Infection Rates of Cercospora apii in Mixed Populations of Susceptible and Tolerant Celery

R. D. Berger

Associate Professor of Plant Pathology, Institute of Food and Agricultural Sciences, University of Florida, Agricultural Research and Education Center, Belle Glade 33430.

Florida Agricultural Experiment Stations Journal Series Paper No. 4571.

Accepted for publication 13 November 1972.

ABSTRACT

Disease incidence and infection rates for blight in susceptible celery decreased as the percentage of blight-tolerant plants in the population increased. This protective effect was largely lost at disease incidences above 25%. Tolerant celery in mixed populations had increasing blight incidence as the percentage of susceptible plants increased but infection rates did not truly reflect such an increase. There was no significant difference in infection rates between susceptible and tolerant celery for a major portion of the epidemic suggesting that the tolerance was effective against only low levels of spore arrivals.

Phytopathology 63:535-537

Additional key words: disease incidence, *Apium graveolens* var. *dulce*, early blight.

Early blight (*Cercospora apii* Fres.) is the most important fungus disease of Florida celery (*Apium graveolens* L. var. *dulce* DC.). A satisfactory disease-forecasting system has been developed (1) and a few celery lines with some tolerance to the disease are available (6, 7). Although seed of tolerant and susceptible crop plants have been blended (3), accurate data on infection rates and disease buildup on the separate entities of the blend have not been published. The principle of disease suppression by a mixture of tolerant and susceptible individuals relies on the fact that the latter should receive some protection from disease buildup as fungus reproduction would be less on tolerant plants and fewer spores would be available for infection. Likewise in the reciprocal situation, tolerant plants in a population of susceptible individuals would be under more disease pressure from the increased number of spore arrivals than they would be in solid plantings of tolerant plants and therefore should have a higher disease incidence (4, 5). Infection rates (r), disease incidences (x), and the progress of an epidemic of early blight in mixed populations of tolerant and susceptible celery are reported in this paper.

MATERIALS AND METHODS.—Celery plants of cultivars 'Fla 683' (susceptible) and 'EES 1624' (tolerant) were grown in flats in the greenhouse for 8 weeks and then transplanted to plots in the field on 10 January 1972. Each plot consisted of 100 plants of all tolerant, all susceptible, or mixed populations of tolerant and susceptible plants (Table 1). The 100 plants of each plot were arranged in five rows 60 cm apart and plants were 15 cm apart in the row. Color-coded stakes were used to identify plants in plots with mixed populations. The individual plots were randomized within the field area and separated from neighboring plots by a 9-m strip of cultivated ground. Each treatment was replicated four times. Seedlings were routinely sprayed with chlorothalonil for disease control in the greenhouse but after transplanting, the plants were not sprayed and the disease was allowed to proceed naturally. Weekly disease ratings were calculated as amount of foliage involved in disease by methods previously described (2). Infection rates were calculated by van der Plank's (4) formula: $r = 2.303/t_2 - t_1 \cdot \log(x_2/l - x_2) - \log(x_1/l - x_1)$.

RESULTS.—*Average disease incidence*.—Celery plants of both cultivars were blight-free when transplanted but blight was observed in the plots within 3 weeks following spore blow-in from infected celery in a small field 100 m distant. Blight was initially more severe in plots nearest that source but the experimental design and method of analysis for disease increase permitted reliable estimates of infection rates. Blight tolerance of cultivar EES 1624 and susceptibility of Fla 683 were immediately expressed following the 12- to 14- day incubation period. This difference in disease incidence between the two cultivars was strongly displayed throughout the season until the experiment was terminated at the end of 133 days (Table 2). The average estimated disease incidence of EES 1624 lagged approximately 3 weeks behind that observed for Fla 683 during the epidemic. At termination nearly all Fla 683 plants in all plots were dead and most of the EES 1624 plants had approximately 90% foliage killed by disease. Although the major portion of the foliage was killed directly by the numerous expanding blight lesions, contribution to disease losses from *Rhizoctonia* sp., *Fusarium* sp., viruses, mites, insects, etc., could not be completely separated in the final results. However, even in the cases where plants eventually succumbed to other causes, the severe blight infection weakened plants and undoubtedly contributed directly to such losses.

Average infection rates.—Although celery cultivar EES 1624 exhibited considerably less blight throughout the season than Fla 683, there was surprisingly little difference in the calculated periodic infection rates between the two cultivars during the first 91 days following the initial infection, except for the period 15 February to 2 March (Table 2). A tremendous increase in healthy tissue of EES 1624

TABLE 1. Percent and arrangement of tolerant and susceptible plants in population treatments

Tolerant plants in population (%)	Plant arrangement[a]
0	all susceptible
1	1 tol. near plot center
5	5 tol. random
10	2 tol. random each row
15	3 tol. random each row
25	5 rol. random each row
50	alternate plants
75	5 sus. random each row
90	2 sus. random each row
95	5 sus. random
99	1 sus. near plot center
100	all tolerant

[a]Plots consisted of 100 plants arranged in five rows with 20 plants per row.

during that period greatly diluted the increase in the amount of infected foliage. The Fla 683 plants did not exhibit such a major flush of new foliage and the infection rates for the period express that difference. The two primary contributing factors for the increased blight severity of Fla 683 over EES 1624 for the season were the higher level of blight in Fla 683 from the initial infection period (0.103% and 0.02% for Fla 683 and EES 1624, respectively) and the lack of substantial growth dilution of infected tissue in Fla 683 as occurred for EES 1624. The average weekly infection rates of Fla 683 were substantially higher than those for EES 1624 during the last 42 days of the experiment but this difference was due to the blight-weakened Fla 683 succumbing to secondary causes.

The average infection rates for the 69-day period (2 March to 10 May) were 0.082 and 0.081 for Fla 683 (susceptible) and EES 1624 (tolerant), respectively; the difference was not significant.

Suppression of r by disease-tolerant plants in the population.—During the early and intermediate stages of the epidemic when disease incidence of the susceptible plants was less than 25%, the protective effect of tolerant plants in the population was reflected on both disease incidence and infection rate of the susceptible plants (Table 3). As the percentage of tolerant plants in the population increased, the protective effect also increased. This was particularly noticeable for r values obtained from the representative periods of 2 to 8 February, 15 February to 2 March, and 15 February to 22 March (Table 3). This protective effect was largely lost as the disease progressed above 25% in later weeks.

The supposed increased blight pressure on disease-tolerant plants (EES 1624) by having progressively more susceptible plants in the population was never well marked on calculated infection rates for blight in EES 1624 at any time during the course of the epidemic although the disease incidences recorded from 5 April to 17 May reflected such an effect.

DISCUSSION.—Plant cultivars resistant or tolerant to disease effect their control by the reduction of infection rate over the season. Thus, it is of particular interest that in this study the average infection rate of the disease-tolerant celery (EES 1624) was not significantly different from that of Fla 683 for most of the epidemic. However, disease incidence of the tolerant cultivar lagged 3 weeks behind that of the susceptible one; the effect coming from the

TABLE 2. Average disease incidences and infection rates of *Cercospora apii* on two celery varieties through the course of an epidemic in 1972[a]

Date	% Disease		Infection rate(r)	
	Fla 683(sus.)	EES 1624(tol.)	Fla 683(sus.)	EES 1624(tol.)
2-2	0.10	0.02		
2-8	0.68	0.30	.314[b]	.452
2-15	1.0	0.52	.057	.080
3-2	4.2	0.76	.104	.013
3-8	7.4	1.6	.108	.150
3-15	10.1	2.5	.045	.071
3-22	19.6	5.5	.114	.118
3-29	28.1	8.4	.072	.069
4-5	38.2	12.7	.067	.068
4-13	50.1	19.9	.062	.068
4-19	67.6	32.3	.124	.108
4-26	80.9	47.7	.102	.095
5-3	84.4	52.9	.035	.030
5-10	93.0	63.3	.130	.063
5-17	97.1	72.8	.136	.063
5-31	99.2	87.0	.127	.065
6-14	99.9	90.1	.156	.022

[a]Average of 11 treatments over four replicates.

[b](.314) represents r value for period 2-2 to 2-8; (.057) for period 2-8 to 2-15, etc.

TABLE 3. Tolerant plant population effects on r values of blight in susceptible celery for selected periods in 1972

Tolerant plants in population (%)	r-Value in susceptible plants for period			
	2/2-2/8 (6 days)	2/15-3/2 (16 days)	2/15-3/22 (36 days)	2/15-4/13 (58 days)
0	.425	.128	.106	.093
1	.459	.127	.101	.092
5	.415	.129	.111	.097
10	.401	.138	.112	.090
15	.514	.134	.108	.088
25	.423	.114	.098	.083
50	.439	.106	.090	.083
75	.253	.086	.088	.080
90	.243	.040	.070	.062
95	.306	-.004	.053	.061
99	.235	.042	.062	.069
100				

difference in amount of initial infection and disease increase when disease incidence was less than 0.1%. Apparently, the EES 1624 cultivar expressed its tolerance by being able to prevent a large number of successful penetrations when the number of spores arriving was very low. This tolerance was insufficient in reducing r at higher disease incidences when the number of spore arrivals must have been much greater; consequently, there were more opportunities for successful penetrations. The difference in susceptibility of the two cultivars would likely have appeared much greater if the plants had been grown utilizing a routine fungicide program to aid in reducing the number of viable spores available for infection.

Artificial inoculation of both cultivars with spores of *C. apii* has always resulted in considerably fewer lesions developing on the EES 1624 cultivar when plants were held at various temperature and day-length regimes in environmental chambers (Berger, *unpublished data*). Thus, the insignificant difference in r values in the field experiment was quite surprising.

Although there was no significant difference in infection rates between the two cultivars, the 3-week delay of the EES 1624 in reaching the disease incidences observed for Fla 683 provided some protection from blight for plants of the latter cultivar in mixed populations. This protection generally increased as percentage of tolerant plants in the population increased. Some increase of blight in the tolerant EES 1624 could be attributed to having a progressively higher percentage of susceptible plants in the population. The readily wind-disseminated nature of the *C. apii* spores probably masked the differences in disease progress between the two cultivars.

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