Application of Azoxystrobin for Control of Benomyl-Resistant *Guignardia citricarpa* on 'Valencia' Oranges in South Africa

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ABSTRACT

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Azoxystrobin was evaluated in replicated small-plot trials from 1995 to 1999 for control of citrus black spot (CBS) on 'Valencia' oranges caused by *Guignardia citricarpa*. Applications of different rates of tank mixes of azoxystrobin and mancozeb during the susceptible period from October to January were compared with an untreated control as well as the standard four applications of mancozeb with or without mineral oil (1.20 g a.i./liter + 0.5% [vol/vol]/liter and 1.60 g a.i./liter of water, respectively). Two applications of azoxystrobin in tank mixtures with mancozeb and mineral oil (0.5% [vol/vol]/liter) in mid-November and mid-January at rates of 0.10, 0.15, and 0.20 g a.i./liter controlled CBS by more than 98 to 99%, 99 to 100% and 95 to 98%, respectively. Concomitantly, where mineral oil was not added to the fungicide mixture, azoxystrobin and mancozeb resulted only in 73 to 95%, 74 to 93% and 92.2 to 92.3% CBS control, respectively. Tank mixtures of benomyl, mancozeb, and mineral oil reduced CBS by only 29%, which could be attributed to the presence of benomyl-resistant pathogen isolates in the experimental orchard. Azoxystrobin applied at rates of 0.05, 0.075, and 0.10 g a.i./liter in tank mixtures with mancozeb (1.2 g a.i./liter) and mineral oil (0.5% [vol/vol]/liter of water) or Agral 90 (0.5% [vol/vol]/liter of water) were equally effective, reducing CBS by more than 99%. When mineral oil was compared to different adjuvants in tank mixtures with azoxystrobin and mancozeb, only mineral oil resulted in 100% clean exportable fruit. There was no difference between Sunspray 6E and Bac oil when mixed with azoxystrobin and mancozeb on the degree of disease control. Furthermore, the concentration of mineral oil in water can be lowered from 0.5% (vol/vol)/liter of water to 0.3% (vol/vol)/liter of water without a loss in efficacy against CBS. It is therefore, recommended that azoxystrobin (0.075 g a.i./liter) must be applied in tank mixtures with mancozeb (1.2 g a.i./liter) and mineral oil, which can be applied at either 0.5% (vol/vol)/liter of water or 0.3% (vol/vol)/liter of water.

Additional keywords: *Citrus sinensis*, fungicides

Control of citrus black spot (CBS), caused by *Guignardia citricarpa* Kiely, is entirely dependent on the application of fungicidal sprays during the critical period of infection from October to January in the southern hemisphere. In South Africa, benomyl as a curative treatment was initially labeled for four applications per season (2). Thereafter, benomyl was labeled as a single application in mid-summer (December) in a tank mix with mineral oil until 1981 when mancozeb was also recommended as a follow-up treatment in January (3). It was only in 1987 that benomyl with mancozeb was labeled as a single application in mid-summer or alternatively as a split application consisting of

applications in November and January (4). The introduction of a single benomyl application in a tank mixture with mancozeb and mineral oil in 1971 came as a breakthrough as it replaced dithiocarbamates such as mancozeb that must be applied in a four-spray protective schedule (12). The latter program is tedious and growers often have difficulty keeping within the time limits due to prolonged rainy periods. Extension of intervals between sprays beyond 28 days often results in serious losses. However, since the detection of *G. citricarpa* resistance to benomyl in the Eastern Transvaal in 1981 (8), emphasis has shifted back to the use of contact fungicides for disease control. These include dithiocarbamates such as mancozeb and copper fungicides in a four-spray program (17). Copper fungicides used for CBS control can result in rind stippling and darkening of blemishes (5,6,18,20). Resistance to benomyl has increased and is now prevalent in all the important citrus producing areas in southern Africa.

Recently, strobilurin fungicides developed from a β -methoxyacrylate of the agaric *Strobilurus tenacellus*, were shown to have fungicidal activity against *G. citricarpa* (1). The strobilurin, azoxystrobin (methyl (E)-2-(2-[6-(2-cyanophenoxy) pyrimidin-4-yloxy] phenyl)-3-methoxy acrylate), a locally systemic, translaminar fungicide, has been tested in field trials against a wide range of economically important crop pathogens (9), including CBS (19,21). Azoxystrobin has protective and curative activity offering the potential for use as foliar, seed, and soil treatments with long lasting residual disease control (9-11). Azoxystrobin reportedly controls fungal pathogens resistant to the 14-demethylase inhibitors, phenylamides, dicarboximides, and benzimidazoles (9). This offered us the opportunity to test the strobilurins in vivo against a benomyl-resistant *G. citricarpa*. The effects of one, two, and four applications of azoxystrobin and another strobilurin, kresoxim-methyl, at rates of 0.10 to 40 g a.i./liter, have been evaluated for the control of CBS. A two-spray application program during November and January compared favorably with 4 applications of mancozeb (19,21). The current study was conducted to reevaluate azoxystrobin at rates lower than 0.10 g a.i./liter against a benomyl-resistant isolate of *G. citricarpa*, in tank mixtures with or without adjuvants, as well as different rates and grades of mineral oil.

MATERIALS AND METHODS

Determination of benomyl resistance. Prior to the execution of each field experiment, 80 CBS-infected fruit were collected before harvest and surface-sterilized with 2.5% sodium hypochlorite for 1 min. The tissue pieces, one from each fruit, were blotted dry on sterile paper towels, placed on potato dextrose agar (PDA) (7,22), then incubated under fluorescent light at 25°C for 7 to 14 days. Thereafter, mycelium of CBS from the latter isolates was cut into 5 × 5-mm pieces and placed on benomyl-amended PDA (5 and 10 μ g a.i. ml⁻¹, Benlate, 50% WP, Du Pont de Nemours International Societe Anonyme, Halfway House, South Africa), incubated at 25°C for 14 days and the presence or absence of benomyl-resistant and sensitive *G. citricarpa* recorded. In this study, only orchards in which benomyl-resistant *G. citricarpa* strains occurred were used.

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Experimental design. A randomized block design with 5 single-tree plots per treatment was used. Fungicides were applied with a trailer-mounted, high volume, high pressure (2,500 to 3,000 kPa) sprayer with two hand-held spray guns. Spray volumes varied according to the size and canopy density of the tree but all trees were sprayed to the point of runoff. Certain treatments commenced in mid-October as previously recommended (12–16), depending on the climatological information required for infection during the critical infection period.

1995–1996 field trial. Azoxystrobin, in tank mixtures with mancozeb with or without mineral oil, was evaluated for efficacy against CBS in a commercial ‘Valencia’ orange (*Citrus sinensis*) grove at Malelane in Mpumalanga Province in South Africa. Results of in vitro screening of *G. citricarpa* isolates prior to the execution of this trial showed that benomyl-resistant isolates were prevalent in the grove at Malelane Estates.

Trees in this grove were selected for uniformity in canopy density and tree size. Each treatment was replicated five times in single-tree plots arranged in a randomized complete block design. Guard trees were located between plots within rows. Spray programs, dates, and fungicide concentrations are listed in Table 1.

Currently, all commercial fungicide applications for CBS control in South Africa begin in mid-October, based on research findings from ascospore release and spore trap data (13–15). The fungicides tested included mancozeb (Sancozeb, 80% WP; Sanachem, Durban, South Africa), benomyl (Benlate, 50% WP; Du Pont de Nemours International Societe Anonyme), azoxystrobin (Ortiva, 25% SC; Zeneca, Gallo Manor, South Africa), and the mineral oil (Sunspray 6E, Avima, Lui-paardsvlei, South Africa).

At fruit maturity in July or August, CBS severity was rated on 100 fruits per tree according to a 3-point index that was de-

scribed previously (13): 0 = clean fruit with no CBS lesions; 1 = one to three CBS lesions per fruit; and 2 = four or more CBS lesions per fruit. Data were analyzed by analysis of variance (ANOVA) and Fisher’s Least Significant Difference (LSD) test ($P = 0.05$).

1996–1997 field trial. Different rates of azoxystrobin with or without Sunspray 6E or Agral 90 were evaluated for efficacy against CBS in commercial ‘Valencia’ orange groves at Malelane and La Rochelle Estates near Malelane, South Africa. In vitro screening of *G. citricarpa* isolates recovered from fruit within these groves prior to the field trial showed that benomyl-resistant isolates were present in both groves. Spray programs, dates, and rates of application are listed in Table 2. Materials tested included mancozeb, azoxystrobin, the mineral oil, Sunspray 6E, as well as the adjuvant Agral 90 (alkylated phenol-ethylene oxide condensate, 940 g/liter; Zeneca). The same application and evalua-

Table 1. Evaluation of azoxystrobin rates with mancozeb in tank mixtures with or without mineral oil applied from October to January during 1995 and 1996 for the control of benzimidazole-resistant *Guignardia citricarpa* on ‘Valencia’ oranges at Malelane Estates, South Africa

Treatment ^y	Concentration (g a.i./liter of water)	Percentage of fruit in each class ^x		
		Lesions/fruit		
		0	1-3	≥4
Azoxystrobin + mancozeb + Sunspray 6E	0.15 + 1.2 + 0.5% vol/vol	99.0 a	0.7 a	0.3 a
Mancozeb + Sunspray 6E ^z	1.20 + 0.5% vol/vol	98.8 a	1.2 ab	0.0 a
Azoxystrobin + mancozeb + Sunspray 6E	0.10 + 0.8 + 0.5% vol/vol	98.3 a	1.2 ab	0.5 a
Azoxystrobin + mancozeb + Sunspray 6E	0.10 + 1.2 + 0.5% vol/vol	96.7 a	1.7 ab	1.6 a
Azoxystrobin + mancozeb + Sunspray 6E	0.20 + 1.2 + 0.5% vol/vol	94.8 a	2.2 ab	3.0 a
Azoxystrobin + mancozeb	0.20 + 1.2	92.3 a	2.5 ab	5.2 a
Azoxystrobin + mancozeb	0.15 + 1.2	74.3 b	2.5 ab	23.2 b
Azoxystrobin + mancozeb	0.10 + 1.2	73.8 b	1.8 ab	24.46 c
Azoxystrobin + mancozeb	0.10 + 0.8	64.8 b	3.8 ab	31.4 bc
Mancozeb ^z	1.6	63.3 b	3.5 ab	33.2 c
Benomyl + mancozeb + Sunspray 6E	0.125 + 1.6 + 0.5% vol/vol	18.3 c	11.0 c	70.7 d
Control		24.3 c	1.8 c	71.4 d

^x Means in a column, based on five replicates, followed by the same letter are not significantly different ($P > 0.05$) according to Fisher’s least significant difference test.

^y All treatments were applied on 7 November 1995 and 3 January 1996.

^z Treatments applied at registered rates on 10 October 1995, 7 November 1995, 5 December 1995, and 3 January 1996.

Table 2. Evaluation of azoxystrobin rates in tank mixtures with Agral 90 or mineral oil applied from October to January during 1996 and 1997 for the control of citrus black spot (CBS) on ‘Valencia’ oranges at Malelane and La Rochelle Estates, Malelane, South Africa

Treatment ^y	Concentration (g a.i./liter of water)	Percentage of fruit in each class ^x					
		Malelane Estates			La Rochelle Estates		
		Lesions/fruit			Lesions/fruit		
		0	1-3	≥4	0	1-3	≥4
Azoxystrobin + mancozeb + Sunspray 6E	0.05 + 1.20 + 0.5% vol/vol	99.1 ab	0.1 b	0.6 bc	99.9 a	0.1 c	0.0 b
Azoxystrobin + mancozeb + Sunspray 6E	0.075 + 1.20 + 0.5% vol/vol	99.4 ab	0.0 b	0.3 bc	98.8 ab	0.8 bc	0.4 b
Azoxystrobin + mancozeb + Sunspray 6E	0.10 + 1.20 + 0.5% vol/vol	99.0 ab	0.0 b	1.0 bc	99.8 a	0.1 c	0.1 b
Azoxystrobin + Sunspray 6E	0.05 + 0.5% vol/vol	99.9 a	0.1 b	0.0 c	97.8 b	1.4 b	0.8 b
Azoxystrobin + Sunspray 6E	0.075 + 0.5% vol/vol	97.4 b	0.2 b	2.4 b	100 a	0.0	0.0 b
Azoxystrobin + Sunspray 6E	0.10 + 0.5% vol/vol	ND	ND	ND	99.7 ab	0.3 c	0.0 b
Azoxystrobin + Agral 90	0.05 + 0.5% vol/vol	99.9 a	0.1 b	0.0 c	99.5 ab	0.3 bc	0.2 b
Azoxystrobin + Agral 90	0.075 + 0.5% vol/vol	100 a	0.0 b	0.0 c	99.9 a	0.1 c	0.0 b
Azoxystrobin + Agral 90	0.10 + 0.5% vol/vol	99.4 ab	0.0 b	0.6 bc	99.3 ab	0.7 bc	0.0 b
Mancozeb + Sunspray 6E ^z	1.20 + 0.5% vol/vol	98.7 ab	0.4 b	0.9 bc	99.9 a	0.1 c	0.0 b
Control		6.1 c	2.3 a	9.6 a	47.9 c	14.4 a	37.7 a

^x Means in a column, based on five replicates, followed by the same letter are not significantly different ($P > 0.05$) according to Fisher’s least significant difference test. ND = not determined.

^y Treatments were applied on 12 November 1996 and 7 January 1997.

^z Treatment applied at registered rates on 15 October 1996, 12 November 1996, 10 December 1996, and 7 January 1997.

tion procedures were followed as described for the 1995/1996 experimental period.

1997–1998 field trial. Different spray adjuvants in tank mixtures with azoxystrobin and mancozeb were evaluated for efficacy against CBS in commercial ‘Valencia’ orange groves at Malelane and Disa Estates near Malelane, South Africa. In vitro screening of *G. citricarpa* isolates from fruit from the site indicated that benomyl-resistant isolates were present in this grove. Spray programs, dates, and rates of applications are listed in Table 3. The fungicides used (mancozeb and azoxystrobin) as well as the mineral oil (Sunspray 6E) and the adjuvant (Agral 90) were the same as mentioned above. Two additional adjuvants, ADD-2 (a polysaccharide hexitan ester, 600 g/liter; Zeneca, Gallo) and TF 8035 (a new experimental adjuvant from Syngenta), were included in the trial. The same application and evaluation procedures were followed as described for the 1995/1996 period.

1998–1999 field trial. Different grades and rates of mineral oil were tested in tank mixtures with azoxystrobin and mancozeb for efficacy against CBS in commercial ‘Valencia’ orange groves at Kaapmuiden

Citrus Estates near Malelane, and Brandwag Farm near Hazyview, South Africa. In vitro screening of *G. citricarpa* isolates made from fruit from the latter groves showed that benomyl-resistant isolates were present at the Kaapmuiden Citrus Estates site. Spray programs, dates, and rates of applications are listed in Table 4. The fungicides, mancozeb and azoxystrobin, as well as the mineral oil, Sunspray 6E, were the same as mentioned before. Bac Oil, a heavy mineral oil, was also included in this trial. The same application and evaluation procedures were followed as described for the 1995/1996 period.

RESULTS

Determination of benomyl resistance.

Results of in vitro fungicide sensitivity assays revealed that 92, 90 and 85% of *G. citricarpa* isolates from Malelane Estates, La Rochelle Estates, and Kaapmuiden Citrus Estates, respectively, were resistant to benomyl, whereas isolates from Disa Estates and Brandwag Farm were still sensitive to benomyl.

1995–1996 field trial. Compared to nontreated fruit, a significantly greater percentage of clean exportable fruit (P

≤ 0.05) was achieved at Malelane Estates with azoxystrobin (0.10, 0.15, and 0.20 g a.i./liter) in tank mixtures with mancozeb and Sunspray 6E, mancozeb (1.20 g a.i./liter) in a tank mixture with Sunspray 6E, mancozeb (1.6g a.i./liter) without Sunspray 6E, as well as all azoxystrobin treatments in tank mixtures with mancozeb which received no Sunspray 6E. Differences between 20 and 30% clean fruit were achieved between those trees which received mineral oil and those that did not. The benomyl (0.125 g a.i./liter) tank mixture with mancozeb and Sunspray 6E resulted in only 18.3% clean fruit. The poor control of CBS may be attributable to the presence of a population of *G. citricarpa* in this orchard that is resistant to benomyl.

Concomitantly, azoxystrobin in tank mixtures with mancozeb and Sunspray 6E resulted in less fruit with one to three as well as four or more CBS lesions. However, the standard mancozeb treatment (1.60 g a.i./liter) resulted in 33.2% fruit with four or more lesions at Malelane Estates, in comparison with the tank mixture of mancozeb (1.20 g a.i./liter) and Sunspray 6E, which resulted in no fruit with four or more CBS lesions (Table 1). This

Table 3. Evaluation of azoxystrobin in tank mixtures with mancozeb and different adjuvants applied from October to January during 1997 and 1998 for the control of benzimidazole-resistant *Guignardia citricarpa* on ‘Valencia’ oranges at Malelane and Disa Estates, Malelane, South Africa

Treatment ^y	Concentration (g a.i./liter of water)	Percentage of fruit in each class ^x					
		Malelane Estates			Disa Estates		
		Lesions/fruit			Lesions/fruit		
		0	1-3	≥4	0	1-3	≥4
Azoxystrobin + mancozeb + Sunspray 6E	0.075 + 1.20 + 0.5% vol/vol	100 a	0.0 a	0.0 a	100 a	0.0 a	0.0 a
Azoxystrobin + mancozeb + Sunspray 6E	0.05 + 1.20 + 0.5% vol/vol	99.7 a	0.3 a	0.0 a	100 a	0.0 a	0.0 a
Azoxystrobin + mancozeb + ADD-2	0.05 + 1.20 + 0.3% vol/vol	98.7 ab	1.3 ab	0.0 a	99.8 a	0.2 a	0.0 a
Azoxystrobin + mancozeb + TF 8035	0.05 + 1.20 + 0.3% vol/vol	98.3 ab	1.5 ab	0.2 a	99.8 a	0.2 a	0.0 a
Mancozeb ^z	1.20	97.2 b	2.2 b	0.6 ab	99.8 a	0.0 a	0.2 a
Azoxystrobin + mancozeb + Agral 90	0.05 + 1.20 + 0.018% vol/vol	96.5 b	2.5 b	1.0 b	99.3 a	0.5 a	0.2 a
Control		13.0 c	8.3 c	78.7 c	86.3 b	8.5 b	5.2 b

^x Means in a column, based on five replicates, followed by the same letter are not significantly different ($P > 0.05$) according to Fisher’s least significant difference test.

^y All treatments were applied on 4 November 1997 and 6 January 1998 at Malelane Estates, and on 5 November 1997 and 7 January 1998 at Disa Estates.

^z Treatment applied at registered rates on 7 October 1997, 4 November 1997, 2 December 1997, and 6 January 1998 at Malelane Estates, and 8 October 1997, 5 November 1997, 3 December 1997 and 7 January 1998 at Disa Estates.

Table 4. Evaluation of azoxystrobin in tank mixtures with mancozeb and different grades of oils applied from October to January during 1998 and 1999 for the control of benomyl-resistant *Guignardia citricarpa* on ‘Valencia’ oranges at Kaapmuiden Citrus Estates, Kaapmuiden, and a benomyl-sensitive strain at Brandwag Farm, Hazyview, South Africa

Treatment ^y	Concentration (g a.i./liter of water)	Percentage of fruit in each class ^x					
		Kaapmuiden Citrus Estates			Brandwag Farm		
		Lesions/fruit			Lesions/fruit		
		0	1-3	≥4	0	1-3	≥4
Azoxystrobin + mancozeb + Sunspray 6E	0.05 + 1.20 + 0.5% vol/vol	95.2 a	3.7 a	1.1 a	85.3 a	3.0 a	11.7 a
Azoxystrobin + mancozeb + Bac oil	0.05 + 1.20 + 0.3% vol/vol	94.3 a	3.5 a	2.2 a	84.5 a	3.5 a	12.0 a
Azoxystrobin + mancozeb + Bac oil	0.05 + 1.20 + 0.5% vol/vol	92.8 a	4.3 a	2.9 a	83.8 a	3.0 a	13.2 a
Azoxystrobin + mancozeb + Sunspray 6E	0.05 + 1.20 + 0.3% vol/vol	92.2 a	4.5 a	3.3 a	75.8 a	4.2 a	20.0 a
Mancozeb + Sunspray 6E ^z	1.20 + 0.5% vol/vol	90.2 a	6.6 a	3.2 a	ND	ND	ND
Control		21.2 b	11.0 b	67.8 b	4.3 b	2.3 a	93.4 b

^x Means in a column, based on five replicates, followed by the same letter are not significantly different ($P > 0.05$) according to Fisher’s least significant difference test. ND = Not determined.

^y Treatments were applied on 11 November 1998 and 6 January 1999 at Kaapmuiden Citrus Estates, and 12 November 1998 and 7 January 1999 at Brandwag farm.

^z Treatments applied at registered rates on 14 October 1998, 11 November 1998, 9 December 1998 and 6 January 1999 at Kaapmuiden Citrus Estates.

may be attributed to poor spray coverage or washoff of mancozeb due to heavy rains experienced during the experimental period.

1996–1997 field trial. At Malelane Estates, there were no significant differences in the percentage of clean, exportable fruit or fruit with one to three CBS lesions between any of the tank mixtures of azoxystrobin at concentrations of 0.10 g a.i./liter or lower with mineral oil (Sunspray 6E), mineral oil and mancozeb, or Agral 90, and the standard registered mancozeb treatment with mineral oil. Only azoxystrobin (0.075 g a.i./liter) in a tank mix with Agral 90 (0.5% [vol/vol]), resulted in 100% clean exportable fruit, but showed phytotoxicity.

At La Rochelle Estates, all fungicide treatments differed significantly ($P \leq 0.05$) from the untreated control with regards to all criteria used for evaluation. There was a significant difference between azoxystrobin (0.05 g a.i./liter) applied in a tank mix with mancozeb and mineral oil compared to azoxystrobin at the same rate with mineral oil but without mancozeb. However, the treatment consisting of azoxystrobin (0.075 g a.i./liter) and mineral oil resulted in the best overall control of CBS. All azoxystrobin treatments provided a high level of disease control with no significant differences among the fungicide treatments for fruit with four or more lesions (Table 2).

1997–1998 field trial. Azoxystrobin, evaluated at Malelane Estates and Disa Estates at rates of 0.05 and 0.075 g a.i./liter in tank mixtures with mancozeb and mineral oil (Sunspray 6E), differed significantly ($P \leq 0.05$) from the standard registered mancozeb treatment, the tank mixture consisting of azoxystrobin (0.05 g a.i./liter), mancozeb (1.20 g a.i./liter), Agral 90, as well as the control. On the other hand, azoxystrobin in tank mixture with mancozeb and either ADD-2 or TF 8035 was not significantly different from azoxystrobin (0.05 and 0.075 g a.i./liter) in tank mixtures with mancozeb and mineral oil or mancozeb alone, or azoxystrobin in tank mixtures with mancozeb and Agral 90. Mineral oil was the only adjuvant in tank mixtures with azoxystrobin at rates of 0.05 and 0.075 g a.i./liter water that resulted in 100% clean fruit for export (Table 3).

1998–1999 field trial. Azoxystrobin, evaluated at Kaapmuiden Citrus Estates and Brandwag Farm in tank mixtures with different grades and rates of mineral oils, did not differ from the standard registered mancozeb treatment but did from the control. The difference in CBS control between the two localities can be attributed to poor tree quality and the high level of CBS inoculum historically present in the Hazyview area (Table 4).

DISCUSSION

Fungicides continue to be essential for effective control of CBS. Dithiocarbamates,

benzimidazoles, and copper fungicides are registered for the control of CBS in South Africa (17). However, resistance to benzimidazoles has increased and is now prevalent in all major citrus producing areas in the summer rainfall regions of South Africa, therefore, the southern African citrus growers are eager to replace the latter fungicidal group with more effective fungicides.

For the time being, the emphasis has shifted back to the use of dithiocarbamates, but a four-spray program is tedious, labor-intensive, and expensive since each tree has to be sprayed with as much as 100 liters of fungicide solution each year. An urgent need exists to alleviate the pressure on growers to spray fungicides at shorter intervals. Increasing pressures are imposed on farmers with regard to low fungicide residues on exported crops as well as using fungicides that have a low toxicity to humans and wildlife, low environmental impact, low residues in food, and compatibility with integrated pest management programs.

The strobilurin, azoxystrobin, has been demonstrated to be such a fungicide. Rates of 0.075 g a.i./liter of water sprayed twice seem to be able to replace the benzimidazoles. However, this compound should be applied in a tank mixture with a contact fungicide such as mancozeb for resistance management. This study has shown that the addition of mineral oil or other additive to the tank mixture along with azoxystrobin can enhance the efficacy of the compound. Mineral oils are well known for their insecticidal properties; however, too much mineral oil may adversely affect citrus plants and reduce yield. This research demonstrated that the adjuvant Agral 90 is just as effective as mineral oil and could serve as an effective replacement especially when trees are vulnerable to damage when too much mineral oil is applied.

Strategies to contain or delay resistance development were not in place when benzimidazoles were introduced to control CBS (19). Benomyl without addition of other fungicides was initially registered for CBS control as four applications per year (2). In 1973, 99% of the citrus crop was of export quality with one application of benomyl plus mineral oil at Lisbon Estates in the Eastern Transvaal (7). Thereafter, tank mixtures of benomyl with mineral oil were used as single applications until 1981 when mancozeb was registered as a follow-up treatment in January (3). During the same year, resistance of *G. citricarpa* to benomyl was detected at Lisbon Estates (8). It was not until 1987 that mancozeb was registered as a tank mixture with benomyl (4), 14 years after the initial availability of benomyl and too late to be used in benomyl-resistant CBS situations. Since 1982, benomyl resistance has become more prevalent and is now present in citrus pro-

ducing areas such as the Lowveld, Swaziland, and Northern Natal.

Nevertheless, an increasingly proactive research stance to improve understanding of CBS resistance to benzimidazoles assisted us in facilitating more effective deployment of antiresistance strategies with strobilurins. How rotation or alternation of strobilurins one year with benzimidazoles the next year would fare in a resistance management operation can only be speculated, but these fungicides must be used in tank mixtures with a contact fungicide such as mancozeb.

This study demonstrated that an adjuvant, such as mineral oil or a spreader sticker, is essential to achieve optimal control of CBS. Mineral oils are registered in South Africa to enhance the efficacy of benzimidazoles. The reason for enhanced efficacy is unclear. In one study, the addition of mineral oil increased the penetration of benzimidazoles into the rind of citrus fruit (13). However, a recent study showed that various mineral oils did not enhance the penetration of benomyl into the rind of 'Valencia' oranges (19). We observed that the addition of mineral oil to strobilurins such as azoxystrobin tended to enhance the performance of these fungicides against CBS. Azoxystrobin is registered now for CBS control in South Africa (17).

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