Peach Rusty Spot Epidemiology: Incidence as Affected by Distance from a Powdery Mildew-Infected Apple Orchard

S. M. Ries and D. J. Royse

Assistant Professor and Graduate Research Assistant, respectively, Department of Plant Pathology, University of Illinois, Urbana, IL 61801. Present address of junior author: Department of Plant Pathology, The Pennsylvania State University, University Park, PA 16802.

Supported in part by the Illinois Agricultural Experiment Station.

The authors thank R. D. Seif, Professor of Biometry, Department of Agronomy and S. M. Lim, Plant Pathologist and Assistant Professor, USDA, ARS, Regional Soybean Research Laboratory, Urbana for suggestions and assistance. The authors also are indebted to the Fred Hartline and Sons Orchard, Alto Pass, IL 62905 for cooperating in this study.

Accepted for publication 17 November 1977.

ABSTRACT

RIES, S. M., and D. J. ROYSE. 1978. Peach rusty spot epidemiology: incidence as affected by distance from a powdery mildew-infected apple orchard. Phytopathology 68: 896-899.

Peach fruits were collected at distances ranging from 10-90 m from an apple (cultivar Jonathan) orchard affected with *Podosphaera leucotricha*, the suspected causal agent of rusty spot. Disease incidence as evidenced by numbers of fruit bearing rusty spot lesions decreased with increasing distance from the apple orchard. Incidence of fruit infection on four sampling dates ranged from a maximum of 43 to 50% at 10 m down to 3 to 10% at 90 m from the nearest *P. leucotricha*-infected apples. Coefficients of determination (R^2) for the calculated gradient always were greater for number of lesions per fruit than for percentage of fruit infected at each sampling date. Lesion enlargement paralleled fruit growth as measured by increase in fruit surface area. There was a significant weight reduction of infected fruit at 2 wk ($P = 0.01$) and 6 wk ($P = 0.05$) after floral tube abscission. Repeated attempts to produce rusty spot symptoms on peach fruit by inoculation with *P. leucotricha* conidia collected from infected apple leaves or with trichomes scraped from infected peach fruit were unsuccessful.

Rusty spot of peach [*Prunus persica* (L.) Batsch] first described by Blodgett (1) is characterized by the presence of rust-colored spots which may cover half or more of the fruit surface. It has been proposed that rusty spot is caused by the apple powdery mildew fungus, *Podosphaera leucotricha* (Ell. & Ev.) Salm. (5, 6, 11). Fungicides that effectively control powdery mildew (e.g., sulfur, benomyl, pyrazophos) have been reported to control rusty spot (11, 14). Manji (11) obtained symptoms similar to rusty spot on peach fruit by inoculating trees with *Podosphaera* sp. Daines et al. (6) and Manji (11) observed that peach trees with rusty spotted fruit were always proximal to orchards of apple (*Malus sylvestris* Mill.) infected with *P. leucotricha*. In 1977, Ries and Royse (12) observed that both the incidence and the severity of rusty spotted peach fruit was significantly greater at 12 m than at 120 m from *P. leucotricha*-infected Jonathan apple trees. In New Jersey, J. K. Springer (Rutgers University, New Jersey, *personal communication*) observed that removal of *P. leucotricha*-affected apple orchards eliminated rusty spot in nearby peach orchards. The cause of peach rusty spot still is unconfirmed.

The incidence of a plant disease measured along a transect or straight line can vary in such a way that when numbers of infections or infected plant parts (y) per unit area of ground surface or plant tissue are plotted against distance traveled (x) a sloping line results (9). The slope of this line describes the measured gradient. The principles of plant disease dispersal gradients were discussed by Gregory (8, 9) and others (7). Tracing a dispersal gradient can sometimes suggest the inoculum source (2, 10, 13).

This paper documents a decrease in the incidence of rusty spot with increasing distances from *P. leucotricha*-infected apple trees and the reduction in weight of rusty spotted fruits below noninfected fruits.

MATERIALS AND METHODS

A 10-yr-old Jackson County, Illinois peach (cultivar Rio Oso Gem) orchard with a history of rusty spot disease was monitored for disease incidence in 1977. The orchard was approximately 90 m by 160 m in size with 8 m between rows. The first row was located 10 m from, and directly north of, a Jonathan apple orchard 45 m by 160 m in size which was moderately affected with *P. leucotricha* (Fig. 1). Percentage powdery mildew infections of the apple trees was estimated on 26 May by examining the 10 uppermost fully expanded leaves of 500 apple terminal shoots for powdery mildew symptoms. The peach orchard received a spray program of sulfur (20 kg/ha) applied with a commercial air-blast sprayer on a 7- to 10-day schedule beginning at prebloom and continuing the full season.

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A 17-yr-old peach (cultivar Redskin) orchard and a 10-yr-old Jonathan apple orchard located on the Plant Pathology Research Center, Urbana, were used in the inoculation trials.

Infection gradient.—Ninety peach fruits per row were collected randomly from alternate rows progressively farther from the apple orchard (Fig. 1). Fruits were collected on 12 May 1977 at 2 wk after floral tube abscission (shuck-fall), endocarp sclerification 26 May (pit hardening), 2 wk after endocarp sclerification (9 June), and 6 wk after endocarp sclerification (7 July). The frequency of peach fruit with rusty spot symptoms, lesions per fruit, and percentage surface area infected were recorded at each sampling date. The percentage of surface area infected was calculated by dividing total lesion area by the total surface area of the peach fruit and multiplying by 100. The total surface area of the peach fruit was estimated by measuring the height and the maximum and minimum widths of 50 fruit with a caliper, averaging the three measurements (d), and using the equation:

$$\text{surface area} = \pi d^2$$

To estimate the gradient, the linear regression of $\log_{10} Y$ on $\log_{10} X$ was calculated using the equation:

$$\hat{Y} = a + bX$$

where $Y = \log_{10}$ of the percentage of peach fruit with rusty spot lesions or the mean number of rusty spot lesions per fruit, and $X = \log_{10}$ of the distance (in m) from the apple orchard for each of the four dates. Percentage of infected fruit and the mean number of rusty spot lesions per fruit were analyzed by analysis of variance using a complete block design. Rows of peach trees at 10, 26, 42, 58, 74, and 90 m from the apple orchard were used as blocks; dates of collection were assigned as treatments.

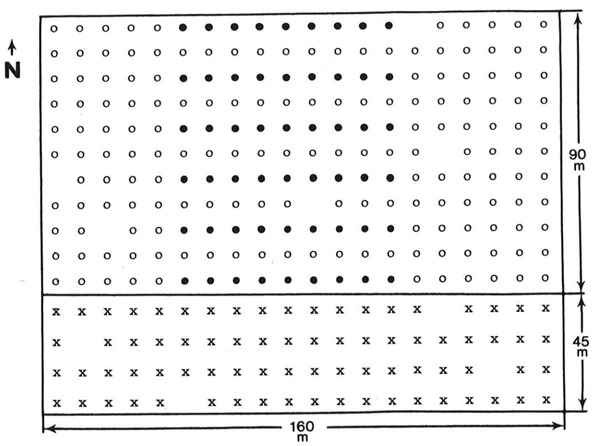

Fig. 1. Schematic diagram showing the spatial arrangement of the peach (*Prunus persica* 'Rio Oso Gem' orchard (o) in relation to the powdery mildew (*Podosphaera leucotricha*)-affected apple (*Malus sylvestris* 'Jonathan') orchard (x). Ninety peach fruit were collected randomly from trees (●) in alternate rows progressively farther from the apple orchard.

Effect of infection on peach fruit weights.—Weights of 180 healthy and 180 rusty spotted fruit were taken at the time of endocarp sclerification (26 May) and 2 and 6 wk after endocarp sclerification (9 June and 7 May, respectively). The weights were compared by Student's *t*-test.

Artificial inoculations.—Conidia were collected 1 May 1977 from *P. leucotricha*-infected greenhouse grown apple seedlings, placed in glass vials with a camel's-hair brush and stored at 4 C until used. At 3-day intervals beginning 3 May and continuing until 31 May, dry conidia were placed with a camel's-hair brush on 15 Redskin peach fruit growing in the Plant Pathology Research Center, Urbana. The percentage of rusty spotted fruit was recorded at harvest and compared with noninoculated fruits.

Peach trichomes were scraped from the surface of rusty spotted Rio Oso Gem peach fruit with a razor blade and placed on the surface of 15 nonwounded healthy Redskin peach fruit. Trichomes also were placed on the uppermost expanding healthy leaf on 25 nonwounded Jonathan apple terminal shoots. Peach fruit and apple terminal shoots were enclosed in polyethylene bags for 48 hr to maintain high humidity after inoculation. The fruit and apple shoots were observed for symptoms at peach fruit maturity. Peach fruit and apple shoots with trichomes scraped from nonsymptomatic fruit served as controls.

RESULTS AND DISCUSSION

Gradient in relation to apples.—Gradient slopes (b) and coefficients of determination (R^2) of the mean number of lesions per fruit always were greater than those

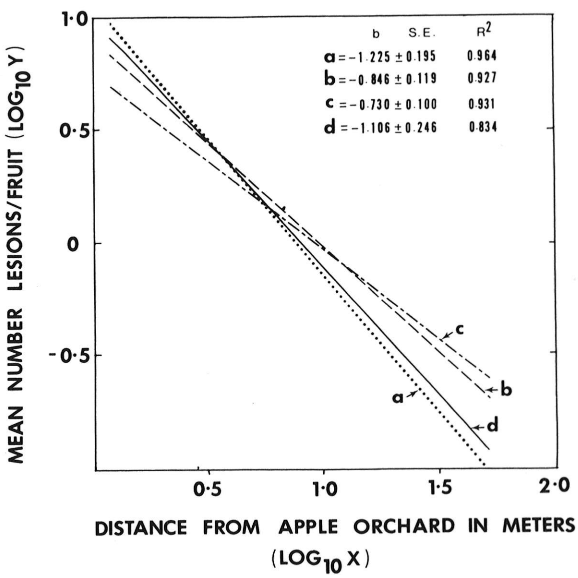

Fig. 2. Peach rusty spot gradient estimated by $\hat{Y} = a+bX$, where $Y = \log_{10}$ of the mean number of rusty spot lesions per fruit, and $X = \log_{10}$ of the distance (meters) from the apple orchard at four different dates in 1977: a = 12 May, b = 26 May, c = 9 June, and d = 7 July.

for the percentage fruit infected at each date sampled (Fig. 2, 3). The gradient (Fig. 3) calculated for 12 May 1977 (mean number of lesions per fruit) was the best variable model since the R^2 value (0.964) was higher than at any other sampling date. All R^2 values were statistically significant, $P = 0.01$.

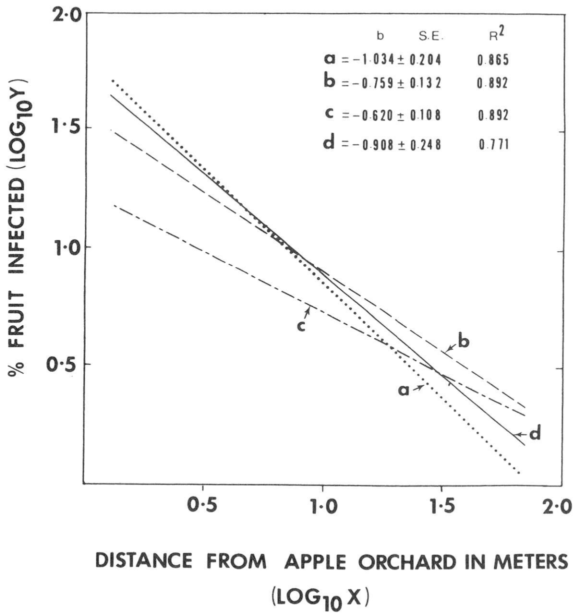

Fig. 3. Peach rusty spot gradient estimated by $\hat{Y} = a + bX$, where $Y = \log_{10}$ of the percent peach fruit with rusty spot lesions, and $X = \log_{10}$ of the distance (meters) from the apple orchard at four different dates in 1977: a = 12 May, b = 26 May, c = 9 June, and d = 7 July.

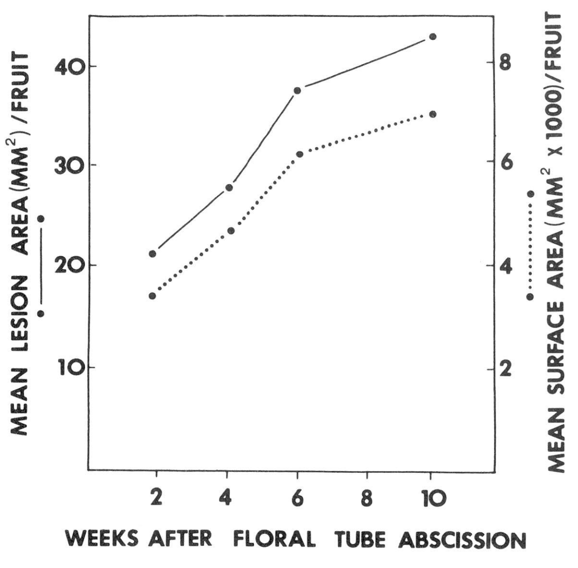

Fig. 4. Mean lesion size (mm^2)/fruit of rusty spot of peach (*Prunus persica* 'Rio Oso Gem') and mean surface area ($mm^2 \times$ 1,000)/fruit at various times following floral tube abscission in 1977.

All rusty spot lesions occurred prior to 12 May since there were no statistically significant differences among treatment (date) means, in the mean number of lesions per fruit, or in percentage of symptomatic fruit (Table 1). These results agree with those of Daines (4) who observed that spray programs to reduce rusty spot incidence must begin early in the growing season near the time of floral tube abscission. We suggest that the slightly lower incidence observed on 12 May as compared to the other dates may have been related to lesion size since smaller lesions, difficult to detect early, become more pronounced at later dates.

Lesion development.—Rusty spot lesions enlarge as a result of fruit surface area growth (Fig. 4). Mean percent surface area (Fig. 4) affected was 1.6, 1.5, 1.9, and 1.8 for 12 and 26 May, 9 June, and 7 July, respectively, and there were no significant ($P = 0.05$) differences between dates. Lesion sizes on 12 May ranged from 1 to 24 mm in diameter. Chandler (3) found that stone fruits increase in size between the time of fertilization and the time of floral tube abscission mainly as a result of cell division. If cell injury occurs at this time, lesion size would be proportional to the number of injured and healthy cell divisions. If cell damage occurs after the cessation of cell division when fruit is growing by cell enlargement only and injured cells enlarge at the same rate as adjacent non-injured cells, the lesion would enlarge at the same rate as surrounding healthy cells. Regardless of when damage was initiated, lesion enlargement paralleled fruit enlargement. Our results contradict the observations of Daines et al. (5, 6) who stated that the margins of lesions advance involving more and more fruit surface.

Infection and fruit weight.—Weights of rusty spotted peach fruits were significantly less than those of nonspotted fruits at 2 ($P = 0.01$) and 6 wk ($P = 0.05$) after endocarp sclerification (Table 2). This is the first report of a reduction in the weight of rusty spotted fruits. There was no significant difference between weights of healthy and diseased fruit at endocarp sclerification (Table 2).

Infection.—Manji (11) reported that *P. leucotricha* obtained from apple and used to inoculated peach fruits produced symptoms similar but not identical to those of rusty spot of peach. In our study, attempts to inoculate peach fruit with conidia of the apple powdery mildew fungus failed to cause rusty spot symptoms. This may be a result of unfavorable environmental conditions or stage of fruit development. Trichomes scraped from rusty spot lesions on Rio Oso Gem peach fruit and placed on either Redskin peach fruit or Jonathan apple leaves failed to produce rusty spot symptoms on peach fruit or powdery mildew symptoms on apples. This suggests that the absence of the pathogen in rusty spot damaged areas at the time of inoculation. The lack of active lesion enlargement (Fig. 4) also suggests that the lesion might be sterile. Our failure to produce symptoms suggests either that apple powdery mildew is not the etiological agent or that the conditions necessary to produce lesions were not met.

Our data provide additional evidence supporting the observations of others (6, 11, 12) that peach orchards with rusty spot are proximal to powdery mildew-affected apple orchards. Our findings document a gradient of

TABLE 1. Rusty spot incidence on peach (*Prunus persica* 'Rio Oso Gem') fruits as affected by distance from a powdery mildew (*Podosphaera leucotricha*)-affected apple (*Malus sylvestris* 'Jonathan') orchard in 1977

Distance from apple orchard	Peach fruit with rusty spot lesions[a]				Rusty spot lesions per fruit[a]			
(m)	12 May (%)	26 May (%)	9 June (%)	7 July (%)	12 May (mean no.)	26 May (mean no.)	9 June (mean no.)	7 July (mean no.)
10	49	48	43	50	0.70	0.60	0.53	0.73
26	26	27	24	27	0.26	0.28	0.29	0.27
42	16	24	22	26	0.17	0.26	0.22	0.26
58	12	18	21	19	0.11	0.18	0.22	0.19
74	8	11	12	11	0.07	0.10	0.13	0.11
90	3	8	10	4	0.04	0.08	0.09	0.04
$\bar{X}$	19.0	22.7	22.0	22.8	$\bar{X}$ 0.33	0.37	0.37	0.40
LSD[b] ($P = 0.05$) = 4.9; ($P = 0.01$) = 6.8					LSD[c] ($P = 0.05$) = 0.08; ($P = 0.01$) = 0.11			

[a]Based on 90 peach fruit per sample.
[b]Least significant difference for comparison between $\bar{X}$'s.
[c]Least significant difference for comparison between $\bar{X}$'s of the mean number of rusty spot lesions per peach.

TABLE 2. Weight of healthy and rusty spotted peach (*Prunus persica* 'Rio Oso Gem') fruit at three different dates in 1977

Date	Mean weight per fruit	
	Healthy (g)	Diseased[a] (g)
26 May[b]	33.7	33.8
9 June	38.1	34.4**[c]
7 July	58.7	55.5*[c]

[a]Fruit with at least one lesion/fruit.
[b]Endocarp sclerification.
[c]Significantly different from healthy fruit at $P = 0.01$ (**) and $P = 0.05$ (*).

reduced incidence and severity with increasing distance from apple trees which had approximately 1% of the shoots infected. This provides additional evidence that *P. leucotricha* is the etiological agent. Symptom initiation in 1977 occurred in early fruit development prior to 12 May. There is no evidence for secondary spread or a second infection period with this disease in 1977.

Addendum: During final preparation of this manuscript Daines and Trout (DAINES, R. H., and J. R. TROUT. 1977. Incidence of rusty spot of peach as influenced by proximity to apple trees. Plant Dis. Rep. 61:835-836) reported reduced incidence of rusty spot in peach orchards proximal to poorly-cared-for apple trees and that removal of the apple trees effectively eliminated rusty spot. Their evidence confirms our observations (12) and those of J. K. Springer (Rutgers University, New Jersey, *personal communication*) that rusty spot disease is related to the presence of nearby apple orchards.

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