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Pest and Disease Incidence in Different Tomato Varieties

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Tomato is an important economic crop in Florida. The production of tomatoes in the state is often constrained by the incidence of tomato chlorotic spot virus transmitted by thrips and tomato yellow leaf curl disease transmitted by whiteflies. Growers of south Florida are using the resistant varieties of tomato to reduce the economic loss. In the present field study, we conducted a varietal study of tomatoes to observe their performance terms of their growth, flower and fruit set production, the pest and disease incidence, and the marketable yield for two growing season. Among the five tomato varieties were tested, 'Varsity' produced more flower and fruit sets than the other varieties. Thrips of different species and whitefly adults were observed with higher numbers in the control tomato varieties than the other varieties, especially at the late sampling dates. Both pests and disease incidence were higher in the second study than the first study. Results from the current study will be helpful for local growers to develop an integrated management program for pest borne diseases.

Tomatoes are Florida's most valuable vegetable crop, export value averaging $75.7 million per year since 2004 (2015 International Report). Tomatoes grown in Florida and Mexico is the main source of fresh market tomatoes in the United States during winter and early spring. More specifically, southern Florida is the predominant U.S. producer of tomatoes during winter (McAvoy and Hampton 2007). Miami-Dade County is a top-two county producing fresh market tomatoes in Florida. Tomato production in south Florida is often compromised with the incidence of pests and diseases, especially tomato chlorotic spot virus (TCSV) transmitted by thrips and tomato yellow leaf curl virus (TYLCV) transmitted by whiteflies.

Tomato chlorotic spot virus (TCSV) was first identified in south Florida (Londono et al. 2012) and from then this viral disease is causing a considerable economic loss. The infected plants are showing symptoms like necrotic lesions, chlorotic spots, terminal stem and leaf death, wilting, necrosis and deformation of leaves (Polston et al. 2013). In the field, the TCSV infected plants are more visible at the edge of the next to the other planting or unmanaged areas (Poudel et al. 2019, Khan et al. 2020). Tomato chlorotic spot virus is a close relative to tomato spotted wilt virus (TSWV), groundnut ring spot virus (Family Bunyaviridae). Thrips of different species are the vector of tospovirus. Transmission of tospovirus by thrips is persistent propagative, indicating the virus is replicated in their vector's body (Whitfield et al. 2005). Thrips feed on the tospovirus infected plants at their early larval instars can be developed as viruliferous adults and can maintain the virus in their body. Viruliferous adult thrips are more competent transmitters than the wingless larvae who serve as a virus host and reintroduce the virus into a healthy plant with their saliva during feeding (Palmer et al. 1989). As tospovirus cannot transmit through trans-ovarially, every new generation of thrips need to acquire virus to be a potent vector (Wijkamp et al. 1996, Riley et al. 2011). In united states, Western flower thrips (*Frankliniella occidentalis* Pergande) and common blossom thrips (*Frankliniella schultzei* Trybom) (Thysanoptera: Thripidae) are the main vectores of TCSV (Webster et al. 2015). Plants at their early developmental stage are more vulnerable to being infected with tospovirus than the later developmental stage (Culbreath et al. 2003, Shrestha et al. 2015). Crops infected earlier at their growth stage cause severe decrease in the plant stand which can be followed by reduced or less yield production at later growth stage (Culbreath et al. 2003, Culbreath and Srinivasan 2011). Development of tospovirus-resistant varieties based on a single SW5 gene offer promise for TSWV management (Krishna Kumar et al. 1993, Saidi and Warade 2008, Riley et al. 2011). However, the field performance of these resistant cultivars including their marketable fruit quality and tolerance to primary disease in south Florida has not been determined.

Tomato yellow leaf curl virus (TYLCV) (Family Gaminiviridae, genus Begomovirus) was identified in 1997 in Florida. The symptoms produced by TYLCV include severe stunting, reduction in the leaf size, upward cupping, chlorosis, mottling, and flower abscission. The TYLCV reduced the marketable yield significantly (Polston et al. 1999). The whitefly (*Bemisia tabaci* Gennadius)-transmitted TYLCV disease is a limiting factor in tomato production Resistance to TYLCV has been discovered in numerous wild tomato species, including *S. pimpinellifolium*, *S. peruvianum*, *S. chilense*, *S. habrochaites*, and *S. cheesmaniae* (Ji et al. 2007; Pico et al. 1996; Scott 2007).

In the present study, we conducted a field study using some tomato cultivars for two growing seasons. The objective of the study was to: 1) determine the field performance including the growth pattern, marketable yield etc. and 2) determine the pests and disease incidence of some resistant cultivars of grower's choice.

Materials and Methods

Location and duration of the study. The present study was conducted in the research field (25°30'33.7''N 80°30'17.1''W) at the Tropical Research and Education Center, University of Florida Institute of Food and Agricultural Sciences (TREC/UF/IFAS), Homestead, FL from Dec. 2021 to Mar. 2022. We repeated the same study from 30 Mar. to 30 May, 2022. This field study was conducted using tomato (*Solanum lycopersicum*) as the main crop. We used five tomato varieties: Sanibel, Red Bounty, Southern Ripe, Varsity, and Plum as treatments.

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Field preparation. The soil type of the research field of TREC/UF/IFAS was Krome gravelly loam (loamy-skeletal, carbonatic hyperthermic lithic Udorthents), consisting of about 67% limestone pebbles (> 2 mm) and 33% finer particles (Noble et al. 1996). We used the standard commercial practices using moldboard plow (CASE International) and disking (Athens Disc Machine) to prepare the field. Each of those raised bed was 0.91 m (3-foot) wide and 0.15 m (6-inch) high with 1.82 m (6-foot) spacing between center to center of two adjacent beds. The beds were prepared by a machine (Kennco Manufacturing Inc., Ruskin, FL). Before covering beds with plastic mulch, a granular fertilizer (8N–16P–16K) (TomatoGain 8–16–16 Tomato Plant Food, Bougainvillea Growers International, St. James City, FL) was applied at 1344.31–1792.57 kg/ha before the beds were covered with plastic mulch. Halosulfuron methyl (0.5 oz/acre, Sandea®, Group#2, Gowan Company LLC., Yuma, AZ) was used as a pre-emergence herbicide to control weeds. Irrigation was provided through two drip tapes (Ro-Drip, USA) with 30 cm emitter spacing placed 15 cm apart on each side parallel to the center of a bed. Experimental plots were then covered with different plastic mulches. Tomato seedlings were transplanted 45 cm apart at the center (transplant row) of each bed and 1.82 meters between beds 21 d after the application of halosulfuron methyl. Research plots were 4.57 m (15 feet) long, and 1.82 m (6 feet) wide with 1.52 m (5 feet) buffer between treatment plots with 12 plants.

Experimental design and treatments. A randomized complete block design was used to conduct the present study. The five different tomato varieties treated with rotation of insecticides were considered as treatments and 'Sanibel' without any chemical treatment was considered as control. We used the rotation of insecticides with spinetoram (Radiant®, Corteva Agricience, Indianapolis IN), spirotetramat (Torac®, Nichino America, Inc, Wilmington DE) and cyantraniliprole (Exirel®, Dupont, Wilmington DE), starting from three weeks after transplanting tomatoes to the field. We followed the label rate for all those insecticides.

Plant material. Five different varieties of tomato were chosen for this field study. Among those tomato varieties, Varsity is resistant to fusarium crown and root rot, tomato spotted wilt virus, tomato yellow leaf curl virus. 'Red Bounty' tomato is resistant to fusarium wilt 1, fusarium wilt 2, fusarium wilt 3, gray leaf spot, root knot nematode, tomato mosaic virus, tomato spotted wilt virus, verticillium wilt, verticillium wilt. 'Southern Ripe' tomato is resistant to tomato spotted wilt virus, alternaria stem canker, fusarium crown and root rot, gray leaf spot, verticillium wilt, root knot nematode. 'Plum' tomato is resistant to alternaria stem canker, bacterial speck, fusarium wilt 1, fusarium wilt 2, fusarium crown rot and root rot, tomato spotted wilt virus, tomato yellow leaf curl virus, verticillium wilt 1, verticillium wilt 2. 'Sanibel' tomato is resistant to verticillium wilt, fusarium wilt race 1, fusarium wilt race 2, and nematodes. Seeds of 'Varsity' (Seedway LLC., Hall, NY), 'Southern Ripe' (Hoss Tools, Norman Park, GA), 'Red Bounty' (Seedway LLC., Hall, NY), 'Plum' (Hudson Valley Seed Co.), and 'Sanibel' (Seminis, St. Louis, MO) were obtained from different seed companies. Seeds were then placed individually in a 5.0-cm^2 cell of a styrifoam seedling tray (Seedling, Inc., Sun City, FL) filled with Pro-Mix growing medium (Premium Horticultural Inc., Quakertown, PA). Plants were allowed to grow in a greenhouse at TREC/UF/IFAS for 6–8 weeks before they were transplanted to the field in Dec. 2021. For the second study, we repeated the same procedure to grow the seedling tomatoes in the greenhouse and transplanted them in the field in Mar. 2022.

Evaluation of treatments

Plant performance. The growth of different tomato varieties was measured as their height and width in inches. Five plants were randomly selected from each plot. The data was obtained at the 5th and 10th week after transplanting to the field.

Sample collection and processing for thrips and whiteflies. We collected both leaf and flower samples to observe the thrips population in different tomato varieties. Five green, full-grown, and widely open leaves from the top stratum were collected from randomly selected five plants from each plot. We also collected five widely open flowers from five randomly selected plants from each experimental plot after each chemical application. Flower samples were collected 6 weeks after transplanting and continued up to 11 weeks after transplanting (6 sampling dates). The leaf and flower samples were placed separately into a pint plastic cup (Uline Crystal Clear Plastic Cups–16 oz, Uline, 12575 Uline Drive, Pleasant Prairie, WI 53158) with a thrips-proof lid and marked with the field, row, block, plastic mulch, and plot numbers along with the sampling date. The samples were brought to the Vegetable Entomology Laboratory at TREC and soaked in 70% ethyl alcohol for 20 minutes to dislodge thrips. The leaves and flowers were then carefully removed from the alcohol, leaving thrips as residue in each cup. The alcohol residue was passed through a sieve (USA Standard Testing Sieve, No. 60, opening 250 µm, Fisher Scientific Company) to separate thrips from the alcohol. Thrips collected on the sieve were transferred to a Petri dish (10 cm diam) using a gentle jet of alcohol from a squirt bottle (Seal and Baranowski 1992). The number of thrips of different species in alcohol was counted using a digital microscope (VHX-6000, Keyence) at 50×. To observe the whitefly adults, we checked the underside of five mature green leaves, randomly selected from five plants per plot.

Marketable yield, number of marketable fruits, and number of TCSV and TYLCV-infected plants. At the end of the season (12 weeks after planting tomatoes), we collected the marketable fruits from the whole plot following the U.S. market standard (USDA 2005). The marketable fruits were weighed for all treated and untreated (control) plots using 31.75 kg (70 lb) capacity scale (CCI Scale Company, Ventura, CA, USA). Tomato plants were carefully inspected for TCSV and TYLCV symptoms and recorded during the time of sample collection each week. We determined the incidence of TCSV and TYLCV based on the symptoms (Polston et al. 2013 and Polston et al. 1999). Infected tomato plants also showed characteristic necrotic ring spots on the fruits.

Statistical analysis. The mean number of thrips from each treatment was compared separately for each study. All responses (plant height, width, flower set, fruit set, number of thrips, and whiteflies) were sqrt(x) transformed before statistical analysis to meet the assumption of normality. A linear mixed model was used to analyze the data. Marketable yield and number of TCSV infected tomatoes were only measured one time for each study and were square root transformed. Non-transformed means are reported in the tables. All responses were analyzed using a linear mixed model (randomized complete block design) with the fixed effect treatment, and the random effect block. (PROC GLIMMIX model, SAS version 9.3, SAS Institute Inc. Cary, NC, 2013). Degrees of freedom were estimated using the Kenward-Roger's method. When the F-value for the overall treatment effect was significant, differences of means among treatments (Least square means) were separated using Tukey's multiple comparisons procedure. All the data were analyzed at the 5% level of significance. All analyses were done using SAS version 9.3, SAS Institute Inc. Cary, NC, 2013.

Results and Discussion

Plant performance. Results from the height of the tomatoes showed the plum tomatoes were significantly taller ($F_{5,33} = 5.33$, $P < 0.0012$) than the other tomatoes at the fifth week after planting (Table 1). At the tenth week after transplanting, 'Varsity' and 'Plum' were significantly taller ($F_{5,33} = 17.37$, $P < 0.0001$) than the other tomatoes. The interaction between the treatments and sampling date on the height of different tomato varieties was significant ($F_{5,33} = 3.60$, $P < 0.0104$). The width data did not show any statistical difference between the treatments (Table 2).

The flower set did not differ statistically between the treatments. However, the fruit set was observed significantly higher ($F_{5,15} = 4.19$, $P < 0.0139$) in 'Plum' than control and other treatments ('Varsity' and 'Sanibel') (Fig. 1).

Table 1. Mean heights of different tomato varieties.

Treatment	Mean heights of tomatoes (inch) 5th week	10th week
Sanibel	19.1 ± 0.75 ab[z]	32.42 ± 0.59 b
Red bounty	17.4 ± 0.93 b	30.72 ± 1.42 b
Southern Ripe	18.40 ± 0.67 b	30.27 ± 0.61 b
Varsity	18.90 ± 0.45 b	37.35 ± 0.78 a
Plum	21.85 ± 0.59 a	38.90 ± 0.54 a
Control (Sanibel)	18.60 ± 0.87 b	31.97 ± 0.35 b

[z]Means within the same column followed by the same letter are not significantly different at $P \leq 0.05$ according to Tukey's HSD test.

Table 2. Mean width of different tomato varieties.

Treatment	Mean width of tomatoes (inch) 5th week	10th week
Sanibel	18.15 ± 1.60 a[z]	32.15 ± 2.32 a
Red bounty	22.50 ± 1.03 a	31.00 ± 0.29 a
Southern Ripe	19.80 ± 2.51 a	31.55 ± 2.46 a
Varsity	22.55 ± 0.33 a	30.00 ± 1.76 a
Plum	21.20 ± 2.16 a	29.15 ± 2.01 a
Control (Sanibel)	20.90 ± 0.61 a	30.20 ± 2.30 a

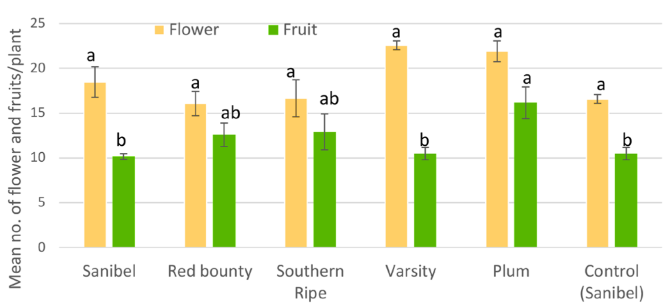

Fig. 1. Mean number of flowers and fruits/plant in different tomato varieties. Means followed by the same letter are not significantly different at $P \leq 0.05$ according to Tukey's HSD test (First Study).

Pest population (thrips and whiteflies) in different tomato varieties (First Study). The mean number of adult thrips population in flowers of different tomato varieties ranged from zero to eleven (0.25 ± 0.25 to 10.75±3.88) at different sampling dates (Fig. 2). Samples were collected for six weeks. The population of adult thrips showed an increasing pattern as their numbers were observed with higher numbers at the later sampling dates. Adult thrips population was significantly higher in control tomatoes than other treatments at the second sampling date ($F_{5,101.7} = 3.92$, $P < 0.0027$) and fifth sampling date ($F_{5,101.7} = 2.59$, $P < 0.0299$). The thrips larvae population in tomato flowers was low, ranging from zero to 0.75 (Fig. 3). There was no statistical difference between the treatments on the abundance of thrips larvae in tomato flowers at different sampling dates.

Thrips population was low in tomato leaves samples compared to the flower samples. The mean number of adult thrips was ranged from zero to 3.50 ± 0.64 (Fig. 4). Adult thrips population was

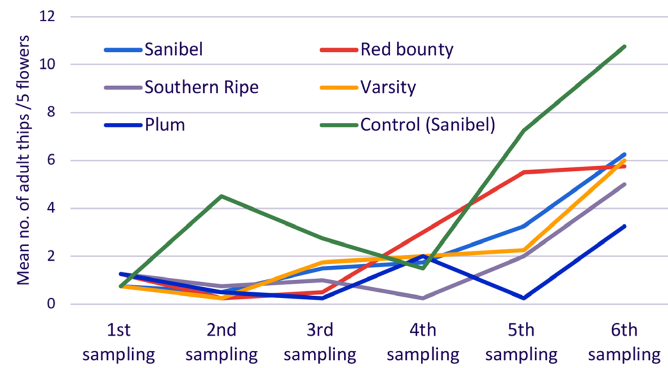

Fig. 2. Mean number of adult thrips/ five flowers in different tomato varieties on different sampling dates (First Study).

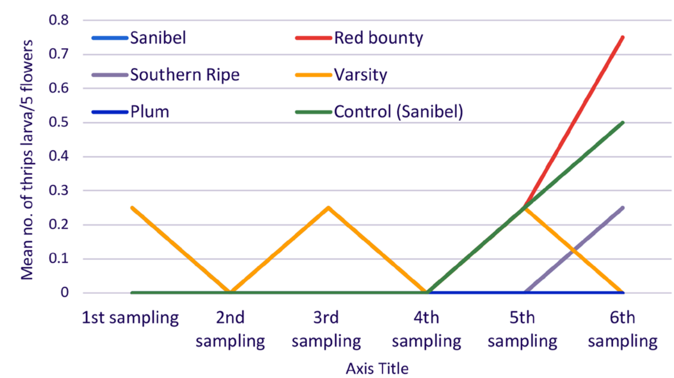

Fig. 3. Mean number of thrips larva/ five leaves in different tomato varieties on different sampling dates (First Study).

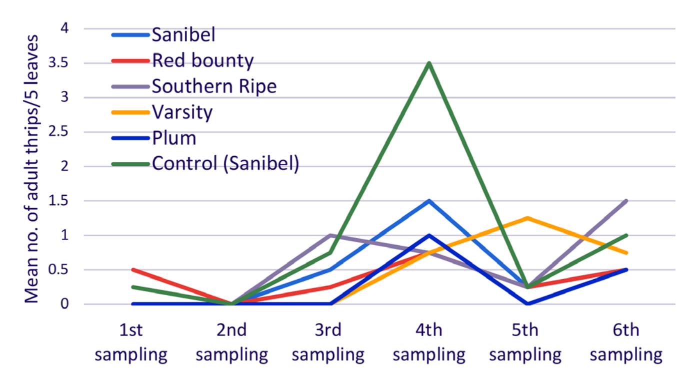

Fig. 4. Mean number of adult thrips/ five leaves in different tomato varieties on different sampling dates (First Study).

significantly higher ($F_{5,105} = 3.42$, $P < 0.0066$) in control than the other treatments. Thrips larvae in different tomato leaves were also low (ranged from zero to 0.75 ± 0.75) and did not show any statistical difference between the treatments at different sampling dates (Fig. 5).

The population of whitefly adults in tomato leaves ranged from zero to 3.62 ± 2.47 (Fig. 6). The whitefly population showed an increased pattern at the later sampling dates. The mean number of whitefly adults was observed significantly higher in control tomatoes at fourth ($F_{5,102} = 4.54$, $P < 0.0009$), fifth ($F_{5,102}$=4.33, $P < 0.0013$) and sixth ($F_{5,102} = 3.13$, $P < 0.0115$) sampling dates than other treatments.

Marketable yield and disease incidence in different tomato varieties (First Study). We observed the marketable yield was significantly higher ($F_{5,15} = 8.46$, $P < 0.0006$) in 'Red Bounty', 'Southern Ripe' and 'Varsity' than in other tomatoes and the control (Fig. 7). The number of marketable fruits was also higher ($F_{5,15} = 10.43$, $P < 0.0002$) in the same varieties mentioned above compared to the control.

The incidence of TCSV was significantly higher ($F_{5,15}$=3.38, $P < 0.0306$) in control tomatoes than other treatments or varieties (Fig. 8). The incidence of TYLCV was significantly higher ($F_{5,15}$=16.48, $P < 0.0001$) in 'Sanibel', 'Red Bounty', 'Southern Ripe' and control tomatoes than the other treatments.

Pest population (thrips and whiteflies) in different tomato varieties (Second Study). In the second study, the adult thrips population in leave samples ranged from 1.25 ± 0.25 to 6.75 ± 0.75) and showed an increased pattern as the sampling dates progressed (Fig. 9). Thrips larvae in leaf samples ranged from 0.25 ± 0.25 to 2.75 ± 0.25 (Fig. 10). The whitefly population was observed significantly higher in control tomatoes than 'Varsity' tomatoes (Fig. 11).

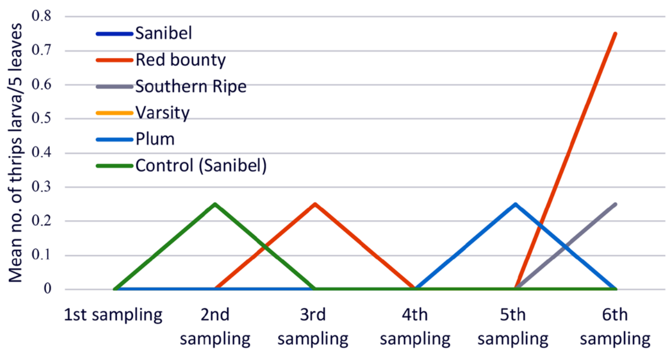

Fig. 5. Mean number of thrips larva/ five flowers in different tomato varieties on different sampling dates (First Study).

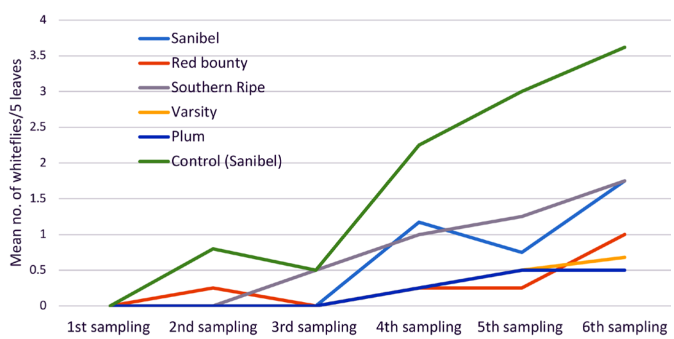

Fig. 6. Mean number of whiteflies/ five flowers in different tomato varieties on different sampling dates (First Study).

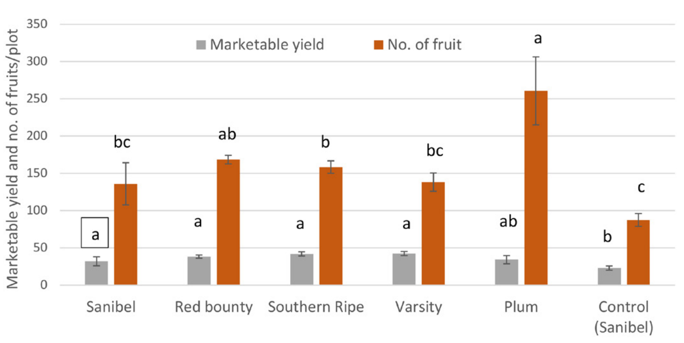

Fig. 7. Mean number of marketable fruits and number of fruits per plot in different tomato varieties (First Study).

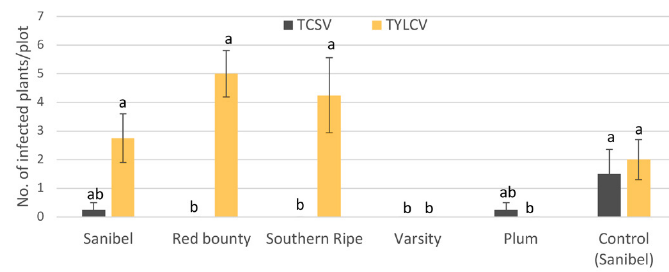

Fig. 8. Mean number TCSV and TYLCV infected plants per plot in different tomato varieties (First Study).

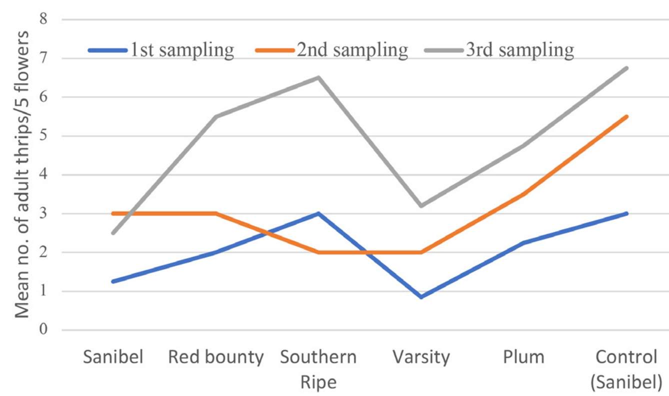

Fig. 9. Mean number of adult thrips/five flowers in different tomato varieties on different sampling dates (Second Study).

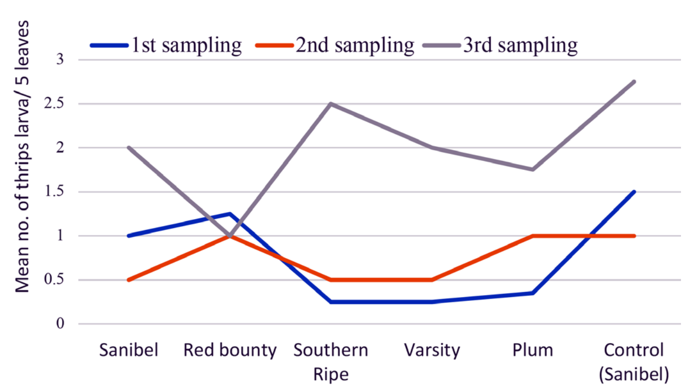

Fig. 10. Mean number of thrips larva/five leaves in different tomato varieties on different sampling dates (Second Study).

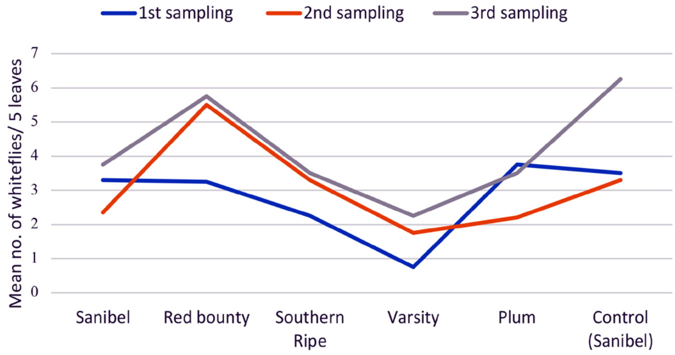

Fig. 11. Mean number of whiteflies/five leaves in different tomato varieties on different sampling dates (Second Study).

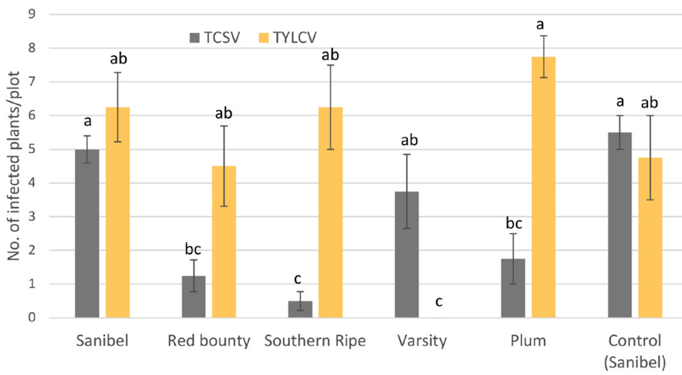

Fig. 12. Mean number TCSV and TYLCV infected plants per plot in different tomato varieties (Second Study).

Disease (TCSV and TYLCV) incidence in different tomato varieties (Second Study). The incidence of TCSV was significantly higher in 'Sanibel' than in other tomatoes except 'Varsity'(Fig. 12). The incidence of TYLCV was significantly lower in 'Varsity' than other treatments.

In a two-season study, we observed the pest and disease incidence in different tomato varieties in south Florida. Viral diseases in plants such as TCSV and TYLCV appeared as the main constraints to grow tomatoes. Using a single management tactic like insecticide is not enough to manage these insects transmitted diseases (Riely et al. 2019). There is a need to apply different management strategies such as use of chemical insecticides and resistant cultivars can give some relief while managing both pests and diseases. Our study results indicate that different tomato varieties had similar performance according to their growth, fruit and flower production with few exceptions. Both thrips and whitefly population appeared in the field as an increased pattern with the season. 'Sanibel' was the most susceptible for TCSV and appeared with infected symptoms in the present study for both seasons. However, the use of rotational insecticides reduced the incidence of TCSV but not the TYLCV when compared to control which is the same variety without any chemical treatment. Zhang et al. (2015) also found that the insecticide spinetoram and cyantraniliprole can significantly reduce the incidence of TCSV in tomatoes. The plants of different tomato varieties of the first study showed less disease incidence than the second study (Fig. 13). The infected tomatoes could not produce any fruit during the second study due to heavy disease pressure. 'Varsity' was observed as the best variety, with less disease incidence and higher marketable yield than other tomato varieties.

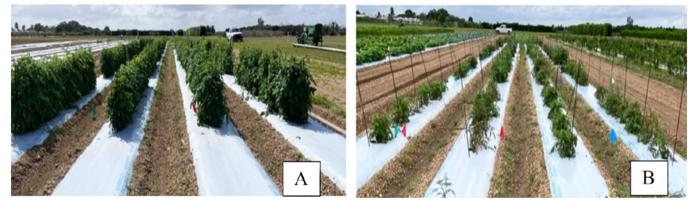

Fig. 13. Experimental plots showing healthy plants [First Study, (**A**)], and TCSV and TYLCV infected plants [Second Study, (**B**)].

The use of resistant cultivars is an important tool for managing diseases and pests. The development of resistant cultivars for tomato spotted wilt virus (TSWV) was based on a single SW5 gene (Krishna Kumar et al. 1993, Saidi and Warade 2008, Riley et al. 2011). Tomato chlorotic spot virus (TCSV) is sharing the same virus family with TSWV. So, using TSWV-resistant tomato varieties would have the potential to minimize the yield loss by TCSV (Ploston et al. 2013, Zhang et al. 2019). However, resistant failure through high selection pressure of these resistant varieties can be possible while depending on a single gene (Thomas-Carroll and Jones 2003, Aramburu and Marti 2003, Ciuffo et al. 2005). The resistance gene for begomovirus is *Ty-5*, and was recently discovered in the breeding line TY172 derived from *S. peruvianum* (Anbinder et al. 2009). Thus, it is always recommended to use more than one management strategy to develop a sustainable management program for insect borne diseases.

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