Epidemiology of Declinio Disease in Citrus Groves in the State of São Paulo, Brazil

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ABSTRACT. A survey of declinio affected trees was conducted in 229 commercial citrus groves at the upland area of State of São Paulo during the 1983-1986 period. The incidence of declinio, expressed as percentage of affected plants in the groves increased continuously with the time, following an exponential mathematical expression. The increase in the incidence of the disease with time were directly proportional to the plant population of the affected orchards. The rate of spread was inversely related to the cation exchange capacity and water retention capacity of the latosol soils.
Index words. Citrus, decline rates, quantitative epidemiology, disease-progress curves.

Citrus declinio was first reported in 1975 from a commercial citrus grove in Conchal, State of São Paulo, Brazil (7). Subsequently the disease was found in isolated groves far from the initial focus. Now the disease occurs in all citrus areas of the state. The spread of declinio is of major concern to the growers and the agricultural regulatory agencies. By 1987 the loss of citrus plants due to declinio was estimated to be about 5 million plants. For this reason the disease is considered one of the most serious problems of the citrus industry of Brazil.

This paper presents the results of several surveys for declinio conducted by the agricultural regulatory agencies of the State of São Paulo in commercial citrus groves of the region which is the major producer of Brazilian citrus.

METHODS AND MATERIALS

Survey procedure. Inspections were conducted in 229 commercial citrus groves, totaling 15.3 million plants, in the upland area of state of São Paulo. The surveys for declinio affected trees were conducted yearly from 1983-1986. All groves surveyed had diseased trees in various stages of decline. The number of declining and healthy trees in each grove was recorded by trained inspectors.

Declinio diagnosis. Identification of the plants with declinio was made visually. Disease symptoms detected visually in the affected trees include zinc deficiency of leaves, wilting of a sector or entire canopy of the tree, delayed flush, thin and pale foliage, dieback and production of water sprouts. Injection of water in the trunks (1) was used to confirm the visual identification. When the water uptake of the trunk was less than 5 ml/min the plant was considered to be affected by declinio.

Soil effect. The effect of the soil on the behavior of the declinio incidence was studied only for Pera sweet orange. From the initial 229 citrus groves inspected, data from 129 orange groves were used for analysis. The classification of the soils on which the orchards were grown was made according to the Soil Commission (3).

Statistical analyses. Mathematic equations for the data were derived by the method of minimum square deviation (4). The selection of equation that best fit was made by the value of the coefficient of determination. The following types of equations were used to fit the data: linear, exponential, bi-logarithmic and semilogarithmic.

RESULTS AND DISCUSSION

Time effect. Figure 1 shows that the number of affected plants of the population increased continuously with time. The representation shows clearly that declinio incidence is not a linear function of the time in the edafo-climatic conditions of the State

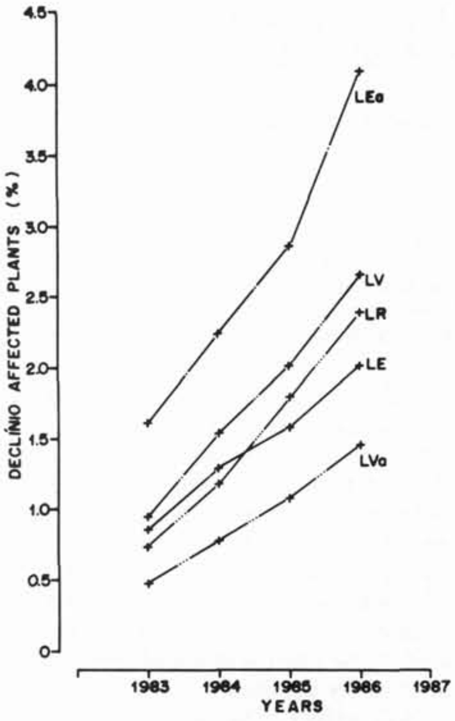

Fig. 1. Relation of declinio incidence with time in 229 citrus groves in the State of São Paulo, Brazil.

of São Paulo. Yomoki *et al.* (8) reported that the blight incidence in Florida was a linear function of time, the slope of the regression line was 3.5% per year for tree spacing of 7.6 x 7.6 m in a Winter Garden grove.

The mean percentage of affected plants in the control population in the State of São Paulo could be expressed by the equation:

$$y = 1.1435\ e^{(0.3255x)} \qquad \text{equation 1}$$

where: y = percentage of affected trees and x = number of years after 1982. The coefficient of determination of this regression was 0.9985.

With the equations used by Yokomi *et al.* (8), it is possible to estimate the period of time in which the disease incidence increases from 0.1% to 100%. This lapse of time was of the order of 28.6 yr for the Winter Garden grove, and 21.7 yr for the Avon Park grove. Using similar procedure with the equation 1 and mentioned lapse of time for the edafo-climatic conditions of the State of São Paulo, the period of time twas 21.2 years. The differences in the values of the lapse of time can be due to the differences in tree spacing as pointed out by Yokomi *et al.* (8).

Population effect. The relationship between the incidence of the disease and the tree population of groves in four agricultural regions in the State of São Paulo is shown in the Fig. 2. The percentage of affected trees increased with the size of the population. Thus the incidence is low in the agricultural region of Sorocaba, where the tree population is small and is high in the agricultural regions of Ribeirão Preto and Campinas, where the tree population is large. Lima *et al.* (5) found that blight incidence in some orchards of the State of São Paulo, Brazil, was directly proportional to the number of blighted trees observed when the grove was surveyed 3 years earlier.

Figure 2 also shows that for the same agricultural region the increase in declinio incidence is not a constant with time. Declinio incidence increases continuously year after year as seen in Fig. 1. Thus, in the same agricultural region, the loss of trees caused by the declinio will increase with time and with the increase of the tree population.

Geographic distribution. The geographic distribution and numbers of diseased trees in 1986 in the 229 citrus groves in the State of São Paulo is shown in the Fig. 3 and Table 1. In the Campinas region there were 289,370 affected trees corresponding to 4.3% of the total population. The diseased trees were mostly found in the municipalities of Casa Branca and Mogi Guaçú. The most affected grove, located in the municipality of Mogi Guaçú, had an incidence of 20%.

In the agricultural region of Ribeirão Preto, there were 299,923 affected trees, corresponding to 5.7% of the total population. The diseased trees were mostly in the municipalities of Bebedouro and Barretos. The most affected grove, with an inci-

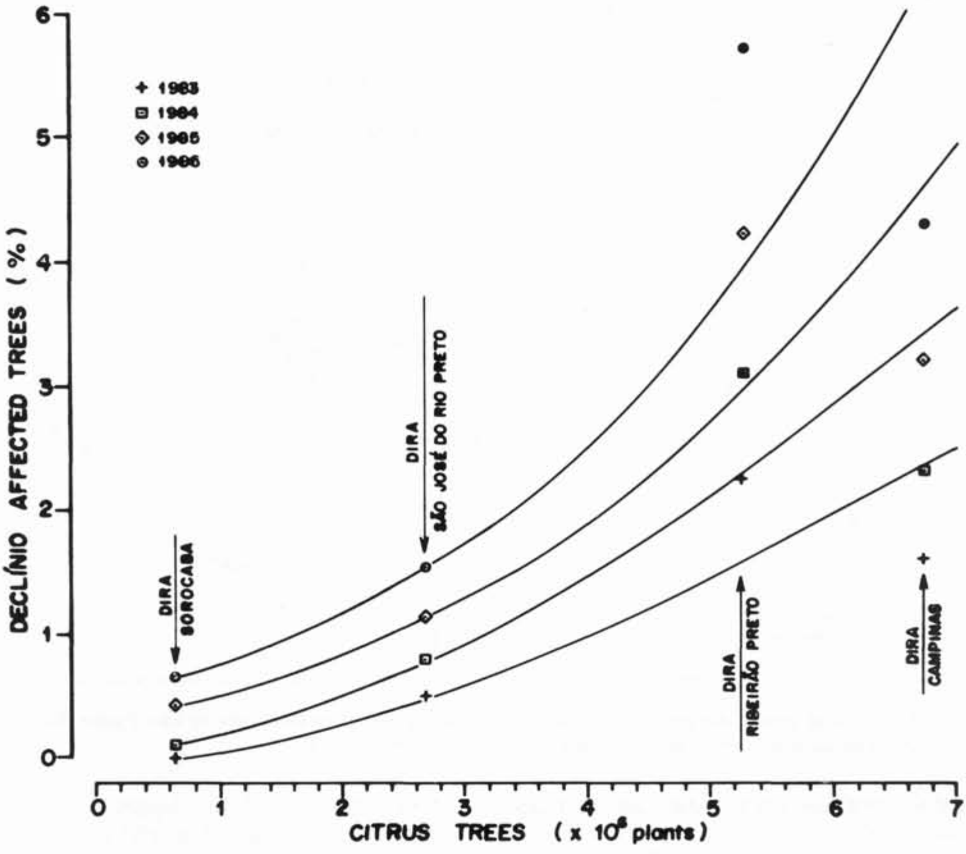

Fig. 2. Increase of the number of declinio affected plants in relation to the total tree population in four agricultural regions of the State of São Paulo, Brazil, from 1983 to 1986.

dence of 33.7%, was located in the municipality of Viradouro.

In the agricultural region of São José do Rio Preto, there were 41,475 affected trees, corresponding to 1.5% of the total population. The diseased trees were mostly in the municipalities of Mendonça and Itajobi. The most affected grove, with an incidence of 7.2%, was located in the municipality of Severínea.

Soil effect. The incidence of declinio increased continuously with time in all agricultural regions and in all types of Latosol soils. The behavior of the disease incidence with the types of Latosol soils in the State of São Paulo is shown in the Fig. 4. Groves grown on Ortho Dark Latosol - LE soil and on Latosol "Roxo" - LR soil, which is a clay soil, shows lower incidence of declinio than groves on Dark-Red Latosol sandy phase - LEa soil or Ortho Red-Yellow Latosol - LV, which presents medium texture (sandy phase). This points out the paramount influence of the soil texture and, consequently, the cation exchange capacity (CEC) and water holding capacity (WHC) of the soils in the incidence of declinio. Soil with clay texture have higher CEC and WHC than soils with medium texture.

Groves on Ortho Dark-Red Latosol - LE soil, which are clay soils, have a lower incidence of declinio than groves on Dark-Red Latosol sandy phase - LEa soil, which have medium texture. Thus the incidence of declinio was lower in groves on soils with higher WHC. Groves grown on Yellow-Red Latosol sandy phase - LVa soil, in the agricultural region of Cam-

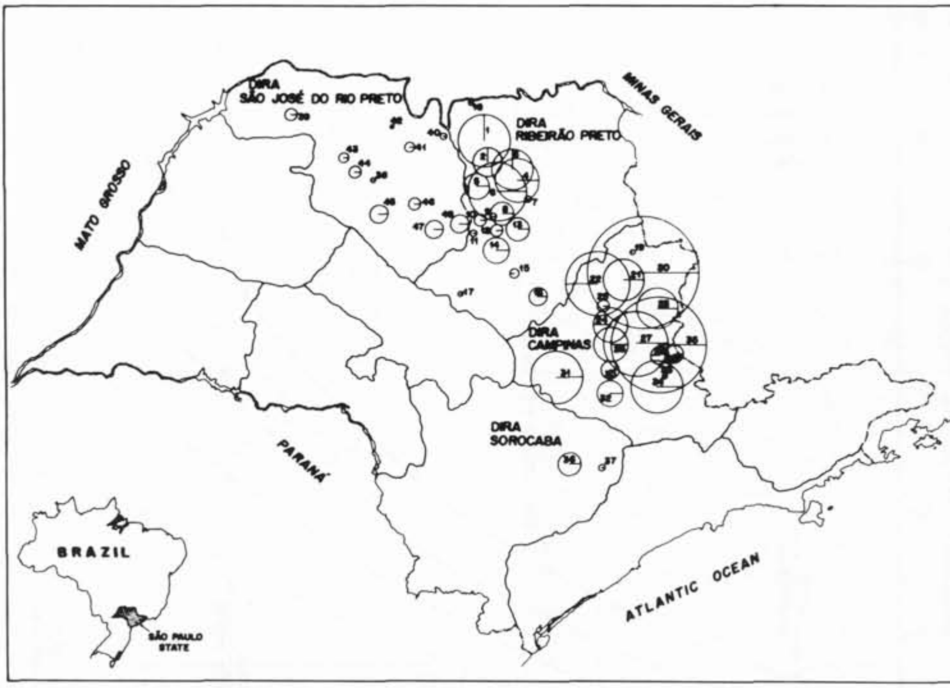

Fig. 3. Incidence of declinio in 229 selected citrus orchards in the State of São Paulo, Brazil in 1986. The numbers refer to the municipalities listed in Table 1.

pinas, are the only exception to that observation.

The following scale of values for incidence of declinio in citrus groves grown on Latossol soils, in decreasing order, was observed in the State of São Paulo: 1. Dark-Red Latosol sandy phase - LEa; 2. Ortho-Red Yellow Lastosol - LV; 3. "Roxo" Latosol - LR; 4. Ortho Dark-Red Latosol - LE; 5. Red-Yellow Latosol sandy phase - LVa.

These results agree with the reports of Rhoads (6) and Cohen (2). Rhoads (6) observed that blight was severe on soils with low WHC and on soils with poor drainage. Cohen (2) observed that areas with high organic soil remained relatively free of blight.

The data obtained from these exhaustive series of surveys to determine the amount and rate of increase of declinio affected trees in citrus orchards of State of São Paulo, Brazil, allows these conclusions. The declinio incidence was not a linear function of the time but instead an exponential function. Using the method of Yokomi *et al.* (8) applied to observations in State of São Paulo, it would take 21.2 yr for the declinio incidence to pass

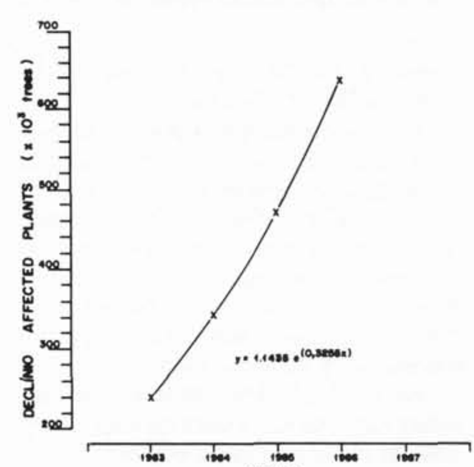

Fig. 4. Relation of the declinio incidence in 129 groves of Pera sweet orange grown in Latosol soils in the State of São Paulo, Brazil; LE = Ortho Dark Latosol soil; Lea = Dark-Red Latosol sandy phase soil; LR = Latosol "Roxo"; LV = Ortho Red-Yellow Latosol soil; Lva = Yellow-Red Latosol sand phase soil.

TABLE 1
NUMBER OF TREES AFFECTED BY DECLINIO IN 229 COMMERCIAL CITRUS GROVES IN 1986 IN STATE OF SÃO PAULO, BRAZIL

Country/ Municipality	No. of diseased trees	Country/ Municipality	No. of diseased trees
Ribeirão Preto		**Campinas**	
1.[z] Barretos	54,000	26. Araras	7,000
2. Colina	21,000	27. Conchal	31,000
3. Terra Roxa	31,000	28. Itapira	3,000
4. Viradouro	35,000	29. Mogi-Mirim	3,000
5. Monte Azul	18,000	30. Limeira	2,000
6. Bebedouro	74,000	31. São Pedro	18,000
7. Pitangueiras	3,000	32. Sta. Barbara do Oeste	5,000
8. Taiúva	11,000	33. Sto. Antônio da Posse	5,000
9. Taiaçú	3,000	34. Jaguariúna	17,000
10. Vista Alegre do Alto	18,000	35. Mogi Guaçú	60,000
11. Fernando Prestes	2,000		
12. Monte Alto	5,000	**Sorocaba**	
13. Jaboticabal	10,000	36. Capela do Alto	4,000
14. Taquaritinga	14,000	37. Sorocaba	250
15. Matão	4,000		
16. Araraquara	7,000	**São José do Rio Preto**	
17. Ibitinga	600	38. Mirassol	600
18. Colombia	600	39. Estrela do Oeste	1,500
		40. Guaraci	318
Campinas		41. Onda Verde	1,000
19. Tambaú	300	42. Palestina	300
20. Casa Branca	89,000	43. Sebastianópilis	1,000
21. Sta. Cruz Palmeiras	9,000	44. Poloni	1,500
22. Porto Ferreira	25,000	45. Mendonça	4,000
23. Aguai	9,000	46. Ibirá	1,000
24. Leme	8,000	47. Itajobi	2,000
25. Pirassununga	4,000	48. Santa Adélia	2,000

[z] Numbers refer to locations on map in Figure 3.

from 0.1% to 100%. The rate of incidence of the declinio incidence was directly proportional to the tree population. The most affected grove in 1986 was in the municipality of Viradouro with an incidence of 33.7%. The most affected agricultural region was Ribeirão Preto, the largest citrus area of the country, with an incidence of 5.7%. The texture of the Latosol soils affected the rate of increase of declinio. Latosol soils with higher CEC and WHC had lower rates of declinio increase.

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