Effect of an Aphid-Transmitted Yellowing Virus on Yield and Quality of Staked Tomatoes

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ABSTRACT

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A newly recognized virus disease of tomato in Florida, referred to here as tomato yellows, significantly reduced yield and quality of staked fresh-market tomatoes. Early infections (2–3 wk after transplanting) caused the greatest plant stunting (8–15%) and reduction in yields (60–83%), but infections occurring as late as 5 wk before harvest resulted in a 25% yield reduction. Fruit quality was also adversely affected, resulting in misshapen and puffy fruit with thin walls. Weekly applications of mineral oil (JMS Stylet-Oil) did not affect plant growth or resultant yields. Infection with this virus may account in part for reported yield reductions for the spring tomato crop grown in several southwestern counties.

During a survey for virus diseases in tomato fields in southern Florida in 1978, an apparently new disease was discovered. The name tomato yellows was applied to this disease, and evidence suggests that it is caused by a strain of potato leaf roll virus (5). Because of extensive distribution of this disease in the affected counties and the potential for yield losses, field studies to assess the damage caused by this virus were initiated in the fall of 1978 at the Agricultural Research Center at Immokalee, FL. A preliminary report of this work has been published (4).

MATERIALS AND METHODS

Tomato plants naturally diseased with tomato yellows were previously found in experimental plots at the Center in the spring of 1978 (5). To minimize the effects of natural virus spread, the experiment was conducted during the fall (August–December) of 1978, when aphid flights are low (1).

Healthy tomato seedlings (*Lycopersicon esculentum* Mill. 'Walter') were started in trays at Immokalee on 24 August 1978 and transplanted to raised, white plastic, mulched beds on 19 September (3½ wk old). Plants were later staked and tied, following commercial practices.

Tomato plants that served as virus source plants were inoculated in a greenhouse at Belle Glade. Twenty-four hours before these potted plants were transported to Immokalee, 8–10 apterous *Myzus persicae* (Sulzer) were placed on each of the two top leaflets on an infected plant. Aphids thus had an acquisition access period of at least 24 hr (5). Infected leaflets with the aphids still attached were cut from the source plants, and one leaflet was intertwined in the top foliage of each plant to be inoculated for the Immokalee field plots. As the detached leaflets wilted, the potentially viruliferous aphids moved onto the healthy foliage. In this manner, plants could be inoculated at definite time intervals and effects of early versus late infections could be established.

Experimental design was a randomized complete block with four replications of five treatments, each with a maximum of 12 plants. Treatments one through four were different dates of inoculation with tomato yellows virus beginning 2, 3, 4, and 5 wk after transplanting. Plants in treatment five were not inoculated and, like the first four treatments, were sprayed weekly with a mineral oil, JMS Stylet-Oil (3). Oil sprays were used to reduce the potential spread of aphid-transmitted viruses within the plots and to gain further insight into the effect oil sprays might have on yield and fruit quality. Treatment six consisted of plants that were neither inoculated nor sprayed with the mineral oil; to keep this treatment separate, the four beds were at the rear of the experimental area.

Oil sprays were applied on the Monday following the Thursday of aphid inoculations so as not to inferfere with the inoculation process. The oil, 750 ml/100 L of water, was applied at 400 psi by using a specially equipped spray boom with Teejet TX-5 nozzles (3). Normal pesticide applications for disease and insect control were made to all treatments a day or two after the oil spray had been applied.

Observations on the effects of virus infection on plant growth were made weekly. Fruits were harvested from 10 interior plants of each plot on 29 November and again on 11 December. Fruits, normally harvested in the mature green or breaking stage, were graded by size as extra large (XL), large (L), medium (MED), small (SM), and mini (MINI). Fruits from each of the six treatments were kept separate, but the XL and L fruit was pooled together in commercial 30-lb (13.6 kg) tomato boxes, as were the MED, SM, and MINI sizes. Fruits were neither treated with ethylene gas nor washed with chlorine and were allowed to ripen in boxes in a laboratory. For high-yielding treatments, only a representative 30-lb sample was taken. Observations for fruit quality were made at both harvest dates.

RESULTS

Infection. The inoculation method was successful, since 183 of the 187 plants in the experiment developed symptoms. Four escape plants were not used in further measurements. Typical yellows symptoms were observed on inoculated plants 2 wk after aphids were added to the plants. No symptoms developed in treatment five plants (not inoculated) that, although located adjacent to heavily infected plots, received weekly oil sprays. Two infected plants appeared in treatment six (not inoculated, not sprayed) and were eliminated before the first harvest. Also, although additional tomato experiments were being conducted during the same time period, the only yellows-diseased tomato plants found were in this experiment.

Mean plant heights (cm) recorded on 26 October for inoculated treatments one ($\bar{x}=59$) and two ($\bar{x}=64$) were significantly different from each other and the noninoculated treatment five ($\bar{x}=69$) ($P=0.05$). The infected plants made a surge of growth, and at the 16 November reading, there were no significant differences between treatments one and two ($\bar{x}=86$ and 87 cm, respectively); they were significantly shorter than treatment five ($\bar{x}=95$ cm) ($P=0.05$). The severity of early infection was particularly noticeable in treatment one where, because of early stunting, the plants had not received the third tying with string and thus were

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bending over due to the lack of support. At the first harvest (November 29), plants in treatment one, two, and three had severe foliar symptoms, compared with very mild symptoms in treatment four.

The number of fruits set depended on the length of the infection period. The mean numbers of fruit set on the first three clusters on 21 November were 3.2, 5.2, 7.4, 8.3, 8.6, and 8.1 for treatments one through six, respectively. Means for the first three treatments were significantly different from each other ($P = 0.05$), and those for treatments three through six were not, according to Duncan's multiple range test.

Yield. Infection with tomato yellows virus dramatically reduced the yield for the first three treatments because of the lower number of fruit set (Table 1). The 25% reduction in yield for treatment four compared with treatment five was unexpected because plants in treatment four showed only mild foliar symptoms at harvest.

Fruit harvested on 29 November was assessed for overall quality (external appearance; worst to best) by nine employees at the Belle Glade Research Center. Fruit selected from the six treatments and representing the five fruit sizes were arranged in rows in six tomato box lids. All evaluators selected treatment one as having the most inferior fruit (Fig. 1), and 86% agreed on treatment two as having the next most inferior fruit. Less agreement was reached on treatments three, four, and five, but 71% selected fruit from treatment six as having the best appearance.

Most of the fruits from treatments one and two exhibited pronounced ribbiness on the shoulders, which was apparent on fruit in all ripening stages. Although fruit color appeared dull, there was no sign of mottle or an irregular ripening pattern. In cross section (Fig. 2), these fruits showed puffiness (cavities) in most of the locules. Locule development was erratic and seeds were either absent or very immature. Fruit from treatment three also displayed some of these internal symptoms, which were not noted for the other treatments.

There was good correlation between the amount of external ribbiness and puffiness for XL and L fruit from treatments one through four (Table 2). The percentage of fruit with immature seeds was quite low in these treatments. Average wall thickness, particularly low for treatment one, reflected the overall poor quality of fruit from plants infected at an early age. Wall thicknesses in XL and L fruit appeared normal for treatments four through six.

Fruit in the MED, SM, and MINI categories also showed ribbiness and associated puffiness, but these conditions were less apparent as the length of infection time was decreased. The percent of fruit lacking seed development or showing immaturity was much higher in these categories. Wall thicknesses were

Table 1. Effect of tomato yellows on marketable yield of Walter tomatoes

Treatment no.[a]	No. of 30-lb boxes per acre[b] 1st harvest	2nd harvest	Total	Yield (% of treatment 5)
1	104 c	103 d	207 e	17
2	196 bc	284 c	480 d	40
3	378 ab	361 c	739 c	62
4	325 ab	576 b	901 bc	75
5	311 ab	889 a	1,200 a	···
6	450 a	576 b	1,026 ab	86

[a] Treatments 1–4 were inoculated with tomato yellows virus at 2, 3, 4, and 5 wk after transplanting, respectively, and received weekly oil sprays. Treatment 5 was not inoculated but was sprayed with oil; treatment 6 was neither inoculated nor sprayed with oil.

[b] Mean separation by Duncan's multiple range test ($P = 0.05$).

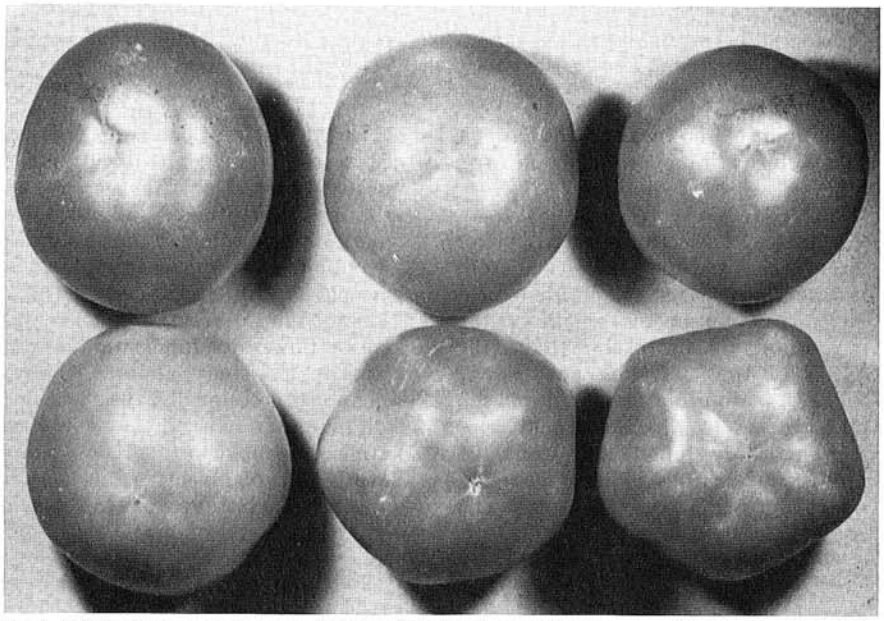

Fig. 1. Effect of tomato yellows on fruit quality. **Top** (L to R): treatments 6, 5, 4. **Bottom** (L to R): treatments 3, 2, 1. (Treatments 5 and 6 were not infected.) All fruits are from first harvest and represent the large size category.

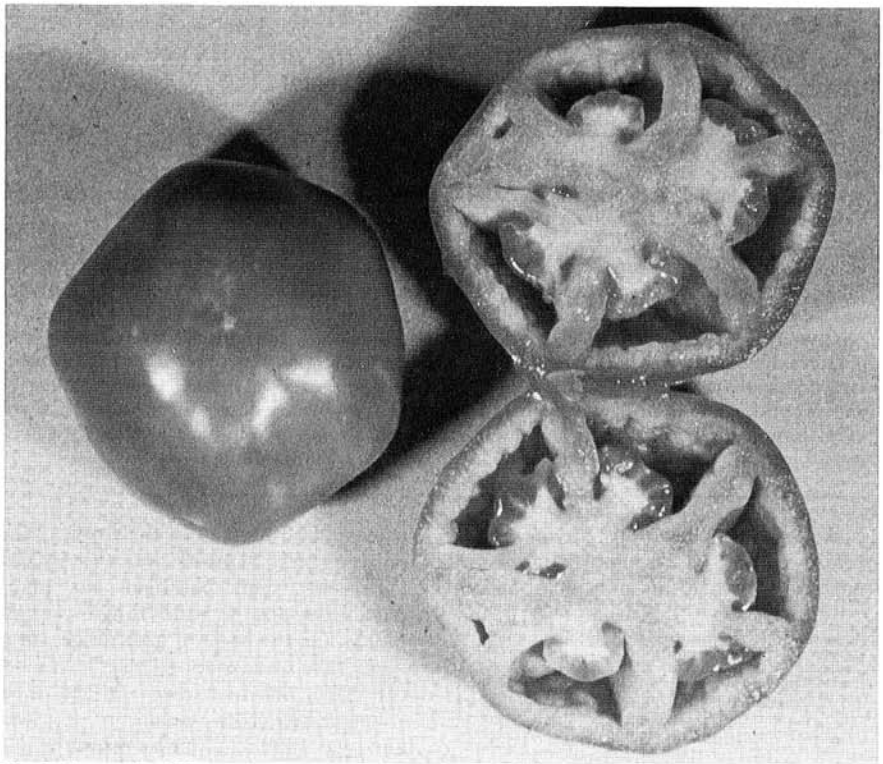

Fig. 2. External and internal appearance of large-size red fruits selected from treatment one. Plants had been diseased with tomato yellows for 7½ wk.

Table 2. Effect of tomato yellows on quality of Walter tomatoes from the second harvest

Treatment no.[b]	XL and L fruit[a]				MED, SM, and MINI fruit			
	Percentage with			Avg. wall thickness (mm)	Percentage with			Avg. wall thickness (mm)
	Ribbiness	Puffiness	Immature seeds		Ribbiness	Puffiness	Immature seeds	
1	100	100	0	3.8	81	67	56	4.8
2	94	82	18	5.1	59	56	22	5.0
3	88	76	12	4.8	68	73	23	5.1
4	59	65	12	5.6	47	41	24	5.6
5	6	12	0	5.7	14	14	9	5.2
6	17	17	0	5.5	18	18	5	5.8

[a] Fruit categories: XL = extra large, L = large, MED = medium, SM = small, MINI = mini. Values are based on at least 12 fruits, except for treatment 1 (XL and L) where only four fruits were observed.

[b] Treatments 1–4 were inoculated with tomato yellows virus at 2, 3, 4, and 5 wk after transplanting, respectively; treatments 5 and 6 were not inoculated.

more uniform and tended to increase in fruit with late or no virus infection.

DISCUSSION

Tomato yellows can adversely affect the quantity and quality of yield from tomatoes, and the effect appears to be a direct response to the length of the infection period. Crill et al (2) studied the effects of virus infection on yield of Walter tomato using a strain of tobacco mosaic virus to which this cultivar is tolerant. They found that decreased yields were due to a significant reduction in the number of fruits per plant and decreased weight of individual fruit and also were a response to the length of infection period. Unlike the present study in which misshapen and puffy fruit were encountered, tobacco mosaic virus infection did not appear to increase the percentage of off-type or cull fruit (2).

Although no accurate records were kept on flower development on infected plants in this study, abnormal flowers were noted occasionally, and the lack of fruit set on severely stunted plants could have been caused by poor pollination. Surprisingly, plants infected as late as 5 wk before harvest (approximate time of anthesis of the first fruit cluster) showed a 25% yield reduction.

The weekly application of mineral oil proved to be safe. Oil applied at the 0.75% concentration did not depress tomato yields, as has occurred with concentrations of 3–4% (3). Little virus spread occurred within the plots because of limited aphid flights and because of possible protection by the use of oil sprays. Reduced spread of tomato yellows in commercial tomato fields receiving oil sprays had previously been noted (3) and needs to be examined further.

ACKNOWLEDGMENT

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