The Effect of Rainfall, Drainage, Tree Spacing, and Fungicide Application on the Incidence of Citrus Brown Rot

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ABSTRACT

We studied the effect of rainfall, land leveling, and tree spacing on the incidence of brown rot in an orange orchard for four seasons. The percentage of fruit loss was 0-23%, and was directly related to the amount of rainfall in September and October. Tree spacing did not affect brown rot incidence. Poor drainage caused by the land leveling prior to planting resulted in a higher brown rot incidence in one year. Another year, a single application of tribasic copper sulfate in early September reduced brown rot from 10.9 to 4.8%. *Phytophthora parasitica* was the only pathogen species isolated from brown rot-affected fruit.

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Additional key words: Phytophthora parasitica.

Until recently, brown rot was not recognized as a problem in Texas citrus orchards. Although outbreaks are sporadic, serious losses of early oranges may occur (3). Brown rot outbreaks in Florida are usually caused by *Phytophthora citrophthora* (Sm. & Sm.) Leonian while *P. parasitica* Dast. [*P. nicotianae* var. *parasitica* (Dast.) Waterhouse] is seldom isolated from brown rot-affected fruit (5). In Texas, *P. parasitica* is the only pathogen species which has been isolated from orchard soils or infected plant parts (4).

In the fall of 1970 an outbreak of brown rot was observed in a spacing trial of oranges [*Citrus sinensis* (L.) Osb. 'Marrs Early']. Variation was observed in the incidence of brown rot in different areas of the orchard, and a study was begun to determine the factors affecting brown rot incidence.

MATERIALS AND METHODS.—The study was conducted in a 10-acre orchard of Marrs Early oranges planted in 1966. Trees were planted 1.82, 2.74, 3.65, 4.56, 5.47, and 6.69 m apart and rows 5.47, 6.69 and 7.90 m apart to determine optimal tree spacing. The 18 spacing treatments were replicated three times. The number of brown rot-incidence trees selected in each spacing treatment was six in 1970 (i.e., 18 per replicate); three in 1971; and five in 1973. On 6 September 1973, three trees in each spacing treatment were sprayed (50 liters/tree) with tribasic copper sulfate at 1.8 g/liter of water using a Hardie hydraulic sprayer operated at 35 kg/cm. Two trees were left as unsprayed controls.

The incidence of brown rot was determined by periodically counting the fallen fruit affected by brown rot. At harvest, the total number of fruit per tree was counted and brown rot incidence expressed as percentage of the total fruit crop. Final counts of affected fruit were made in October, and fruit was harvested in November. Rainfall data collected at a near-by weather station are presented in Table 1.

The orchard site was primarily a Hidalgo sandy clay loam soil, with a high area of about 1.0 hectare (ha) in the center covered by 20-45 cm of clay. The site was leveled prior to planting to facilitate flood irrigation. From the center or cut area, 20-45 cm of clay was removed, leaving a sandy clay or sandy clay loam on the surface. In the fill area, from 5-70 cm of this clay were deposited around the perimeter of the orchard over the original sandy clay loam surface. Leveling affected drainage patterns substantially. The time required for penetration of 10-12 cm of irrigation water was 10-18 h in the cut area, and 22-32 h in the fill area.

The causal organism was isolated from fruit and soil by previously described methods (4) and all isolates were identified.

Percentages were transformed to the arcsin values and were treated by standard analysis of variance. Means were separated by Duncan's multiple range test (2).

RESULTS AND DISCUSSION.—Brown rot outbreaks were restricted to the early fall when temperatures were warm and rainfall abundant (Table 1). All affected fruit were within 1 m of the ground. Serious losses occurred in 3 of the 4 years studied. Brown rot was not observed in 1972 when rainfall was low and occurred on relatively few days. The percentage loss to brown rot was directly related to total rainfall in the principal infection period in September and early October (Table 1). Differences in brown rot incidence between years were significant ($P = 0.05$) (Table 1) and were attributable to differences in total rainfall.

Neither the distance between trees (Table 2) nor the distance between rows significantly affected the incidence of brown rot in any year. Although better air circulation and more rapid drying of widely spaced trees might have been expected to influence brown rot incidence, no such effect was observed.

Brown rot incidence was significantly higher ($P = 0.001$) in the fill areas than in the cut areas in 1970, but no difference was observed in 1971 or 1973 (Table 2). In 1970, rainfall was abundant, but occurred on relatively few days during the infection period. Much of the infection probably occurred by splashing of propagules of *P. parasitica* which were present in standing water in the orchard. Since water remained longer in the fill areas, the percentage of infection was greater here than in the cut areas. In contrast, rainfall in 1971 and 1973 was spread over a greater number of days, and surface water was seldom present. Most of the infection probably originated from the splashing of sporangia produced on infected fruit in contact with soil.

Land leveling often has a detrimental effect on crop growth (1). In most cases, problems arise in cut areas because of their low fertility and lack of organic matter, but, in this case, the most severe problems occurred in the fill area, primarily because of poor drainage.

The loss due to brown rot on trees sprayed with tribasic copper sulfate in 1973 was 4.8%, which was significantly

TABLE 1. Effect of the amount and distribution of rainfall on the percentage of fruit affected by brown rot

Year	Principle period of infection	Rainfall during period (mm)	Days of rain/ days in period	Brown rot (%)
1970	12 Sept - 5 Oct	242	9/24	16.9 c
1971	10 - 30 Sept	297	16/21	23.6 d
1972	1 - 30 Sept	65	7/30	0.0 a
1973	14 - 28 Sept	106	9/15	
	11 - 15 Oct	73	5/5	10.4 b

[a] Means not followed by a common letter are significantly different, $P = 0.05$.

TABLE 2. Effect of tree spacing, cut and fill, and fungicide application on the percentage of brown rot-affected fruit in 1970, 1971, and 1973[a]

Distance between trees (m)	Brown Rot (%)						
	1970		1971		1973		
	cut[b]	fill	cut	fill	cut	fill	Avg.[c]
1.82	12.1	21.3	17.8	28.8	12.7(6.2)[d]	10.3(5.4)	17.2
2.74	12.5	20.1	27.8	33.1	7.6(3.9)	10.0(4.9)	18.5
3.65	12.8	28.6	17.4	13.9	11.9(7.7)	8.2(2.9)	15.5
4.56	15.9	27.9	38.2	13.7	12.6(0.7)	7.7(4.8)	19.3
5.47	11.2	16.1	33.1	22.9	15.2(3.4)	12.8(6.7)	18.6
6.69	7.3	16.5	18.0	18.5	10.7(3.3)	11.6(7.9)	13.8
Avg.[e]	12.0	21.8	25.4	21.8	11.8(4.2)	10.1(5.4)	

[a] No brown rot occurred in 1972.
[b] cut = areas where clay topsoil was removed; fill = areas where topsoil was deposited in land leveling.
[c] No significant differences in brown rot incidence were observed between the different spacings. Figures represent the averages of unsprayed tree only.
[d] Numbers in parentheses represent the percent of brown rot on trees sprayed with tribasic copper sulfate.
[e] Differences in the incidence of brown rot between cut and fill areas were significant ($P = 0.001$) in 1970, but not in other years.

less ($P = 0.001$) than the incidence on unsprayed trees, 10.9% (Table 2). No significant differences between spacing treatments or cut and fill areas were observed on sprayed trees.

All isolates recovered from soil and from infected fruit were identified as *P. parasitica*. Since *P. citrophthora* produces more sporangia in less time on infected fruit than does *P. parasitica*, it is more frequently the cause of brown rot outbreaks in Florida (5). In South Texas, where high rainfall and warm temperatures are common in early fall, and where clay soils often restrict drainage, serious outbreaks of brown rot caused by *P. parasitica* may occur.

Brown rot problems have been largely ignored and control measures are seldom used. Losses of 10-23% observed in 3 of the 4 years of this study are substantial and merit control. Where poor drainage causes water to stand in the orchard, some control of brown rot may be obtained by improving surface or subsurface drainage. Wide spacing of trees to facilitate drying of the trees apparently does little to reduce brown rot infection. Application of tribasic copper sulfate just prior to the rainy period in September is probably the most effective measure to control brown rot.

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