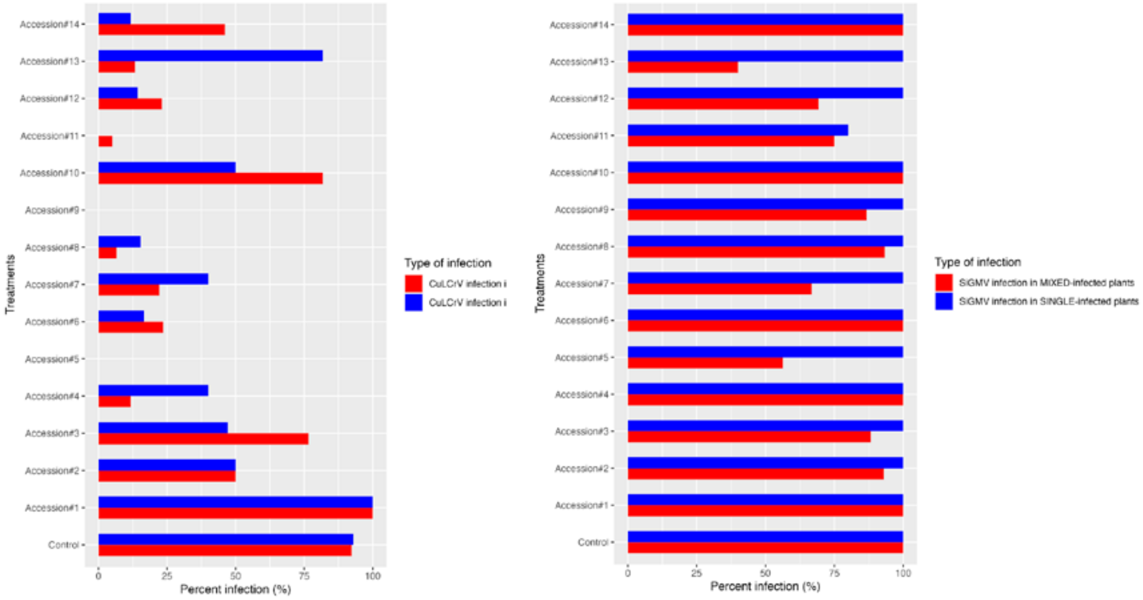

Figure 6. CuLCrV and/or SiGMV infection percentages in snap bean accessions.

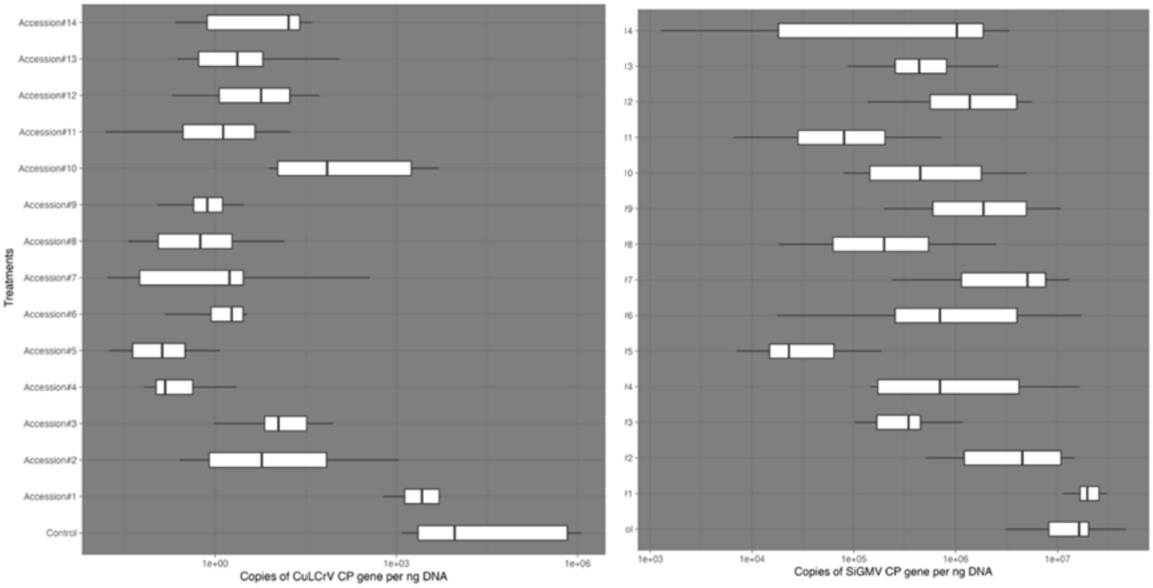

Figure 7. CuLCrV and/or SiGMV accumulation (loads) in snap bean accessories.

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