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Incidence and Distribution of Tomato Yellow Leaf Curl Virus (TYLCV) and the Potential of TYLCV-resistant Cultivars to Manage TYLCV and Other Tomato Diseases in South Florida

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Tomato yellow leaf curl virus (TYLCV), transmitted by whitefly (*Bemicia tabaci*), has been one of the major limiting factors in tomato production in Florida since its introduction in 1990s. Current control of TYLCV largely relies on heavy sprays for whiteflies. Planting resistant cultivars is the best way to manage TYLCV and reduces grower expenses for pesticides. Tomato cultivars commonly planted in south Florida are resistant to the devastating tomato chlorotic spot tospovirus (TCSV) but are susceptible to TYLCV. In early March 2021, a high level of TYLCV was observed in two tomato fields with cultivar 'Southern Ripe'. The average incidence was 30% and 34% on the south side of Fields 1 and 2, respectively, but 11% on the north side of Field 2. Two field trials were conducted in Homestead, Fla. to evaluate the performance of tomato cultivars resistant to both TCSV and TYLCV. In the first trial, planted December 2020, the incidence of TYLCV in cultivar 'Red Bounty' was 29.2%, while no TYLC was observed in cultivar 'Varsity'. No TCSV was observed on either cultivar. Total fruit yield was 46,575 and 47,475 kg/ha for 'Red Bounty' and 'Varsity', respectively. Yield of extra-large and large fruit was 40,163 and 45,900 kg/ha for 'Red bounty' and 'Varsity', respectively. In the second trial, planted February 2021, no TCSV or TYLCV was observed on any of the six cultivars, including 'Varsity', 'Packout', '895FS', 'Vanessa', 'Shanty', and 'Katya'. Fruit yield was 27,900, 24,188, 30,713, 24,863, 26,550, and 24,975 kg/ha, respectively. Severity of bacterial spot was 7.5%, 2.7%, 5.0%, 11.7%, 12.5%, and 11.7%, respectively, at the end of the season with a rotation program of Actigard and ManKocide. This study provided south Florida growers with information about tomato cultivars with yield potential comparable to currently used cultivars and reduced disease management costs.

Florida is the leading producer of fresh market tomatoes in the United States (USDA-NASS, 2016). In Florida, tomatoes are grown almost year-round except the hot summer in south Florida and cold winter in central and north Florida. Besides the limitation of the environmental factors, diseases, including viral diseases are a major production constraint for tomato growers.

Tomato yellow leaf curl virus (TYLCV) was first found in a Florida tomato field in 1997 (Polston et al., 1999). It has become a chronic problem affecting tomato production in the entire state of Florida. TYLCV is vectored by the silverleaf whitefly (*Bemisia tabaci*). Infection of tomato plants is through feeding by a whitefly nymph or adult. Typical symptoms of TYLCV begin to show up around two weeks after infection. Infection early on can lead to severe stunting and no fruit production; infection during late stage does not have much effect on fruit yield. The first six weeks are considered the most critical period for protecting tomato plants from TYLCV infection (Smith and Nagle, 2014). Though planting TYLCV-resistant cultivars is the best and most economic strategy, these resistant cultivars have not been widely planted because of their unfavorable horticultural characters. Currently, management of TYLCV is mainly through controlling the whitefly populations by applying pesticides. In south Florida, tomato planting usually stops in early January mainly due to the difficulties in controlling whitefly populations even with heavy pesticide use. Tomato production could be extended for at least one month if TYLCV were under control, for example, by using resistant cultivars.

Tomato spotted wilt virus (TSWV) has been affecting tomato production in the northern parts of Florida since early 2000 (Adkins et al., 2006; Momol et al., 2004). Tomato chlorotic spot tospovirus (TCSV), a virus closely related to TSWV, has recently emerged and is a devastating disease in tomato, mainly in south Florida (Londoño et al., 2012; Zhang et al., 2015). TCSV is transmitted by thrips; early infection can kill tomato plants. Because management of TCSV by controlling thrips has been unsuccessful, planting TCSV-resistant cultivars is the most effective way for growers to manage TCSV (Liu et al., 2020; Pappu et al., 2009; Zhang et al., 2019). Tomato cultivars, such as 'Sanibel' and 'FL 47', which used to be widely planted in south Florida but are susceptible to TCSV, have been replaced by TCVS-resistant cultivars, including 'Southern Ripe' and 'Red Bounty'. However, these TCVS-resistant tomato cultivars are highly susceptible to TYLCV. Thus, TYLCV has once again become the major constraint to tomato production in south Florida.

Planting tomato cultivars resistant to both TCSV and TYLCV is the most effective and economical approach in south Florida. 'Red Snapper', a cultivar resistant to both viral diseases, has been planted on a small scale in recent years. Other tomato cultivars

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have not been evaluated for their resistance to both viruses and yield potential in south Florida. In this study, a recent epidemic of TYLCV was found in growers' fields. The performance of tomato cultivars resistant to both viruses were evaluated in the field conditions for their disease resistance and yield potential. Cultivars with dual resistance would provide growers with more options for disease management.

Materials and Methods

Incidence and distribution of TYLCV in growers' tomato field. In early Mar. 2021, severe infections of TYLCV were found in two growers' fields in the Homestead area, Miami-Dade County, FL. The incidence and severity of TYLCV were determined. In the first field, two cultivars were planted on white-on-black plastic mulch, including a TYLCV-susceptible cultivar 'Southern Ripe' and a TYLCV-resistant cultivar 'Red Snapper'. Sampling was done on the south side of the field where infection was heavy. The number of plants with typical symptoms of TYLCV infection in the first 100 plants in a row, starting from the south end, was recorded as one sample. A total of four samples were recorded by inspecting every third row. In the second tomato field, 'Southern Ripe' (susceptible) was planted; metalized plastic mulch was used on the first 12 rows on the west side and the rest of the field had black-on-white plastic mulch. Sampling was conducted at various locations due to uneven disease incidence in the field, including the northwest corner, middle location at north side, southwest corner, and middle of the south side. In addition, incidence of TYLCV infection was recorded separately in plants on metalized and black plastic mulches in northwest and southwest corner locations. Differences in disease incidence between tomato cultivars, between locations of the field, and between plastic mulches were analyzed using Student's *t*-test in SAS (SAS version 9.4, Cary, NC).

Performance of tomato cultivars against viral and bacterial diseases and their fruit yield. The performance of six tomato cultivars that are resistant to both TCSV and TYLCV was evaluated in two field trials in Homestead, FL for disease resistance under field conditions in south Florida against the two viral diseases plus bacterial spot and for fruit yield. These six cultivars included 'Varsity' and 'Packout' from Syngenta, 895FS from Florida Seeds, and 'Katya', 'Shanty', and 'Vanessa' from Hazera Seeds Inc. 'Varsity' and 'Packout' are globe-shaped tomatoes, and other four cultivars are all Romas. In the first field trial, two cultivars 'Red Bounty' and 'Varsity' were transplanted 26 Dec. 2020. Plots consisted of a single 12-ft bed; the buffer zone between plots was 2.5 ft. There were 8 plants per plot. There were three replicates of each cultivar; cultivars were completely randomized. Fertilization was applied according to the recommendations of Vegetable Production Handbook of Florida (***query: please either cite this reference in the Literature Cited section or delete the reference***). Plants were sprayed for common diseases (except bacterial spot) and insects in the area. Both cultivars were inoculated around one month after transplanting with a bacterial suspension of *Xanthomonas perforans* (1×10^8 CFU/mL). Disease severity was rated when symptoms were fully developed. Incidence of TCSV and TYLCV were recorded weekly after the first plant showing typical symptoms. Fruit were harvested three times and graded by size. Differences between the two cultivars were analyzed using Student's *t*-test for incidence of TCSV and TYLCV, severity of bacterial spot, yield of extra-large and large sized fruit, and total fruit.

In the second field trial, six tomato cultivars were transplanted on 26 Feb. 2021. Slow-release fertilizer was applied at the base of each plant after transplanting, and 20–20–20 (one teaspoon per gallon of water) liquid fertilizer was applied weekly as a foliar spray. Common diseases and insects were managed through weekly sprays of chemicals recommended in the Vegetable Production Handbook of Florida. Bacterial spot was managed with a rotation of ManKocide and Actigard. Tomato fruit were harvested every 10 days for a total of three times. Disease incidence for TCSV and TYLCV and severity of bacterial spot were recorded after first fruit harvest. Disease severity of bacterial spot and total fruit yield were analyzed by cultivar.

Results and Discussion

Incidence and distribution of TYLCV in growers' fields. In tomato Field 1, there was significantly less TYLCV infection on 'Red Snapper' (1.3%) than that on 'Southern Ripe' (30.0%) (Fig. 1). In tomato Field 2 where 'Southern ripe' was planted, there was significantly less TYLCV incidence on the north side of the field (12.5%) than on the south side of the field (34.5%) (Fig. 1). At the northwest corner of the second field, TYLCV incidence was 8.5% and 19.0% in plants on metalized plastic mulch and black-on-white plastic mulch, respectively (Table 1). TYLCV incidence was 7.5% in plants on black-on-white plastic mulch at the middle location on the north side. At the southwest corner of the second field, TYLCV incidence was 41.0% and

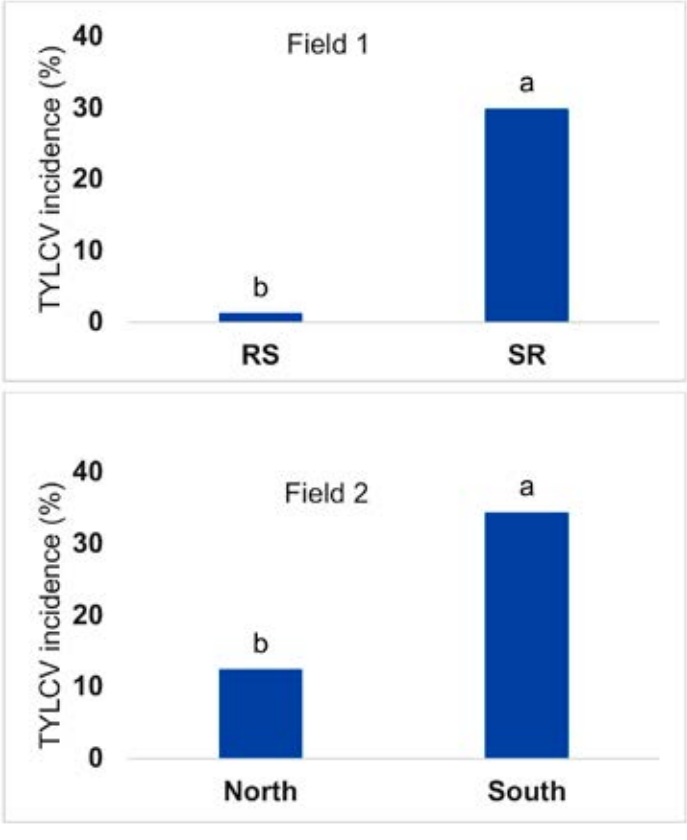

Fig. 1. Incidence of tomato yellow leaf curl virus (TYLCV) in two tomato growers' fields. In Field 1 (top), TYLCV incidence was sampled at the south side of the field for 'Red Snapper' (RS) and 'Southern Ripe' (SR). In Field 2 (bottom), TYLCV incidence in 'Southern Ripe' was sampled at both south and north sides of the field. In each figure, bars labeled with different letters were significantly different at $P = 0.05$..

31.5% in plants on metalized plastic mulch and black-on-white plastic mulch, respectively (Table 1). TYLCV incidence was 31.0% in plants on black-on-white plastic mulch at the middle location on the north side. 'Red Snapper' tomato has resistance to both TCSV and TYLCV so it was no surprise that very few plants were infected with TYLCV. In both fields, the average TYLCV incidence reached 30% in the susceptible cultivar 'Southern Ripe'. Fruit production was greatly affected as tomato plants were mildly stunted. In Field 2, there was significantly more TYLCV on south side of the field than the north side suggesting that the prevailing wind direction may play a role in the dispersal of the whitefly vector. This has also been observed with the thrips vector of TCSV in this area (Liu et al., 2020). Metalized plastic mulch has been shown effective in reducing TYLCV incidence during the early growth stages in tomato by affecting the behavior of whitefly (Smith et al., 2007). This was seen at the northwest corner of the field in our study. However, the higher incidence of TYLCV in tomato plants on metalized plastic mulch compared to black-on-white plastic mulch suggests that the vector population was too high for the metalized plastic mulch to repel the whiteflies effectively which precluded reducing TYLCV incidence. In addition, such disease patterns indicated that the whiteflies may be more likely to be found on the south side of the field rather than on the north (Fig. 1).

Table 1. Incidence of tomato yellow leaf curl virus (TYLCV) in tomato 'Southern Ripe' at different locations of the field and on different plastic mulches

	Plastic mulch	
Location	Metalized	Black on white
Northwest	8.5 ± 0.5[z]	19.0 ± 2.0
North middle	–	7.5 ± 0.5
Southwest	41.0 ± 1.0	31.5 ± 1.5
South middle	–	31.0 ± 2.0

[z]Average TYLCV incidence of two samples, followed by standard error of the mean.

Table 2. Disease incidence, severity, and fruit yield of two tomato cultivars in the first field trial.

	Cultivar	
Action	Red Bounty	Varsity
Incidence of TCSV(%)[z]	0	0
Incidence of TYLCV (%)[z]	29.2	0
Severity of bacterial spot (%)[z, y]	34.6 b	50.4 a
Yield of extra-large and large fruit (kg/ha)[z, x]	40163 a	45900 a
Total fruit yield (kg/ha)[z, x]	46575 a	47475 a

[z]Means of three replicates. Values followed by the same letter were not significantly different at $P = 0.05$ according to the Fisher's protected least significant difference value.

[y]Plants were artificially inoculated with *Xanthomonas perforans* ($1x10^8$ CFU/mL) around one month after transplanting.

[x]Yield was the total of three harvests.

TCSV = tomato chlorotic spot tospovirus; TYLCV = tomato yellow leaf curl virus

Performance of tomato cultivars against viral and bacterial diseases and fruit yield. In the first field trial, TCSV was not observed on either 'Red Bounty' or 'Varsity' throughout the trial. However, 29.2% of the plants of 'Red Bounty' showed symptoms of TYLCV at the end of the trial, while none of the plants of 'Varsity' were infected (Table 2). Both 'Red Bounty' and 'Varsity' were susceptible to bacterial spot, but 'Red bounty' had significantly lower disease severity than 'Varsity'. There were no significant differences between the two cultivars for total fruit or large and extra-large sized fruit. 'Varsity' produced relatively more fruit compared to the major local cultivar 'Red Bounty'. In the second field trial, neither TCSV nor TYLCV was observed on any plants of the six cultivars tested (Table 3). With natural infection by *X. perforans*, disease severity of bacterial spot was 7.5%, 2.7%, 5.0%, 11.7%, 12.5%, and 11.7% on cultivars 'Varsity', 'Packout', '895FS', 'Shanty', 'Vanessa', and 'Katya', respectively (Table 3). Total fruit yield (kg/ha) was 27,900, 24,188, 30,713, 24,863, 26,550, and 24,975 for cultivars 'Varsity', 'Packout', '895FS', 'Shanty', 'Vanessa', and 'Katya', respectively (Table 3). These six cultivars had excellent disease resistance to TCSV and TYLCV under field conditions in south Florida, even though the tomato seedlings were planted quite late by area standards and with high whitefly populations during the growing period. All six cultivars had good fruit yield potential during this initial field trial, especially cultivar '895FS'. Further field evaluation need to be conducted on a relatively larger scale to confirm fruit yield potential and other horticultural characters as well.

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Table 3. Disease incidence, severity, and fruit yield of six tomato cultivars in the second field trial.

Performance of six tomato cultivars for disease resistance and fruit yield[z]				
Cultivar	Incidence of TCSV (%)	Incidence of TYLCV (%)	Severity of bacterial spot (%)	Fruit yield (kg/ha)
Varsity	0	0	7.5	27,900
Packout	0	0	2.7	24,188
895FS	0	0	5.0	30,713
Shanty	0	0	11.7	24,863
Vanessa	0	0	12.5	26,550
Katya	0	0	11.7	24,975

[z]Values were the average of three replicates for each cultivar.

TCSV = tomato chlorotic spot tospovirus; TYLCV = tomato yellow leaf curl virus

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