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RELATIONSHIP BETWEEN DEVELOPMENT OF CITRUS CANKER AND ROOTSTOCK CULTIVAR FOR YOUNG 'VALENCIA' ORANGE TREES IN MISIONES, ARGENTINA

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Abstract. **In 1980, citrus canker caused by *Xanthomonas campestris* pv. *citri* (Hasse) Dow. (Xcc) (type A) appeared in a rootstock trial of 'Valencia' sweet orange (*Citrus sinensis* (L.) Osb.) on 20 different rootstock varieties established in 1979 in Misiones, Argentina. The development of the disease was followed by grouping the rootstocks into 3 vigor categories (vigorous, intermediate, non-vigorous) based on canopy size in 1985, and determining the rate of increase in canker incidence for each group from 1980 to 1985. The rate of disease spread on 'Valencia' was higher for the vigorous and intermediate groups of rootstocks than for the non-vigorous group. Likewise, the rate of increase in disease severity from Jan. 1984 to Jan. 1985 was greater for rootstocks in the vigorous or intermediate category, such as rough lemon and Carrizo citrange, than for non-vigorous cultivars like trifoliate orange. By 1985, the incidence and severity of canker was linearly correlated with canopy volume for the 20 rootstocks. Furthermore, there was a strong linear correlation (r = 0.93) between disease incidence and severity. Increased susceptibility of young 'Valencia' trees on vigorous rootstocks to citrus canker may be due to the greater occurrence of susceptible leaf flushes during the long, warm, and wet growing season in northeastern Argentina.**

Differential susceptibility of scion cultivars to citrus canker caused by *Xanthomonas campestris* pv. *citri* (Xcc) is well documented (1, 4). In Argentina, Danos et al. (2) found that rate of disease spread was greater for the more susceptible Navel orange than for resistant mandarin types. Furthermore, they reported that rootstock may affect disease development on the same scion. Infection rate of 'Valencia' sweet orange trees was higher for trees on rough lemon rootstock than for trees on trifoliate orange rootstock. Since only young leaf tissue and fruit are susceptible to canker infection (1, 6, 7), Danos et al. (2) judged that rootstock may indirectly affect spread of canker because scion varieties on rough lemon rootstock had longer and more frequent growth flushes (i.e., were more vigorous) than trees on trifoliate orange rootstock.

The Asiatic strain of Xcc (type A) has been present in Misiones, Argentina since 1972 (2). In 1980, canker appeared in a rootstock trial of 'Valencia' sweet orange on 20 different rootstock cultivars established in 1979 near Montecarlo, Misiones. In this study, we report on the influence of rootstock cultivars on the incidence and severity of canker on 'Valencia' orange during the 5-yr period subsequent to the detection of canker.

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Materials and Methods

The study was conducted in a rootstock trial at the INTA Experimental Field Station near Montecarlo, Misiones, Argentina. The trial was established in 1979 with greenhouse-grown trees of nucellar 'Valencia' sweet orange (*Citrus sinensis*) on each of the 20 different rootstocks listed in Table 1. The trees were free of visual canker symptoms when planted in the field. The rootstock treatments were arranged in a randomized complete block design with 4 replicate blocks of 4 trees per block for each rootstock. Trees were spaced 7 m × 6 m within the 80 block experiment.

The trial was established on previously forested land but an orchard infested with canker was located within 100 m of the site. Disinfestation of personnel and machinery to prevent introduction of Xcc was not practiced.

Canker was first observed in the trial in 1980. Subsequently, the incidence of canker, i.e., the number of trees on each rootstock with visual symptoms of canker, was recorded each Jan. from 1981 to 1985. In Jan. and June 1984, and Jan. 1985, the severity of canker in each 4-tree block was rated visually on the following scale: 0 = no symptoms, 1 = isolated leaf lesions, 2 = lesions restricted to one side of the canopy, 3 = lesions distributed over the entire canopy, and 4 = greater occurrence of leaf lesions than in 3. In Jan. 1985, the volume of the tree canopy in m^3 was determined from the measurement of the height and width of the canopy using the formula $v = \frac{2}{3}\pi r^2 h$.

Table 1. Citrus rootstock cultivars for 'Valencia' sweet orange and the incidence of citrus declinamiento (CD) on them in Jan 1985.

Citrus species	Cultivars	CD incidence[z] (%)
Poncirus trifoliata (L.) Raf.	Pomeroy	69
Trifoliate orange	Beneke	56
	Local	50
	Barnes	44
	Rubidoux	19
P. trifoliata × *C. sinensis* (L.) Osb.	Troyer	31
Citrange	C-35	19
	Carrizo	6
	Yuma	0
P. trifoliata × *C. paradisi* Macf.	Sacaton citrumelo	0
C. sinensis	Common	0
Sweet orange	Koethen	0
C. jambhiri Lush	Common	0
Routh lemon	Red	0
C. limonia Osb.	Rangpur lime	0
C. reticulata Blanco	Cleopatra mandarin	0
C. reticulata × *C. paradisi*	Orlando tangelo	0
C. volkameriana Pasq.	Volkamer lemon	0
C. amblicarpa Ochse		0
C. taiwanica Tan. y Shim		0

[z]Percentage of 16 trees with decline symptoms.

Table 2. Canopy volume and the incidence and severity of citrus canker for 'Valencia' orange on 20 rootstock cultivars in Jan 1985.

Cultivar	Canopy volume (m^3)	Incidence (y)[z]	Disease severity (0-4)[y]
Vigorous			
Volkamer lemon	9.50	0.81	2.07
Cleopatra mandarin	8.44	0.63	1.37
Orlando tangelo	8.35	0.94	2.78
Rough lemon	8.00	0.94	2.90
Rangpur lime	7.98	0.50	1.15
Common sweet orange	7.12	0.56	1.13
Intermediate			
Red rough lemon	6.40	0.81	2.21
C. amblicarpa	6.28	0.75	1.62
C-35	6.05	0.75	1.15
Rubidoux trifoliate	5.84	0.56	0.90
Carrizo citrange	5.72	0.56	1.27
C. taiwanica	5.72	0.75	1.85
Troyer citrange	5.46	0.44	1.12
Koethen sweet orange	4.41	0.69	1.12
Non-vigorous			
Pomeroy trifoliate	3.05	0.13	0.12
Local trifoliate	2.88	0.25	0.49
Barnes trifoliate	2.76	0.44	0.56
Beneke trifoliate	2.64	0.13	0.12
Yuma citrange	1.47	0.31	0.37
Sacaton citrumelo	1.15	0.19	0.18

[z] Proportion of 16 trees with canker symptoms.
[y] Mean of 5 canker ratings (1 rating per 4 tree block) where 0 = no disease and 4 = severe (see text).

The canker incidence curves were linearized using the logistic transformation (8). Thus, the disease proportion (y) was transformed by logit (y) = ln ($y/(1-y)$). The slope of linear regression lines was an estimate of the rate of increase in canker incidence (K_i). Furthermore, the rate of increase in disease severity (K_s) and the relationships between disease severity or incidence and canopy size were determined by linear regression analysis.

Results

In Table 2, the rootstock varieties are listed in order of decreasing canopy volume. The different rootstocks are arbitrarily divided into 3 groups based on canopy size and referred to as vigorous (canopy volume 7 to 10 m^3), intermediate (4 to 6 m^3), and non-vigorous (1 to 3 m^3). The relative vigor imparted to 'Valencia' orange by the different rootstock groups is similar to that reported elsewhere (3, 9), i.e., Volkamer lemon, rough lemon, Rangpur lime, and Cleopatra mandarin were the most vigorous, citranges were of intermediate vigor, and cultivars of trifoliate orange were the least vigorous. By 1985, all trifoliate orange and 3 of the 4 citrange cultivars were affected by citrus declinamiento (CD) (Table 1) which resulted in cessation of stem growth and leaf flushing, and stunting of the canopy (Table 2). The incidence of CD was greatest on trifoliate orange cultivars (Table 1), which to some extent accounted for their low canopy volume as a group (Table 2). The citranges were affected by CD to varying degrees (Table 1). This may have altered their ranking within the intermediate canopy size group (Table 2). Overall, the general categorization of these rootstocks was probably not affected but CD reduced their relative vigor. Yuma citrange and Sacaton citrumelo trees were apparently less vigorous because of stunting by a severe strain of citrus tristeza virus.

Since the previous study (2) indicated a relationship between scion vigor and canker spread, the rate of increase in disease incidence (K_i) was determined for each vigor group rather than for individual rootstocks to increase the power of the regression analyses. When this was done the rate of disease spread on 'Valencia' was significantly higher for the vigorous (K_i = 1.17) and intermediate (K_i = 1.00) rootstocks than for the non-vigorous cultivars (K_i = 0.64) (Fig. 1).

Likewise, when the increase in severity of canker for the year from Jan. 1984 to 1985 was determined for each canopy group, the rate (K_s) was significantly greater for the vigorous (K_s = 0.52) and intermediate (K_s = 0.48) groups than for the non-vigorous group (K_s = 0.12) (Fig. 2).

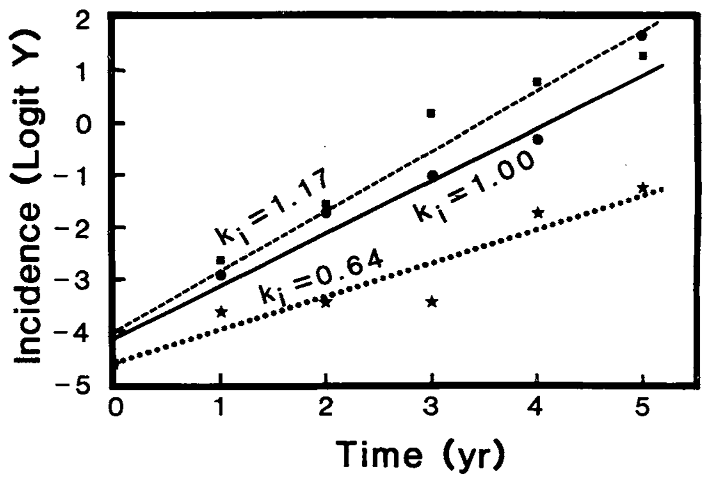

Fig. 1. Increase in incidence of citrus canker for 3 groups of rootstocks which impart different degrees of vigor to 'Valencia' sweet orange. Points represent the mean of rootstocks in each group: vigorous ■----■, intermediate●——●, and nonvigorous *. . . . . .* (see Table 2). The slope of the linear regression line of transformed disease proportions (y) is the rate of disease spread (k_i), which is significantly different at the 1% level between the vigorous or intermediate group and the non-vigorous group according to Student's t-test.

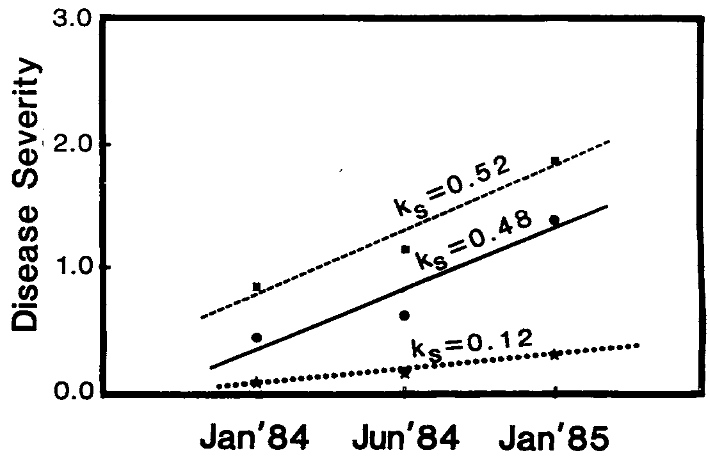

Fig. 2. Increase in severity of citrus canker for 3 groups of rootstocks which impart different degrees of vigor to 'Valencia' sweet orange. Points represent the mean of rootstocks in each group: vigorous ■----■, intermediate●——●, and nonvigorous *. . . . . .* (see Table 2). The slope of the linear regression is the rate of increase in disease severity, which is significantly different at the 1% level between the vigorous or intermediate group and the non-vigorous group according to Student's t-test.

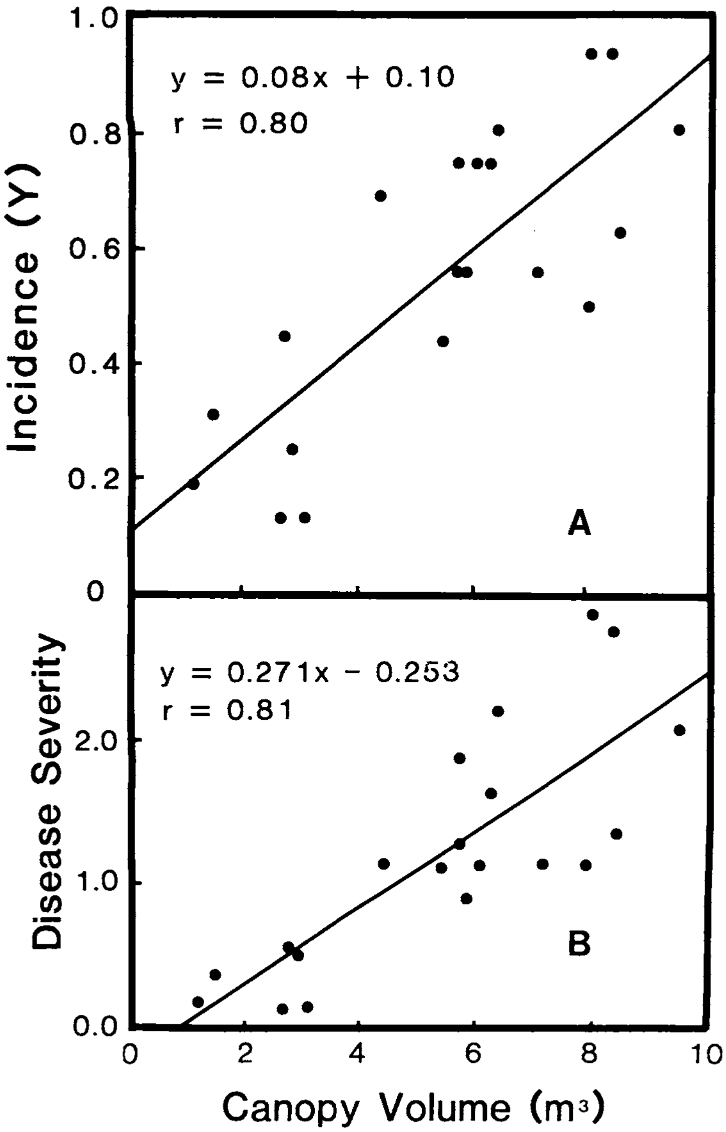

Fig. 3. Relationship between canopy size of 'Valencia' sweet orange on 20 different rootstocks and (A) disease incidence of citrus canker (proportion of 16 trees with canker symptoms) and (B) disease severity (0 = no disease, 4 = severe; see text) in Jan. 1985. Correlation coefficients are significant at the 1% level.

By 1985, when the vigor and disease susceptibility of individual rootstocks was considered (Table 2), there were significant linear correlations between canopy volume and disease incidence (Fig 3A) and disease severity (Fig. 3B). Furthermore, a strong correlation between disease incidence and disease severity was found (Fig. 4).

Discussion

As previously suggested (2), rootstock can indirectly affect spread and severity of canker on a given scion variety under the same cultural conditions. In this study, rootstocks that produced the largest canopies, such as rough lemon, Cleopatra mandarin and Orlando tangelo, had the greatest incidence and severity of canker. The slower spread of canker on the trifoliate/citrange rootstock trees may have been due in part to the incidence of CD, which reduced their relative vigor.

The monthly rates of disease spread on the rootstocks of highest and intermediate vigor (0.10 and 0.08) are in

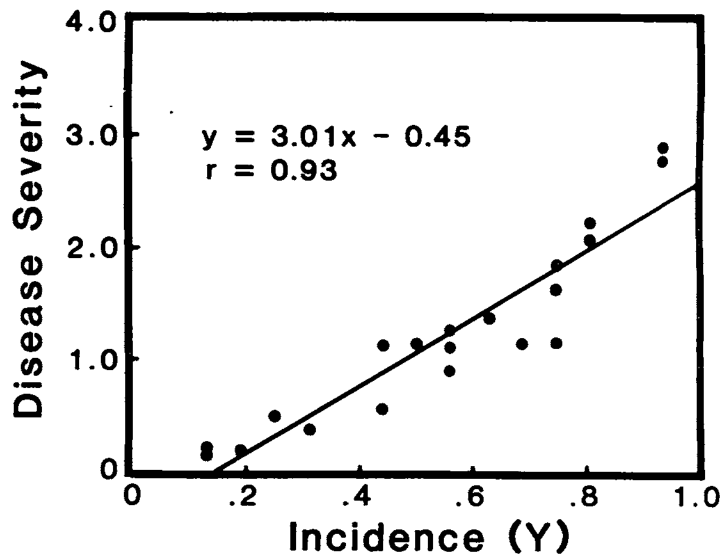

Fig. 4. Relationship between disease incidence and severity of citrus canker for 'Valencia' sweet orange on 20 different rootstocks (see Fig. 3). Correlation coefficient is significant at the 1% level.

close agreement with that reported by Danos et al. (2) for 'Valencia' on rough lemon (0.12) and the rate for the non-vigorous group (0.05) is comparable to findings of the same workers for trifoliate rootstock (0.04). Their observations were made for trees located in the nearby province of Entre Rios where minimal eradication and sanitation were practiced at the time.

Rootstocks which impart vigor are those with a greater frequency, size and duration of leaf flushes, and thus are most susceptible to infection and spread of Xcc within the tree canopy (1, 6, 7). In northern Argentina, average maximum temperatures exceeding 30 C accompanied by rainfall of 100 mm per month or more may occur for up to 5 months of the year (5). Thus, leaf flushes occur when weather conditions are ideal for infection and spread of Xcc (1, 7). In support of this, both the incidence and severity of canker as influenced by rootstock were highly correlated with canopy size.

Danos et al. (2) followed spread of canker by measuring disease incidence, a much easier method for determination of disease development than assessing the severity of the disease on individual trees or groups of trees. In our study, there was a strong correlation between incidence and severity, suggesting that disease development could be usefully and more simply followed by determining disease incidence.

Knowledge of the severity and spread of canker as influenced by stock/scion interactions may have a bearing on choice of rootstocks where canker is endemic. In Florida, 'Valencia' sweet orange on rough lemon rootstock is a widely occurring combination. If canker should become established in Florida, more rapid spread of Xcc and greater disease severity resulting in yield losses might be anticipated on rough lemon than on a less vigorous rootstock like Carrizo citrange.

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CONTROL OF MEXICAN LIME BACTERIOSIS WITH COPPER-BASED PRODUCTS

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Abstract. **Mexican lime bacteriosis (MLB), a suspected form of citrus canker, was detected in Colima, Mexico in 1981 on twigs and leaves of Mexican lime (*Citrus aurantifolia* (Christm.) Swingle) trees. The disease is now known to affect more than 20,000 hectares in 5 Mexican states. This study was done to determine the effect of number and rate of copper sprays on the incidence of MLB, and also to compare the effect of different copper-based fungicides on the incidence of MLB. Eight experiments were done between December 1983 and April 1985. Studied variables were: percent leaves infected (PIL), number of lesions per total leaves (L/TL), and number of lesions per infected leaf (L/IL). Percent leaves fallen (PFL) was included in some of the experiments. Results indicated that two to four copper oxychloride (CuOCl) or tribasic-copper sulfate sprays decreased PIL 30-86% in comparison to untreated controls. Similar results were found with L/TL and L/IL variables. Infection levels decreased as both dosages and spray number increased. Better MLB control on developing shoots was achieved by spraying 2.5 g CuOCl/liter 2 or 3 times, than by spraying the total dosage (5.0 or 7.5 g/liter, respectively) in a single application. Other experiments showed zinc/maneb and CuOCl/maneb to give better disease control, as compared to CuOCl, basic copper sulfate, or terramycin-copper sulfate. Symptoms of MLB were apparent on leaves of new shoots that were 5 to at least 30-days-old.**

In 1981, symptoms resembling those of citrus bacterial canker disease (CBCD) caused by *Xanthomonas campestris* pv. *citri* ((Hasse) Dow.) were seen on Mexican lime (*Citrus aurantifolia*) trees in the state of Colima, Mexico (2). Due to the unknown nature of the disease and the causal agent, the disease was called 'Mexican lime bacteriosis' (MLB); and internal and external quarantines were placed on movement of citrus from Colima. A chemical spray program using copper oxychloride (CuOCl), based on an Argentine program to control CBCD (6, 7), was initiated to control MLB (3, 10). As in Argentina (7), eradication of the disease was not considered feasible. MLB causes foliar and twig lesions, but no symptoms have been observed on fruit (2, 4). Bacteria identified as *Xanthomonas campestris* have been isolated from MLB lesions and found to be pathogenic on Mexican lime leaves (4, 5). Also, MLB symptoms have been observed on other citrus varieties growing near infected Mexican lime trees in Colima (8; Stapleton and Perez-Serrato, unpublished observations). The objective of this study was to determine the effect of numbers and rates of copper sprays on the incidence of MLB, and also to compare the effect of several copper- and non-copper disease control chemicals.

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Materials and Methods

Copper spray application for protection of vegetative flushes. Applications of CuOCl WP at 2.5 g Cu + 1.5 ml adherent/liter water were made every 5 days, beginning at shoot emergence, to protect tender vegetative growth flushes. The spray schedule was patterned after the experiments of Stall et al. in Argentina (6,7) to control CBCD (Table 1). The experiments were done in two Mexican lime groves ('Microondas' and 'Ibanez') with MLB. Two identical experiments were subsequently done in 'Ibanez' and 'El Llano' groves, except that tribasic-copper sulfate was applied, rather than CuOCl, at the latter site.

All groves contained 4-yr-old trees grafted on *C. macrophylla* Wester rootstocks. Treatments at each site were replicated four times in 4 × 4 tree configurations. The inner four trees were the experimental unit, being surrounded by 12 border trees. Treatments were randomized at each site. Eight vegetative shoot initials per tree were tagged at the beginning of a vegetative flush. Sprays, when applied, were done at 5-day intervals, beginning 5 days after shoot tagging. Two weeks after the final application (20 days after shoot-tagging), two leaves from each of the 8 shoots/tree were randomly sampled and the following parameters were assayed: percentage of infected leaves