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Control of Citrus Canker with Agrochemicals

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ABSTRACT

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Out of 15 agrochemicals examined for controlling citrus canker caused by *Xanthomonas campestris* pv. *citri*, Cuprosan 311 SD 72.5% WP, Antracol 70% WP, Maneb 80% WP, Atakin 68.8% WP and Kocide 606 37.5% WP at the recommended doses inhibited the *in vitro* growth, without yielding resistant mutation, of all the 72 strains of *X. campestris* pv. *citri* isolated from the cankerous leaves, twigs and fruits of various citrus species, cultivars and hybrids throughout the island of Taiwan. Sprays of Cuprosan 311 SD 72.5% WP diluted 500-fold with water at 3-week intervals, beginning from the fruitlet stage in early May, reduced the canker infection on leaves and fruits of Liucheng sweet orange and grapefruit trees, from which 1.92 times more fruits were harvested than those of the control. An additional spray of Cuprosan 311 SD 72.5% WP on the next day after a heavy rain or typhoon attained better control of the canker on grapefruit trees, which yielded 1.74 times more fruits than those of the control. Antracol 70% WP, Maneb 80% WP, Atakin 68.8% WP and Kocide 606 37.5% WP failed to reduce the canker infection on Liucheng sweet orange and grapefruit. Thus, sprays of Cuprosan 311 SD 72.5% WP diluted 500-fold with water at 3-week intervals with an additional spray on the next day after a heavy rain or typhoon, beginning from the fruitlet stage in early May, may be recommended as one of the effective means for control of citrus canker in Taiwan.

Key words: *Xanthomonas campestris* pv. *citri*, citrus canker, control, Cuprosan 311 SD.

INTRODUCTION

Canker caused by *Xanthomonas campestris* pv. *citri* has widely occurred throughout the island of Taiwan on grapefruit, Liucheng sweet orange and lemon, as well as on some other citrus species, cultivars and hybrids grown experimentally. Grapefruit trees mainly cultivated in Hsinchu, Chiayi, Hualien and Taitung have been severely infected with canker. In November 1986 and 1987, all the grapefruit trees grown at Chihsan Farm, Land Bank of Taiwan, Chihsan, Taitung were infected with canker, and 31% and 45% of the fruits were infected, respectively. Liucheng sweet orange trees cultivated throughout the island have also been heavily infected with canker. In November 1986, all of the Liucheng sweet orange trees grown at a farm owned by T. C. Tzeng at Tungshang, Tainan were heavily infected with this disease, and 24% of the fruits were infected. Lemon trees mainly cultivated in Kaohsiung and Pingtung have also been widely infected with canker, although no survey has been conducted (14,16, 18).

Sprays of 4-4 Bordeaux mixture, Metrox 56% WP, Hikacide 50% WP, Sankel 65% WP or Kasuran 81.3% WP, along with planting of canker-free citrus seedlings and wind breaks, as well as eradication of infected citrus leaves, twigs and fruits, have been officially recommended since 1975 (12). They, however, have not effectively protected the commercially cultivated grapefruit, Liucheng and lemon each year as shown by the severe damages due to canker disease (14,16,18). Many reasons for this situation may exist; of these, the application of inadequate agrochemicals may be one of the main factors. This study, therefore, was conducted to answer this question by testing sensitivity of the *X. campestris* pv. *citri* strains isolated from the cankerous tissues of various citrus species, cultivars and hybrids throughout the island of Taiwan against the agrochemicals recommended officially or from the agrochemical companies and then evaluating the selected agrochemicals which were capable of inhibiting the *in vitro* growth, without yielding resistant mutation, of all the *X. campestris* pv. *citri* strains for their efficacies in the field. Part of the results has already been presented in abstract (15) and review (14,16) forms.

TABLE 1. Sensitivity to agrochemicals of the 72 strains of *Xanthomonas campestris* pv. *citri* isolated from various citrus species, cultivars and hybrides[1] at various localities in Taiwan from 1977–1979

Agrochemical	Dose (-fold dilution)	No. of sensitive strains	No. of the sensitive strains yielding resistant mutation	Frequency
Cuprosan 311 SD 72.5% WP	500	72		
Antracol 70% WP	500	72		
Maneb 80% WP	400	72		
Atakin 68.8% WP	700	72		
Kocide 606 37.5% WP	800	72		
Tetracycline 30% WP	400	72	7	10^{-8}
Streptomycin 12.5% WP sol'n	1000	72	7	10^{-8}
Mancozeb 80% WP	500	72	3	10^{-8}
Kasuran 81.3% WP	1000	72	6	10^{-8}
Yonepon 40% WP	500	72	47	$10^{-8}-10^{-6}$
Quinolate 40% WP	1500	72	11	$10^{-8}-10^{-7}$
Benomyl 50% WP	3000	24	12	$10^{-8}-10^{-6}$
Sankel 65% WP	400	5	5	$10^{-8}-10^{-6}$
Hinodan 35% WP	1000	0		
Topsin-M 70% WP	1000	0		

1. They included grapefruit, sweet oranges, lemon, rough lemon, trifoliate orange, Ponkan, Tankan, sour orange, sunki, oblate sunki, lime, rangpur lime, mandarins, pomelos, fingered citron, citrange and tangelo.

TABLE 2. Comparisions of agrochemical sprays for controlling canker on Liucheng sweet orange at Tungshang, Tainan, Taiwan in 1985

Treatment	Dose (-fold dilution)	Infection (%)[1] on leaf	Infection (%)[1] on fruit	Canker lesions[1] per leaf	Canker lesions[1] per fruit
Survey on August 30					
Cuprosan 311 SD 72.5% WP	500	2.39 b	10.24 b	0.04 a	0.21 a
Antracol 70% WP	500	4.68 b	12.91 b	0.21 b	0.57 b
Maneb 80% WP	400	2.82 b	21.76 b	0.06 b	0.71 b
Control		3.43 b	8.81 b	0.07 b	0.43 b
Survey on October 6					
Cuprosan 311 SD 72.5% WP	500	0.77 b	2.46 a	0.01 b	0.04 a
Antracol 70% WP	500	1.01 b	4.46 b	0.02 b	0.06 b
Maneb 80% WP	400	1.17 b	5.84 b	0.03 b	0.11 b
Control		1.16 b	5.44 b	0.02 b	0.09 b

1. Means of 10 replicate trees. Figures followed by different letters denote a significant effect at the $t = 0.05$ from that treatment according to the Student's t test.

Evaluation of Cuprosan 311 SD, Atakin and Kocide 606 in the orchard

Cuprosan 311 SD 72.5% WP, Atakin 68.8% WP and Kocide 606 37.5% WP were then tested in a grapefruit orchard at Chihsan Farm, Land Bank of Taiwan, Chihsan, Taitung in 1986 and 1987, respectively. On August 6, 1986 at the middle-growing stage of fruits, Cuprosan 311 SD 72.5% WP significantly suppressed the canker infection on fruits of grapefruit, whereas Atakin 68.8% WP failed to do so. On November 1986, at the harvest, Cuprosan 311 SD 72.5% WP and Atakin 68.8% WP were not significantly effective in controlling canker on fruits of the grapefruit; however, those sprayed with Cuprosan 311 SD 72.5% WP yielded approximately 27 kg fruits per tree in average, 1.92 times more than those of the control (Table 3). In the 1987 trial, in addition to the regular sprays, a spray of Cuprosan 311 SD 72.5% WP and Kocide 606 37.5% WP, respectively, was applied on the next day after a heavy rain or typhoon; in total, 2 addtional sprays were applied. As shown in both surveys made on July 31 and November 21 (Table 4), Cuprosan 311 SD 72.5% WP, but

TABLE 3. Comparisions of agrochemical sprays for controlling canker on grapefruit at Chihsan Farm, Land Bank of Taiwan, Chihsan, Taitung, Taiwan in 1986

Treatment	Dose (-fold dilution)	Infection (%)[1] on fruit	Canker lesions[1] per fruit	Fruits[1] harvested per tree (kg)
Survey on August 6				
Cuprosan 311 SD 72.5% WP	500	4.27 a	0.15 a	
Atakin 68.8% WP	1000	16.85 b	0.97 b	
Control		14.44 b	0.69 b	
Survey on August 30[2]				
Cuprosan 311 SD 72.5% WP	500	43.72 b	2.45 b	26.78 a
Atakin 68.8% WP	1000	49.12 b	3.12 b	15.76 b
Control		49.45 b	2.91 b	13.92 b

1. Means of 10 replicate trees. Figures followed by different letters denote a significant effect at the $t = 0.05$ from that treatment according to the Student's t test.
2. Abby typhoon invaded Hualien and Taitung, Taiwan on September 19, 1986 with strong wind (5.9 m/sec) and rainfall (134 mm); strong wind (3.6 m/sec) and high rainfall (184 mm) remained on the next day.

TABLE 4. Comparisions of agrochemical sprays for controlling canker on grapefruit at Chihsan Farm, Land Bank of Taiwan, Chihsan, Taitung, Taiwan in 1987

Treatment[1]	Dose (-fold dilution)	Infection (%)[2] on		Canker lesions[2] per		Fruits[2] harvested per tree (kg)
		leaf	fruit	leaf	fruit	
Survey on July 31						
Cuprosan 311 SD 72.5% WP	500		2.88 a		0.08 a	
Kocide 606 37.5% WP	800		9.18 b		0.59 b	
Control			13.74 b		0.43 b	
Survey on November 21						
Cuprosan 311 SD 72.5% WP	500	9.46 a	9.29 a	0.28 a	0.88 a	35.97 a
Kocide 606 37.5% WP	800	38.52 b	32.83 b	3.81 b	2.03 b	23.23 b
Control		48.79 b	31.41 b	5.04 b	2.01 b	20.71 b

1. In addition to the regular sprays, a spray of the agrochemical was applied on the next day after a heavy rain or typhoon.
2. Means of 10 replicate trees. Figures followed by different letters denote highly significant effects at the $t = 0.01$ from that treatment according to the Student's t test.

not Kocide 606 37.5% WP, significantly suppressed the canker infection on leaves and fruits of grapefruit, from which 36 kg fruits per tree in average were harvested, 1.74 times more than those of the control.

Phytotoxic effects

None of the Liucheng sweet orange and grapefruit trees showed phytotoxicity responses with Cuprosan 311 SD 72.5% WP, Antrocol 70% WP, Maneb 80% WP, Atakin 68.8% WP or Kocide 606 37.5% WP in the orchards. Application of Cuprosan 311 SD 72.5% WP even led increase in vigor of the Liucheng sweet orange and grapefruit trees.

DISCUSSION

Application of inadequate agrochemicals as demonstrated in this study is one of the main factors unable to protect grapefruit and Liucheng sweet orange from the severe damages due to canker in Taiwan. Sprays of 4-4 Bordeaux mixture have not been well accepted by the growers, because of inconvenience; Metrox 50% WP and Hikacide 50% WP have not been available in the markets; Kasuran 81.3% WP, along with Tetracyclne 30% WP, Streptomycin 12.5% solution, Maneb 80% WP, Yonepon 40% WP and Quinolate 40% WP, inhibits the *in vitro* growth, but yielding resistant mutation at the frequencies of 10^{-8}–10^{-7}, of all the 72 *X. campestris* pv. *citri* strains; Sankel 65% WP fails to inhibit the *in vitro* growth of most of the *X. campestris* pv. *citri* strains tested, and all of the bacterial strains which were inhibited also give rise to resistant mutation at the frequencies of 10^{-8}–10^{-6}. Antracol 70% WP, Maneb 80% WP, Atakin 68.8% WP and Kocide 606 37.5% WP have shown to

inhibit the *in vitro* growth, without yielding resistant mutation, of all the *X. campestris* pv. *citri* strains; they, however, fail to control the canker infection of Liucheng sweet orange and grapefruit in the orchards. Possibly useful or new agrochemicals received from chemical and citrus industries, therefore, are to be tested *in vitro* for capable of inhibiting growth, without yielding resistant mutation, of all the *X. campestris* pv. *citri* strains tested and then proceeded to evaluating their efficacies in control of citrus canker in the orchards.

Cuprosan 311 SD 72.5% WP has been reported to be effective for controls of tomato blight and false smut of datepalm trees caused by *Alternaria solani* and *Graphiola phoenicis*, respectively, in Egypt (2,3). In this study, it can effectively inhibit the *in vitro* growth, without yielding resistant mutation, of all the *X. campestris* pv. *citri* strains tested and also effectively control citrus canker. Sprays of Cuprosan 311 SD 72.5% WP diluted 500-fold with water at 3-week intervals, beginning from the fruitlet stage in early May, reduced the canker infection on leaves and fruits of Liucheng sweet orange in 1985, but not grapefruit in 1986, probably due to the establishment of new wounds and re-infection by the pathogenic bacterium after the invasion of Abby typhoon in the middle September in 1986. Additional spray of Cuprosan 311 SD 72.5% WP on the next day after a heavy rain or typhoon in the next year significantly suppressed the canker infection of grapefruit and increased the yield of fruits up to approximately 2 times more than that of the control. No phytotoxicity has been observed with this compound during the treatments. Sprays of Cuprosan 311 SD 72.5% WP, therefore, may be recommended as one of the effective means for control of citrus canker in Taiwan. Highly effective control of this disease may be achieved by incorporation of spraying Cuprosan 311 SD 72.5% WP into other existing disease management approaches (14,16).

The copper-containing agrochemicals have been applied for control of citrus canker for many years (1,5,7,8,9,10,13). Copper can be built up in soil through the accumulation of running off after spraying and the decomposition of treated leaves (11). The increase in copper in the soil alters its ecology and can lead to a decline in tree vigor and inhibit the development of beneficial mycorrhizae (4). Although resistance to Cuprosan 311 SD 72.5% WP has not been observed here with the *X. campestris* pv. *citri* strains tested, resistance to copper has been developed with other agrochemicals in another pathovar of *Xanthomonas campestris* (6). Cuprosan 311 SD 72.5% WP contains 52.5% copper oxychloride. Repeated sprays of it may also lead to a decline in tree vigor and inhibit the development of beneficial mycorrhizae and may also induce copper resistance in *X. campestris* pv. *citri*. Thus, finding alternatives to Cuprosan 311 SD 72.5% WP for controlling citrus canker are deemed necessary.

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摘　　要

吳文川、吳秀玲． 1992. **柑桔潰瘍病的藥劑防治．** 植病會刊 1:37-42. (台中市　國立中興大學植物病理學研究所)

銅鋅錳乃浦(久保丹，Cuprosan 311 SD 72.5% WP)、甲基鋅乃浦(Antracol 70% WP)、多保鏈黴素(Atakin 68.8% WP)、錳乃浦(Maneb 80% WP)及氫氧化銅(Kocide 606 37.5% WP)等藥劑，經稀釋成田間使用時的推薦濃度時，皆能完全抑制從台灣各地各種柑桔類潰瘍病罹病組織所分離的柑桔潰瘍病菌72個菌株的生長，但皆不產生抗性。於田間，使用銅鋅錳乃浦500倍稀釋液，每三星期撒佈一次可減少柳橙、葡萄柚葉部和果實上潰瘍病的感染，且能使葡萄柚產量比對照者增加約2倍。於大雨或颱風過後翌日，多一次銅鋅錳乃浦的撒佈更能顯著地抑制葡萄柚葉部和果實上潰瘍病的發生。但是，甲基鋅乃浦、多保鏈黴素、錳乃浦、氫氧化銅等藥劑的撒佈皆不能有效地抑制柳橙、葡萄柚潰瘍病的發生。因此，使用銅鋅錳乃浦500倍稀釋液，自五月初小果期開始，每三星期撒佈一次，且於大雨或颱風過後翌日多撒佈一次，可推薦作防治柑桔潰瘍病的一項措施。

關鍵字：*Xanthomonas campestris* pv. *citri*、柑桔潰瘍病、藥劑防治、銅鋅錳乃浦。