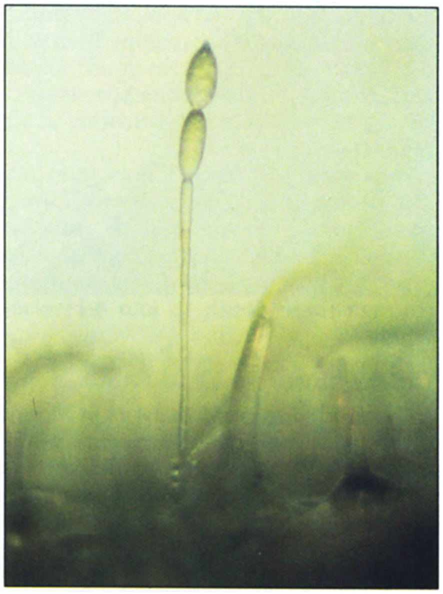
The epidemiology of powdery mildew on tomatoes

James C. Correll ❑ Thomas R. Gordon ❑ Vern J. Elliott

Fresh market tomatoes are susceptible but yields don't seem to be affected



Powdery mildew spores (conidia) and spore-bearing structures (conidiophores).

TABLE 1. Crop and weed hosts of *Leveillula taurica* in California

Plant, family, common name, species	Cross infectivity to tomato*
Amaryllidaceae	
Onion, *Allium cepa* L.	+
Compositae	
Annual sowthistle, *Sonchus oleraceus* L.	+
Artichoke, *Cynara scolymus* L.	−
Wild artichoke, *Cynara cardunculus* L.†	NT
Cocklebur, *Xanthium strumarium* L	NT
Common groundsel, *Senecio vulgaris* L.	NT
Cruciferae	
Shepherd's purse, *Capsella bursa-pastoris* (L.) Medic	NT
Geraniaceae	
Whitestem filaree, *Erodium moschatum* (L.) L'He'r†	NT
Malvaceae	
Cotton, *Gossypium hirsutum* L.	+
Solanaceae	
Groundcherry, *Physalis* sp.	+
Chili pepper, *Capsicum annuum* L. var. *longum* Bailey	+
Tomato, *Lycopersicon esculentum* Mill.	+

* (+) = positive infection; (−) no infection; (NT) = not tested.
† Reported by K. Sims, Plant Pathologist, San Diego County.

Powdery mildew epidemics on tomatoes are often sporadic and unpredictable, making it difficult for researchers to determine the overall impact of the disease on tomato production. In a three-year study, we evaluated several factors influencing powdery mildew epidemics and assessed the effect of this disease on the production of fresh market tomatoes in California.

Powdery mildew of tomato, caused by the fungus *Leveillula taurica* (=*Oidiopsis taurica*), was first reported in California in 1978 and has subsequently been found in all tomato-growing regions of the state. The fungus has also been found on several other crop and weed hosts, and all strains tested, except the one from artichoke, were capable of infecting tomato (table 1).

Powdery mildew lesions initially appear as very small (less than 0.3 cm in diameter) light green to yellow blemishes on the older leaves of tomato plants 10 to 15 days after infection. Spores (conidia) and spore-bearing structures (conidiophores) can often be observed on the undersurfaces of these young lesions. Subsequently, lesions expand into bright yellow chlorotic areas on which dense sporulation can often be seen. The chlorotic lesions frequently develop brownish or necrotic centers, which expand until an entire leaflet turns brown; this may take from 20 to 35 days depending on the temperature (fig. 1). In general, leaf necrosis proceeds from the lower (older) leaves up through the tomato canopy.

Conidia of *L. taurica* can germinate over a range in temperature from 50° to 95°F. Under greenhouse conditions, however, infection is favored by moderate to cool temperatures (less than 86°F).

Once an infection has become established in a tomato leaf, temperatures above 86°F can accelerate both symptom development and death of leaf tissue. In the San Joaquin Valley, daytime temperatures during the growing season often exceed 86° to 95°F during powdery mildew epidemics but cool night-time temperatures are apparently sufficient to permit infection by the fungus. Some of the most severe epidemics we have observed in both commercial and experimental plots in the San Joaquin Valley have been during the warmest part of the growing season.

Results of our research indicate that susceptibility to infection by *L. taurica* is independent of leaf age. We have consistently been able to infect mature (expanded) and immature (emerging) tomato leaves under both field and greenhouse conditions. Field observations indicate, however, that the older leaves on a tomato plant frequently have more lesions than do younger leaves.

This disease "gradient" on individual plants is apparently due to the fact that the fungus has a relatively long latent period (time from infection until symptoms develop). As a result, leaves have usually become fully expanded by the time symptoms appear. Also, disease on a single

TABLE 2. Yield, leaf necrosis, and disease severity in fungicide sprayed and unsprayed commercial fresh market tomato fields

County and cultivar	Planting date	Harvest date	Fungicide treatment*	Disease severity at harvest†	Fresh fruit/ plant‡	No. of necrotic leaves/ plant§
Stanislaus						
Royal Flush	7/14/84‡‡	10/4/84	Unsprayed	559	2.52 a**	34 a
			Sprayed	47	2.45 a	10 b
Merced						
Royal Flush	7/18/84	10/11/84	Unsprayed	394	1.54 a	36 a
			Sprayed	39	1.59 a	12 b
Merced						
Sunny	7/18/85	10/16/85	Unsprayed	189	6.34 a	28 a
			Sprayed	17	6.02 a	15 b

* Treated plots received one application of Bayleton (4 oz/acre) about 45 days after thinning.
† Lesions per 100 leaflets; 25 leaves were sampled from each of five replications.
‡ Fresh fruit weight per plant (kg) at commercial harvest date, mature green stage. Three plants sampled in each of five replications.
§ Number of leaves with >75% of the leaflets necrotic.
‡‡ Field was direct-seeded and thinned on this date.
** Variables followed by the same letter within a plot are not significantly different by a paired "t" test comparison (P = 0.01).

plant is continually "diluted" by the production of new host tissue.

Powdery mildew epidemics were monitored in commercial and experimental fresh market tomato fields throughout California in the 1983, 1984, and 1985 seasons. In general, disease symptoms first appeared at or near the time of fruit set (approximately 45 days after transplanting) and increased in severity up until the time of harvest. In experimental plots with different planting dates, however, disease onset occurred at an earlier stage of crop development with each successive planting; disease onset was as early as the bloom and pre-bloom stages in the later plantings.

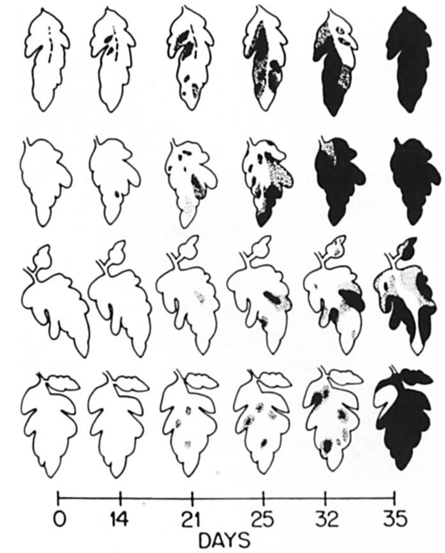
Presumably, the proximity of diseased plants increased the amount of the fungus available to infect plants in the later plantings. Disease onset is thus apparently related to available inoculum and not to a particular stage of crop development or specific environmental conditions. Late-planted tomatoes (after mid- to late June) in the central San Joaquin Valley are particularly prone to a higher inoculum pressure because of the regional buildup of the fungus from tomatoes planted earlier.

Although disease severity varies from field to field, the highest average disease severities we recorded in field plots at harvest were approximately 600 lesions per 100 leaflets. High disease severity can cause substantial defoliation in the tomato canopy. Even in severely affected fields, however, we did not observe any yield reduction, compared with yields of control plots treated with the fungicide Bayleton 50 WP (triadimefon) in either commercial (table 2) or experimental field trials (table 3). Furthermore, the disease had no obvious effect on the incidence of sunburning. All of the commercial fields

TABLE 3. Effect of planting date and Bayleton application on tomato yield, leaf necrosis, and powdery mildew severity at harvest, West Side Field Station, 1985

Planting date	Harvest date	Cultivar	Fungicide treatment*	Disease severity†	Fresh fruit/ plant‡	No. of necrotic leaves/ plant§
4/02	7/02	Royal Flush	Unsprayed	0	4.60 a¶	15 a
			Sprayed	0	3.99 a	13 a
		Jackpot	Unsprayed	—	4.87 a	17 a
			Sprayed	—	4.42 a	16 a
5/16	8/09	Royal Flush	Unsprayed	107	4.49 a	22 b
			Sprayed	10	4.53 a	21 b
		Jackpot	Unsprayed	—	3.91 a	22 b
			Sprayed	—	4.20 a	21 b
7/02	9/17	Royal Flush	Unsprayed	325	4.12 a	43 e
			Sprayed	40	4.37 a	25 c
		Jackpot	Unsprayed	—	3.76 a	43 e
			Sprayed	—	4.23 a	24 c
7/03	10/16	Royal Flush	Unsprayed	204	3.96 a	36 d
			Sprayed	41	4.38 a	15 a
		Jackpot	Unsprayed	—	4.41 a	37 d
			Sprayed	—	4.40 a	16 a

* Treated plots received one application of Bayleton (4 oz/acre) about 45 days after transplanting.
† Lesions per 100 leaflets; 25 leaves were sampled from each of three replications at harvest.
‡ Fresh fruit weight per plant (kg) at mature green stage. Five plants from each of three replications were sampled.
§ Number of leaves with >75% of leaflets necrotic.
¶ Variables followed by the same letter are not significantly different according to Duncan's Multiple Range Test (P = 0.05).



Symptom development of powdery mildew on mature tomato leaflets inoculated with *L. taurica* fungus spores and monitored for 35 days. The stippling indicates chlorotic (yellowing) areas; solid areas are necrotic (dead) tissue. Photo shows range of symptoms on leaflets.

TABLE 4. Disease severity of powdery mildew (*Leveillula taurica*) on selected commercial and primitive tomato lines

Tomato	Disease rating*
Primitive:	
Lycopersicon parviflorum	0.4 ab†
L. peruvianum (L.) Mill.	0.7 ab
L. chmielewskii	0.7 ab
L. hirsutum Humb. & Bonpl.	1.1 abc
L. glandulosum C.H. Muller	1.1 abc
L. pimpinellifolium (L.) Mill. 722	1.4 bcd
L. pimpinellifolium (L.) Mill. (Yellow Current)	1.7 cdef
Commercial, *L. esculentum* Mill. cv.:	
'Kenya Wild'	1.0 abc
'Cherry SRD' (from Turkey)	2.2 defg
(from Turkey)	2.3 efgh
'Thessalonica'	2.4 efgh
'Murrieta'	2.5 fghi
'UC-82'	2.5 fghi
'Roma'	2.5 fghi
'San Marzano'	2.8 ghij
'Ace'	2.9 ghij
'Castlemart 11'	3.0 ghij
'Giant Kada'	3.0 ghij
'Narcarlang'	3.0 ghij
'Valerie'	3.1 hij
'Kiolea'	3.2 ijk
'GS-372'	3.5 jkl
'Royal Flush'	3.5 jkl
'VF-145-7879'	3.5 jkl
'Moscow VR'	4.0 klm
'Blazer'	4.1 lmn
'Jackpot'	4.4 mn
're de los temperos'	4.8 n

* Disease rating is the mean of three plants from each of four replications; scale of 0 to 5: 0 = no lesions visible and no apparent defoliation; 1 = <10% leaves with lesions and minimal defoliation; 2 = approximately 25% of leaves with lesions and 10% defoliation; 3 = 50% of leaves with lesions and 25% defoliation; 4 = 75% of leaves with lesions and 50% defoliation; and 5 = most leaves (>90%) with lesions and extensive defoliation (75%).
† Numbers followed by the same letter are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

with very severe disease also had other problems such as soil compaction, overwatering, and/or phytophthora root rot. Even in these instances, however, powdery mildew did not reduce yields.

In our field trials, Bayleton 50WP has been very effective in controlling powdery mildew epidemics. In all instances, one application at a rate of 4 ounces per acre approximately 45 days after transplanting reduced the final disease severity to less than 50 lesions per 100 leaflets (table 3). This level of disease did not cause significant defoliation. Frequently, conidia and conidiophores on existing lesions appeared shriveled and distorted seven to ten days after the fungicide application.

Twenty-one commercial tomato cultivars and five primitive tomato species were evaluated for their susceptibility to powdery mildew. We screened the plants in a commercial tomato field in the San Joaquin Valley (Stanislaus County). The surrounding tomato fields had a very high level of disease.

All of the commercial tomato cultivars tested were susceptible to powdery mildew, although some differed considerably in the degree of susceptibility (table 4). The tomato cultivars tested differed in many characteristics, however, including vegetative growth habit, yielding capacity, and rate of maturation; all of these factors may influence powdery mildew severity.

Conclusions

We were not able to demonstrate any significant reduction in yield of fresh market tomatoes due to powdery mildew in either commercial or experimental field plots when tomatoes were harvested at the mature green stage of development. However, the fact that powdery mildew can substantially increase defoliation may predispose fruit to damage such as sunburning, reduced solid content, and insect damage although this has not yet been observed. Processing tomatoes are harvested much later in their development than are fresh market tomatoes and a high level of powdery mildew could have a substantial effect on fruit quality. This, however, has not been demonstrated.

James C. Correll is Post-doctoral Research Associate, and Thomas R. Gordon is Assistant Professor, Department of Plant Pathology, University of California, Berkeley; and Vern J. Elliott is Research Scientist, U.S. Department of Agriculture Agricultural Research Service, Research Laboratory, Oxford, North Carolina. *This work was supported by the California Fresh Market Tomato Advisory Board. The authors also thank Beltran Farms, Labar Farms, R. W. Scheuerman, and P. P. Osterli for their cooperation.*

Biological control of leafminers on greenhouse marigolds

Kevin M. Heinz ❑ Julie P. Newman ❑ Michael P. Parrella

In greenhouse marigolds grown for seed, a parasitic wasp suppressed leafminers for two months after establishment

Marigolds grown for seed in the Lompoc area of California (northern Santa Barbara County) are attacked by many pests. Some damage to foliage can be tolerated in seed crops, as opposed to most of those grown for cut flowers, but injury that may reduce seed production must be prevented. Pesticide applications are usually avoided after hand-pollination because of the possibility of seed shatter from the force of the spray. For those reasons, and because plants grown for seed are usually maintained for five months to three years, the use of biological control agents would be appropriate.

One of the most serious pests is the leafminer, *Liriomyza trifolii* (Burgess). This leafminer has a short developmental time, has a high egg-laying capacity, and rapidly develops insecticide resistance. These traits, coupled with increased restrictions on insecticide use, have contributed to the difficulty in controlling *L. trifolii* in greenhouses.

Use of the parasitic wasp *Diglyphus* sp. has shown great promise as a means of suppressing *L. trifolii* populations on greenhouse chrysanthemums (*California Agriculture*, November-December 1982, January-February 1986). We therefore established a trial to evaluate the use of *D. begini* (Ashmead) for control of *L. trifolii* on greenhouse marigolds.

Greenhouse trial

The trial was conducted from July through October 1986 in a 10,000-square-foot greenhouse in Lompoc planted with about 8,000 African marigolds. Male and female parental lines were maintained on separate plants. Plant composition was 50 percent female (variety D154), 50 percent male (variety Diamond Jubilee), and pollen was physically collected from male flowers and applied to female flowers for pollination.

To monitor the leafminer population in the absence of any parasites, a 3- by 5- by 3-foot control cage was placed over a section of female plants at the time of planting, enclosing the resident leafminers and preventing insects from entering. A small box fan inside the cage maintained temperatures similar to those of the surrounding greenhouse. Probes attached to a Data-pod continuously monitored temperature and relative humidity inside the greenhouse and the control cage.

Adult insect populations were monitored with six Zoëcon yellow sticky cards uniformly distributed to sample the adult leafminer and parasite populations within the entire greenhouse. One card was also placed in each of the four cardinal directions, 30 feet outside the greenhouse walls, to monitor any surrounding insect populations that might have been able to get into the greenhouse. One small card was placed in the center of the control cage. Since insects stuck to the cards are physically removed from the population, the smaller card was used in the control cage to minimize the effect of sampling on the leafminer population. Cards in the greenhouse and in the control cage were changed every three to four days; those on the outside were changed weekly. The number of insects per species was counted for each card.

To estimate the number of immature leafminers and degree of parasitism, we subdivided the greenhouse into 18 equal sections. In each section, one plant per sample period was randomly selected and an average of five leaves collected randomly at intervals along the length of the plant. In the control cage, leaves were selected in the same way from two randomly chosen plants per sampling. Leaves were examined microscopically within 48 hours of collection and scored for the number of live, dead, and parasitized leafminer larvae.

Adult parasites were uniformly released into the greenhouse twice weekly, no later than 7:30 a.m., between July 28 and September 11. A total of 66,000 parasites, 30 to 50 percent female, were released over the entire trial for an average of 3,700 per release. At the time of release, the parasitic wasps were two to three days old and had been held in glass test tubes with honey for 36 hours. No insecticide applications for leafminer control were made during the trial.