Impact and Management of Tomato Yellow Leaf Curl Virus on Tomato in Southwest Florida

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Anyone who has seen TYLCV in the field cannot help but be impressed by the severity of symptoms and the obvious impact on production. Once symptoms become apparent, most blooms become necrotic and very little fruit is set. Symptoms can be expected to appear 10 to 15 days after virus inoculation by the whitefly, depending on growing conditions. Consequently, protection against TYLCV early in the crop cycle is critical as with all virus diseases of vegetables. Nevertheless, the impact of each disease on yield is different, and it is useful to have some quantitative measure of expected losses as a function of crop age at the time of symptom appearance to aid in prioritizing management decisions.

What would these management decisions entail? Contrary to the usual tenants of IPM, the most effective measures are proactive rather than reactive. A crop free period to reduce virus and vector inoculum levels is still the basis of our management system, so growers should continue to take crops down early and keep fields clean over the summer. Application of imidacloprid in the transplant house and at or soon after transplanting is now standard practice. Similar products may soon appear in the market, but otherwise this practice will probably always be necessary although not sufficient for a successful crop. Reflective mulches remain an option that has not yet gained general acceptance but may offer additional protection from whiteflies during the early, critical period. Finally, additional insecticidal treatments may be necessary to maintain control later in the crop cycle and to protect successive crops.

Last spring we evaluated reflective mulches and insecticidal control of whitefly in two separate trials reported here. Incidence of TYLCV was considerable so we took advantage of the opportunity to evaluate impact virus infection on yield. For the mulch trial, 4 raised beds 32 inches wide and 240 ft long on12 ft centers were prepared by fumigating with 67/33% methyl bromide/chloropicrin at 300 lbs/acre, and fertilizing with a bottom mix of 700 lbs/acre 5-16-8. A single drip tape irrigation line with emitters spaced every 12 inches was laid on the surface of each bed. Beds were divided into 4 plots 60 ft long and the following treatments of polyethylene mulch film assigned in a Latin Square design using each bed as a replicate: (1) white-faced - the grower standard for early fall and late spring planting, (2) black - the grower standard for late fall and early winter planting, (3) white painted with a green latex computer-matched to a tomato leaf, and (4) aluminized white with a 30 cm white center strip. The green treatment was chosen as a substitute for living mulches that we have seen to be effective in slowing movement of geminivirus in Costa Rica. The 0.3 mil polyethylene mulch for treatments 1-3 was manufactured by SONOCO Corp. Hartsville, South Carolina, the aluminized mulch was manufactured by Vacumet Corp. Wayne, New Jersey. Tomato "Florida 49" was transplanted 17 Mar into the beds at 18 inch spacing. Plants were sprayed with Bt and fungicides on a weekly basis.

The same cultural methods were used for the insecticide trial which consisted of 4 beds of tomatoes. However, 2 beds of collards had been planted a month earlier as a source of whiteflies between beds 1 and 2 and between beds 3 and 4. Each bed of tomatoes was divided into 5 plots in a completely randomized block design with 4 replications. Admire® 2F was applied at a half rate of 8 oz./ac = .125 lb (ai) on 7 April in 10 ml of water per plant in two treatments, one receiving 5 weekly applications of Neemix® 4.5% at 4 oz/ac = .012 lb (ai) beginning 15 Apr. and the other receiving no further treatment. Actara 25 WG at 3.4 lb/ac = .85 lb (ai) and Knack .86 EC at 8.2 oz = .055 lb (ai) were also applied on 15 Apr. On 14 May, plots that had been sprayed with Knack were sprayed with Applaud 70 WP at .5 lb/ac = .35 lb (ai). Applications were made using a high clearance sprayer driven by a hydraulic pump operating at 200 psi and delivering the spray through two drop booms equipped with 2 yellow hollow cone ceramic Albuz® nozzles each for a rate of 44 GPA. On 29 Apr., another nozzle was added to each drop for an output of 66 GPA for the remaining applications.

Whitefly adults were monitored first on 5 April (19 days, after transplanting) by inverting 5 leaflets per leaf on 20 plants per plot. Thenceforward until 19 May adult whiteflies were monitored weekly by beating 1 side of 4 plants at 4 locations per plot with a 9 x 13 inch pie pan painted black and coated with a 9:1 mixture of vegetable oil and liquid detergent. Immature stages were monitored from one leaf removed from the 6th node of 6 centrally located plants in each plot. All whitefly stages were counted that appeared in a 2 cm^2 ring placed on 3 leaflets of each of the 6 leaves for a total surface are of 36 cm^2 per sample. Plants showing symptoms of TYLCV were flagged every 3 or 4 day and harvested once individually. The effect of first symptom expression on yield was analysed by regression. Yield of the remaining plants was evaluated on 24 May by weighing and grading all marketable fruit to make a total (with those previously harvested falling into the designated area) of 10 plants per plot. ANOVA was used to analyze treatment effects with mean separation by LSD at $P < 0.05$.

Plants expressing symptoms at 31 days after transplanting produced only 5.5% (number of extra-large fruit) and 18.0% (total fruit weight) of the yield of uninfected plants. Yields increased steadily as time to first symptom expression increased in a strong, linear relationship (Fig. 1). There was no significant effect of infection on average fruit weight ($P < 0.38$), indicating that TYLCV affected yield by reducing fruit number rather than fruit size.

In general, fewer whiteflies were observed on plants growing on light colored mulches, especially aluminum, than on dark mulches, especially green (Table 1). Significantly fewer adult whiteflies were sampled from tomato growing on aluminiumized mulch compared to green and black on every date but 19 May and compared to white on 30 Apr. and 12 May. More adult whiteflies were observed on plants growing on green mulch than black mulch or mulch of any other color on 30 Apr. and 12 May. Immature stages were relatively scarce and less indicative of different responses to mulch color (Table 2). Nevertheless, where differences were significant, lowest numbers were seen on plants growing on aluminum mulch.

TYLCV had appeared in the field by 19 April but tended to be localized more by replicate than treatment until 19 May. By that time there was significantly greater incidence of virus in plants on white or green mulch compared to aluminum, with black mulch intermediate (Table 4).

Analysis of the one-time harvest of 10 plants per plot showed some significant differences among mulch types (Table 4). More small size fruit were harvested from plants on dark mulch (black and green) compared to light-colored mulch (white and aluminized, data not shown). Medium fruit weight was greater from plants on silver compared to white and more large fruit was harvested from plants on aluminum compared to green (data not shown). Significant differences in the all-important extra-large category and also in total fruit were between black (high) and white (low) with green and aluminum intermediate. Culls from insect damage or other causes showed no effects of mulch type (data not shown). Overall average fruit weight was greatest from plants on aluminum compared to green, with black and white intermediate. Maximum soil temperatures recorded during the first month of the growing season were highest under green and lowest under aluminum (Table 5).

All insecticide treatments provided significant levels of adult whitefly control throughout the entire experiment (Table 6). Lowest numbers were observed on plants treated with Admire alone, Admire + Neemix and Actara on 21 Apr, and Admire alone, Admire + Neemix and Knack on 5 and 19 May. Neemix never provided significant additional control to that achieved by Admire alone although whitefly numbers tended to be lower. Actara applied as a foliar only provided comparable control to soil-applied Admire once on 21 Apr.

Immature counts told a similar story (Table 7). Numbers of eggs and totol immatures were generally fewest in the two treatement with Admire. The addition of Neemix sprays resulted in consistently lower numbers but never significantly so. Actara gave similar control to Admire through 06 May but subsequently lost ground. On 28 Apr. and 6 May there were actually more eggs observed on plants treated with Knack than the control, although supposedly many of these eggs were sterile. Number of eggs on 12 May was lowest on plants treated with Admire and Neemix but not significantly less than Admire alone. All treatments on that date had fewer eggs than the control except for Knack. However there were fewest nymphs + pupae with Admire+Neemix, Admire alone and Knack with Actara intermediate between these and the check. Similar results were seen on 20 May. On 28 May there were statistically as many eggs on plants treated with Knack/Applaud and Actara as on untreated plants. However, fewest nymphs+pupae were seen on plants treated with the IGRs (Knack and Applaud). Over all dates fewest eggs were seen on plants treated with Admire and Neemix and there was no difference between the IGRs and the control. Nymphs + pupae grouped both Admire treatments with the IGRs and there was no difference between Actara and the check.

The distribution of TYLCV-infected plants was aggregated over the field but did show some treatment effects, especially toward the end of the trial. Significantly less new virus infection was seen on 3 May in plots treated with Admire compared to the control (and Knack treatment, Table 8). Significant differences in new infections were not seen again until 19 May when the 2 treatments with Admire were clearly differentiated from the other treatments. However, over all dates the lowest percentage of new virus was seen in plots treated with both Admire and Neemix, although not significantly less than Admire alone. Cumulative virus incidence on 19 May was also least in plots treated with Admire + Neemix (6.3%) although not significantly less than than Admire alone (10%). The remaining treatments were not significantly different from the check.

Yields did not differ greatly among treatments, in spite of effects on virus incidence. This was probably because the initial distribution of infected plants played a significant role in determining which plants were subsequently infected. The treatments only began to exert a significant influence on this distribution late in the crop cycle when virus impact on yield was minimal. Nevertheless, we see the same trends seen in whitefly counts: lowest on plants treated with Admire + Neemix and highest in the controls.

It must be emphasized that the intention of testing Admire or the IGRs alone was not to suggest that they should be used alone in a management program, but rather to assess their individual contributions to control. The best program would combine these effects, utilizing a soil-applied systemic to provide protection early in the crop cycle and the IGRs later to reduce whitefly reproduction within the crop.

TYLCV is most devastating when plants are young. This coincides with the time the mulch is most visible to insects and therefore most effective. Fewer whiteflies translated into an overall reduction TYLCV infection of plants on aluminum mulch. Yield on the white-centered aluminum was probably reduced by soil temperatures 4.5 _C lower at 5 cm depth than under black early in the season. However in contrast to the situation on white, yields on aluminum were not significantly less than on black because of the compensating effect of less TYLCV on aluminum. Clearly, the cooling effects of aluminum mulch can be a disadvantage for early season plantings. Also, some leaf burn on young plants from reflected heat has been observed in other tests under extremely hot conditions. Nevertheless, UV reflective mulches may offer a useful tool when vector management is a high priority in vegetable production.

Our results emphasize the importance of controlling early movement of TYLCV into the crop, either by viruliferous whiteflies or virus-infected transplants. Not only is this disease devastating to young plants, but it is difficult to eliminate all impact on production with any treatment when virus shows up early. Growers can best guard against early virus infection by the following practices: (1) finish early and maintain fields clean when not in use to maximize the crop-free period and reduction of primary virus and vector innoculum, (2) do not plant near infected fields (whiteflies have been seen to spread TYLCV up to 5 miles!), (3) use transplants that have not been exposed to viruliferous whiteflies, (4) consider using reflective mulch, (5) make a drench application of a systemic insecticide (Admire) at or soon after transplanting, (6) follow up with foliar applications of different insecticides as needed, keeping in mind that IGRs are good but act slowly by suppressing egg hatch and development of immatures.

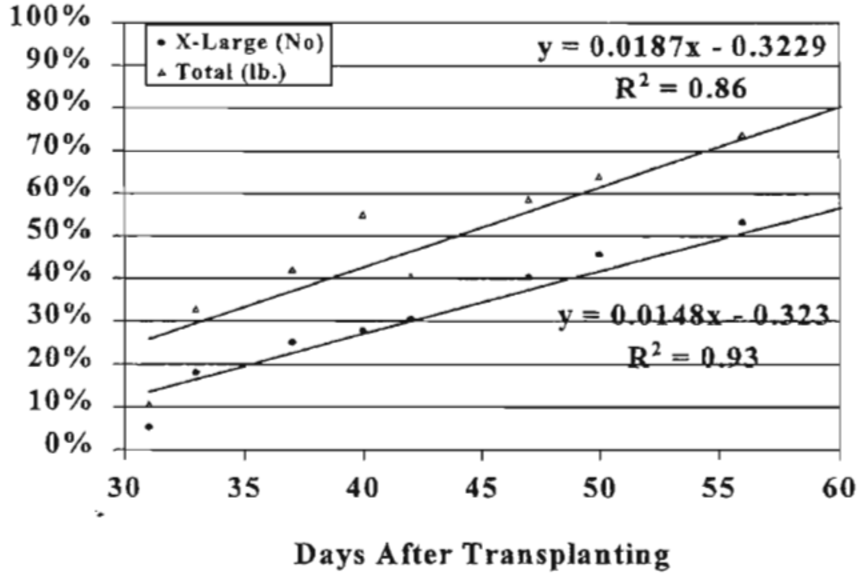

Figure 1 Percentage extra large fruit and total weight of fruit per plant by day of first symptom expression compared to uninfected plants.

Table 1. Adult whiteflies obtained by turning 1 tomato leaf (6 Apr.) or beating 2 plant equivalents.

	6 Apr	15 Apr	22 Apr	30 Apr	5 May	12 May	19 May
Green	1.59 a	33.0 a	37.4 a	25.6 a	34.6 a	84.9 a	181.0 a
Black	1.36 a	40.0 a	35.1 a	18.6 b	31.5 a	64.3 b	165.6 a
White	1.63 a	39.2 a	20.8 b	17.3 b	21.6 b	41.5 b	95.6 b
Aluminum	0.79 b	20.5 b	24.0 b	10.6 c	20.4 b	59.8 c	135.6 ab

Table 2. Mean number of eggs and total immatures (sum nymphs and pupae) per 36 cm^2)

	15 April		27 May		Average	
	Eggs	Nymphs + Pupae	Eggs	Nymphs + Pupae	Eggs	Nymphs + Pupae
Green	1.6 b	1.4 b	1.5 ab	3.5 a	1.6 a	2.2 a
Black	1.1 b	1.3 b	1.8 a	2.7 a	1.4 a	1.9 a
White	2.2 a	1.3 b	1.5 ab	3.1 a	1.9 a	2.0 a
Aluminum	1.2 b	0.6 a	1.0 b	2.8 a	1.1 a	1.5 a

Table 3. Cumulative incidence (%) of TYLCV on 19 May (62 days after transplanting) by mulch color.

	Cumulative Incidence (%)
Green	15.5 a
Black	12.3 ab
White	16.3 a
Aluminum	6.8 b

Table 4. Yield from one-time harvest of 10 tomato plants by mulch color

	Extra-large (No.)	Extra-large (lb)	Total Fruit (No.)	Total Fruit (lb)	Average Weight (lb)
Green	29.5 ab	14.0 ab	106.8 ab	30.7 ab	0.34 b
Black	43.3 a	20.0 a	126.0 a	40.1 a	0.40 ab
White	21.5 b	10.4 b	79.8 b	24.2 b	0.36 ab
Aluminum	37.8 ab	16.7 ab	104.0 ab	35.1 ab	0.42 a

Table 5. Maximum soil temperatures (ºC) recorded through 6 May 1999.

Mulch	5 cm	10 cm	15 cm	20 cm
White	35.26	32.64	30.3	28.50
Black	37.77	35.42	33.22	31.19
Aluminum	32.03	29.89	28.52	27.62
Green	40.11	37.07	34.15	32.04

Table 6. Number of whitefly adults obtained from 4 beats.

Treatment	21-Apr	28-Apr	5-May	12-May	19-May	Average
Admire + Neemix	19.4 c	64.8 d	28.1 c	42.1 d	93.8 c	49.6 b
Admire	24.4 c	72.4 d	39.4 c	47.1 cd	71.8 c	51.0 b
Knack / Applaud	62.6 b	109.4 cb	69.8 c	154.8 bc	79.5 c	95.2 b
Actara	21.3 c	120.1 b	127.6 b	168.6 b	216.5 b	130.8 b
Untreated	103.4 a	201.9 a	213.3 a	390.8 a	384.4 a	258.8 a

Table 7. Mean number of Immature whiteflies on 36 cm^2 of leaf surface.

Treatment	21-Apr		28-Apr		06-May	
	Eggs	Nymphs + Pupae	Eggs	Nymphs + Pupae	Eggs	Nymphs + Pupae
Admire + Neemix	0.49 c	0.38 d	1.81 c	1.12 c	2.39 b	2.03 b
Admire	0.70 c	0.73 cd	1.41 c	1.12 c	3.9 b	2.08 b
Knack / Applaud	1.69 b	3.06 b	7.31 a	3.32 b	6.32 a	1.57 b
Actara	1.42 b	1.32 c	1.19 c	1.67 c	2.89 b	2.03 b
Untreated	3.94 a	4.64 a	4.93 b	6.71 a	2.65 b	6.6 a

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Treatment	12-May		20-May		28-May		Average over dates	
	Eggs	Nymphs + Pupae	Eggs	Nymphs + Pupae	Eggs	Nymphs + Pupae	Eggs	Nymphs + Pupae
Admire + Neemix	1.51 c	2.25 c	0.81 c	3.31 b	1.49 b	6.16 b	1.41 c	2.33 b
Admire	3.22 bc	4.63 c	0.97 c	3.52 b	2.17 b	8.51 b	2.06 c	3.13 b
Knack / Applaud	7.83 a	4.27 c	5.03 a	2.78 b	3.8 a	2.11 c	5.42 a	2.90 b
Actara	4.3 b	9.14 b	2.11 b	8.49 a	3.98 a	15.77 a	2.57 bc	5.85 b
Untreated	7.87 a	19.57 a	0.69 c	8.79 a	3.66 a	18.51 a	3.97 ab	10.35 a

Table 8. Percentage plants newly infected with TYLCV.

	New Virus					
Treatment	29-Apr	3-May	6-May	12-May	19-May	Average
Admire + Neemix	0.5	1.5 b	0.5	0.5	2.25 b	0.84
Admire	0.75	1.5 b	2	2	2.25 b	1.25
Knack / Applaud	1.75	4.5 a	0.75	0.75	5 a	1.75
Actara	1.5	4.25 ab	1.5	1.75	6.25 a	2.09
Untreated	2.75	4.75 a	1	1	6.75 a	2.22

Table 9. Cumulative percentage plants infected with TYLCV.

	CumulativeVirus				
Treatment	29-Apr	3-May	6-May	12-May	19-May
Admire + Neemix	2.0	3.5	4.0	4.5	6.8 c
Admire	2.3	3.8	5.8	7.8	10.0 bc
Knack / Applaud	3.0	7.5	8.3	9.0	14.0 ab
Actara	3.0	7.3	8.8	10.5	16.8 ab
Untreated	4.3	9.0	10.0	11.0	17.8 a

Table 10. Number and weight of extra-large and total fruit from 12 tomato plants.

	Extra-Large		Total	
Treatment	(No.)	(lb.)	(No.)	(lb.)
Admire + Neemix	83.25 a	30.28 a	163.53 a	62.15 a
Admire	76.50 a	35.55 ab	163.05 ab	66.45 ab
Knack / Applaud	64.50 ab	28.88 ab	174.38 ab	61.73 ab
Actara	66.75 ab	39.9 ab	185.65 ab	74.13 ab
Untreated	45.00 b	25.28 b	156.53 a	55.45 a