Cercospora apii Damage of Celery—Effects of Plant Spacing and Growth on Raised Beds

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ABSTRACT

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Damage caused by *Cercospora apii* on leaves and petioles of celery (*Apium graveolens* var. *dulce*) was measured on plants grown at different plant spacings on both flat soil and on raised beds under conditions that simulated those in commercial production. Infection rates of *Cercospora apii* were not affected either by plant spacing or by growth on raised beds. In celery plots that received weekly fungicide applications (which were necessary for commercially acceptable disease control) average infection rates (r) ranged from −0.13 to −0.15 throughout the fall season, and 0.17 to 0.23 in the spring season. Hours of leaf wetness and disease damage measured as percent leaf area infected or as numbers of diseased petioles per plant requiring removal at harvest time did not differ significantly among plant-spacing or bed-height treatments, nor did yields or stalk weights vary significantly among comparable plant populations.

Additional key words: disease management.

The use of plant spacing to provide microclimates unfavorable to life systems of pests has been suggested as a tactic of insect and disease management (5, 8). In a practical test of this tactic, Berger (2) found that infection rates of *Cercospora apii* Fres. were greater in close-spaced populations of celery, *Apium graveolens* L. var. *dulce,* than in wide-spaced populations. However, Berger detected these differences in infection rates in plantings spaced 70 × 20 cm up to 60 × 60 cm. In this study, we sought to establish the usefulness of this tactic under conditions that more closely simulate those of commercial celery production (3) including the use of fungicides, and report here comparisons of disease damage, infection rates, and yields under different plant spacings on flat ground or raised beds. Additionally, the effects of plant spacing and growth on raised beds on the duration of leaf wetness also were examined.

MATERIALS AND METHODS

Florida 2-14 celery plants were transplanted on 29 September 1975 and 23 January 1976, in an organic soil (soil type: Everglades mucky-peat) at Zellwood, Florida. Plant spacings of 91 × 15, 91 × 30, 46 × 15, and 46 × 30 cm were used on flat ground, and plant spacings of 91 × 15 and 91 × 30 cm were used on raised beds approximately 20 cm high. Plot design consisted of six replicates of four treatments (fall 1975) and four replicates of six treatments (spring 1976). Replicates measured 3.6 × 6.1 m and were in a randomized, incomplete-block design with plots separated by a minimum of 6 m of cultivated soil. Fungicides were applied at 1-wk intervals with tractor-drawn, hydraulic spray equipment that provided a nozzle pressure of 12 kg/cm^2. A mancozeb fungicide (1.3 kg/ha active ingredient) was alternated with a mancozeb-benomyl mixture (1.3 kg + 0.2 kg/ha active ingredient) applied in 185 liter/ha of water. Disease ratings at weekly intervals were based on 20 terminal leaflets selected at random from each replicate. Leaflets were selected from within the leaf canopy at a level of approximately two-thirds of the total plant height. In early growth stages, leaves were not detached, but were evaluated in situ. Later, leaflets were removed and evaluated in the laboratory. Percentages of leaf area damaged by *C. apii* were estimated with a pictorial key similar to those described by James (4). Our key categorized leaves into classes containing 0-1, 2-5, 6-10, 11-15, 16-25, and 25-50% leaf area damaged by the pathogen. Estimates of overall disease damage were made by multiplying the number of leaves in each disease class by the maximum percent of damage for each class and dividing by the number of leaves in the sample. Infection rates were calculated by the method of van der Plank (9).

During the spring experiment, the total leaf area of celery plants was estimated at weekly intervals. All leaves from each of five celery plants were selected at random from a plot which was grown at a plant spacing of 46 × 16 cm under identical conditions and directly adjacent to the spacing plots. Leaves were removed, pressed, and dried between sheets of newsprint. Later, the area of these pressed leaves was measured with a LiCor LI-3000 area meter (Lambda Instruments Corp., P.O. Box 4425, 4421 Superior St., Lincoln, NB 68504). Leaf shrinkage after drying was estimated to be less than 2% and was not considered in our analysis of the data.

Celery plots were harvested on 22 January and 28 April

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1976. Weights and yields of graded and trimmed celery were measured using U.S. No. 1 celery grading standards after trimming the stalks to a uniform marketing length of 38.5 cm. Reasons for individual petiole removal (stripping) were recorded for 20 stalks from each replicate.

The duration of leaf wetness was measured [as described by Melching (6)] during the spring, 1976, season in the following plots: raised beds—plants spaced 91 × 30 cm (35,877 plants/ha) and 91 × 15 cm (71,754 plants/ha); flat soil—plants spaced 91 × 15 cm (71,754 plants/ha) and 46 × 15 cm (143,508 plants/ha). Leaf wetness was measured during 13 days (20 March - 13 April) on leaves within the canopy at about two-thirds total plant height or about 36 cm above the soil surface.

RESULTS

There were no significant differences in foliar damage or damage of petioles at harvest time caused by *C. apii* among any of the plant spacings or between those of plants planted on beds or on flat soil (Tables 1, 2). During the fall season (data summarized in Table 1), average infection rates were negative (range −0.13 to −0.15) and agreed very closely among different treatments. Negative r values were caused by a combination of new growth and slower disease development during the cool, dry conditions in the winter months. Accordingly, numbers of petioles removed at harvest because of *C. apii* damage did not differ significantly among treatments. Stalk weights and yields did not differ among comparable plant

TABLE 1. *Cercospora apii* disease damage, infection rates, and yield of four celery plant populations. Fall season, 1975-76, at Zellwood, Florida

Spacing between		Plant	Estimate of	Leaf area	Petioles/stalk removed due		
Row (cm)	Plant (cm)	population per ha	average r-value over a 10-wk period[a]	diseased at harvest (%)	to Cercospora damage[b] (avg. no.)	Avg. stalk wt. (g)[c]	Yield[d] (crates/ha)
91	15	71,754	−0.15	11.6	1.47	721.2	1,828
91	15[e]	71,754	−0.13	12.9	1.75	719.4	1,888
91	31	35,877	−0.15	11.4	1.08	995.2	1,379
46	15	143,508	−0.14	10.6	1.48	563.3	2,809
F-value			...	0.5 NS	2.0 NS	26.7**	73.6**

[a]This, and all values, is an average for six replicates, r value estimated from calculated slope of regression line, $\log_e \times (1\text{-}X)^{-1}$ plotted against time [van der Plank (9)].
[b]Grower practice is to remove damaged petioles (stripping).
[c]Weight of stalks stripped, trimmed to 38.5 cm in length.
[d]Yield in trimmed celery stalks (27-kg crates).
[e]Planted on raised beds 20 cm high.
[f]Abbreviations and symbols: NS = means not significantly different ($P > 0.05$); double asterisks (**) = means significantly different ($P < 0.01$); and ... = value not calculated.

TABLE 2. *Cercospora apii* disease damage, infection rates, and yields in several celery plant populations and spacings in flat and bedded culture. Spring season, 1976, at Zellwood, Florida

Spacing between:		Plant	Estimate of	Leaf area		Petioles/stalk removed due	
Row (cm)	Plant (cm)	population per ha	average r-value over an 8-wk period[a]	diseased at harvest[b] (%)	Stalk wt. (g)	to Cercospora damage (avg. no.)	Yield[c] (crates/ha)
91	15	71,754	0.20	7.75	702	4.97	1,959
91	30	35,877	0.19	6.55	992	4.87	1,480
46	15	143,508	0.19	9.60	497	4.96	2,772
46	30	71,754	0.17	10.12	763	6.13	2,367
91	15[d]	71,754	0.23	9.55	637	5.75	1,759
91	30[d]	35,877	0.22	10.72	914	5.47	1,394
F-value[e]			...	0.72 NS	7.89**	0.75 NS	12.70**

[a]Estimated from slope of calculated regression line, $\log_e (1\text{-}X)^{-1}$ plotted against time [van der Plank (9)].
[b]This and all values are averages for four replicates from leaf samples.
[c]Yield in trimmed celery stalks (27-kg crates). Means of treatments having comparable plant populations do not differ ($P > 0.05$).
[d]Planted on raised beds 20 cm high.
[e]Abbreviations and symbols: NS = means not significantly different ($P > 0.05$); double asterisks (**) = means significantly different ($P < 0.01$); and ... = value not calculated.

populations although these values did differ among treatments because of plant spacing (Table 1). During the spring season, results were similar except that infection rates were positive and ranged from 0.17 to 0.23. No significant differences in infected leaf area, numbers of damaged petioles, stalk weights, or yields were detected among comparable plant populations (Table 2).

Infection rates for *C. apii* were examined in greater detail during the spring season. Average values of r for the 9-wk growing period did not differ significantly among treatments nor were there significant differences in foliar damage at harvest (Table 2). Moreover, values of r expressed in units/day and calculated at 1-wk intervals during this period did not differ significantly among treatments for any of the weekly periods examined (Table 3).

Total leaf area per celery plant increased approximately 230 cm^2/day for the first 6 wk after transplanting, then leveled off and decreased rapidly after the 9th wk. This decrease in leaf area was a result of the loss of the oldest or outer leaves owing to severe *C. apii* damage. By the 9th wk, numerous lesions on the oldest leaves had coalesced, and the leaves were killed. The actual leaf area damaged by *C. apii* (measured leaf area × percentage of infected area) increased at an average rate of 22 cm^2/day throughout the 9-wk period (Fig. 1).

The duration of leaf wetness ranged from 9-18 hr during the 13 nights that measurements were obtained. Leaf wetness was primarily caused by dew but two periods of light (less than 1 cm) rainfall contributed to the longer (16-18 hr) periods measured. Average duration of leaf wetness among the four treatments ranged from 14.0 to 14.4 hr. The values were not significantly different ($P = 0.05$).

DISCUSSION

Disease damage and infection rates of *Cercospora apii* did not differ significantly among different celery plant spacings and cultural methods selected to cover those which might be employed by commercial growers of celery. Although Berger (2) confirmed that decreased infection rates resulted when the distance between host plants was increased, we agree with his conclusion that such a tactic may not be useful to the grower. Our results indicate that growers in Florida can maximize yields (commensurate with size, grade,, and marketing requirements) without concern for *C. apii* control other than to provide an effective fungus control program. We used the minimum number of fungicide applications (one application every 7 days) required for satisfactory control of *C. apii* under our experimental growing conditions. Similar results should be obtained in commercial situations where adequate control programs are in use. Our results do not indicate that either plant spacing or planting on beds for improved air circulation among plants improves the control of *Cercospora apii*. Techniques such as disease forecasting or spore monitoring of *C. apii* to better time or eliminate fungicide sprays appear feasible irrespective of plant populations (1).

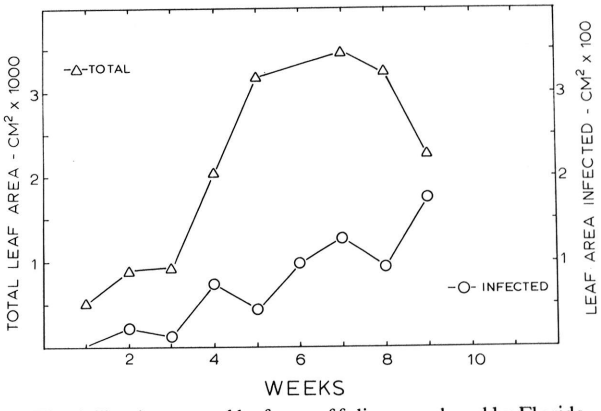

Fig. 1. Total measured leaf area of foliage produced by Florida 2-14 celery plants spaced 46 cm (between rows) by 15 cm (between plants) compared with the total leaf area infected by *Cercospora apii* calculated from evaluated leaf samples. Rapid decrease in leaf area after week 7 was caused by *C. apii* damage to older leaves.

TABLE 3. Infection rates of *Cercospora apii* under different plant spacings and cultural methods, spring season, 1976, at Zellwood, Florida

Spacing between:		r value for period[a]						
Rows (cm)	Plants (cm)	9 Mar to 16 Mar	16 Mar to 23 Mar	23 Mar to 30 Mar	30 Mar to 6 Apr	6 Apr to 13 Apr	13 Apr to 20 Apr	20 Apr to 27 Apr
91	15	−.09	+.16	−.14	+.16	−.01	−.04	+.16
91	30	−.10	+.12	−.09	+.20	−.07	−.04	+.14
46	15	−.09	+.15	−.14	+.19	−.02	−.06	+.18
46	30	−.09	+.16	−.10	+.11	−.02	−.05	+.20
91	15[b]	−.08	+.15	−.12	+.11	+.02	−.01	+.15
91	30[b]	−.06	+.13	−.12	+.24	+.08	−.07	+.25
	Mean	−.08	+.14	−.12	+.17	−.03	−.04	+.18
	F-value	0.2 NS[c]	0.4 NS	0.4 NS	0.8 NS	0.3 NS	0.3 NS	0.8 NS

[a]Average for four replicates, expressed as units per day over the 7-day period.
[b]Planted on raised beds 20 cm high.
[c]Abbreviation: NS = means not significantly different ($P > 0.05$).

Disease management programs depend on accurate and efficient sampling methods. Our results demonstrated some of the complexities of disease assessment introduced by the rapid growth of new celery foliage. Rapid growth tends to create the illusion that disease was decreasing during some weeks (Table 2) while the actual area of diseased celery leaves was increasing at an approximately constant rate (Fig. 1), even under acceptable disease-control conditions.

Hours of foliar wetness did not appear to be affected by different plant spacings or by growth on raised beds. The range of plant spacings examined did not decrease the duration of leaf wetness to a point where it was unfavorable for the pathogen.

Although varied plant spacings and planting on raised beds had no detectable effects on infection rates of *C. apii* or petiole infection by *Rhizoctonia solani,* these variables did affect population densities of the two-spotted mite (Strandberg and White, *unpublished*), as well as the celery leaf miner and its parasites (7). However, little is known of the effects of different plant spacing on other important disease or insect problems in celery. Since plant spacing, in principle, affects disease development and other pest-life systems, its potential use in disease management should be evaluated on a situation-by-situation basis.

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