Chemical Control of Mango Blossom Diseases and the Effect on Fruit Set and Yield

J. H. LONSDALE, Plant Pathologist, Merensky Technological Services, Westfalia Estate, P.O. Box 14, Duiwelskloof, 0835, South Africa; and J. M. KOTZÉ, Head of Department, Department of Microbiology and Plant Pathology, University of Pretoria, Pretoria, 0002, South Africa

ABSTRACT

Lonsdale, J. H., and Kotzé, J. M. 1993. Chemical control of mango blossom diseases and the effect on fruit set and yield. Plant Dis. 77:558-562.

Blossom sprays with iprodione, chinomethionat, prochloraz manganese chloride, triadimenol, copper oxychloride, mancozeb, flusilazol, calcium polysulfide, and pyrazophos, applied fortnightly, were evaluated over two seasons (1989–1991) for the control of powdery mildew (*Oidium mangiferae*), blight (*Nattrassia mangiferae*), and blossom spot (*Alternaria alternata* and *Colletotrichum gloeosporioides*) of mango (*Mangifera indica*). Blossom sprays with the systemic fungicides flusilazol or pyrazophos resulted in significantly better disease control and consistently higher fruit set and yield than nontreated controls.

Mango (*Mangifera indica* L.) blossom diseases result in poor fruit set and reduced yields (5,9,21,23–26). In South Africa there are four main diseases which attack mango during bloom: powdery mildew, caused by *Oidium mangiferae* Berthet (25); blossom malformation, caused by *Fusarium subglutinans* (Wollenweb. & Reinking) P.E. Nelson, T.A. Toussoun, & Marasas (30); blossom spot, caused by *Alternaria alternata* (Fr.:Fr.) Keissl. (3) and *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. in Penz. (5); and blossom blight, caused by *Nattrassia mangiferae* (H. & P. Syd.) Sutton & Dyko (19) (formerly *Hendersonia creberrima* Syd. & Butl. [2]).

Regular applications of fungicides during bloom are necessary to ensure effective control of mango blossom diseases. Many fungicide treatments applied during bloom have been screened against these diseases, but there has been a tendency to concentrate on one disease at a time (4,6–8,12,13,20,21,23–25,31). In practice, however, two or more diseases may occur in the same locality at the same time. It is therefore better to adopt a holistic approach.

The purpose of this study was to evaluate various fungicidal spray treatments for the simultaneous control of powdery mildew, blight, and blossom spot. Blossom malformation was excluded from this study because fungicides have proven to give relatively poor control of the disease (8,14,18,31).

Accepted for publication 16 December 1992.

MATERIALS AND METHODS

Nine fungicides, six of which are registered for use on mango in South Africa, were used in this study: iprodione (Rovral, 25% EC), chinomethionat (Morestan, 25% WP), prochloraz manganese chloride (Octave, 50% WP), triadimenol (Bayfidan, 25% EC), copper oxychloride (Demildex, 85% WP), mancozeb (Dithane M-45, 80% WP), flusilazol (Nustar, 40% EC), calcium polysulfide (lime sulfur, 32% solution), and pyrazophos (Afugan, 29.5% EC).

The experiments were initiated in the 1989–90 season. Two sites were chosen, one at Lisbon Estates with 6-yr-old mango trees, cultivar Irwin; the other in the Deer Park area with 12-yr-old trees of the same cultivar. Flood irrigation was used at the Lisbon site and no irrigation at Deer Park. Treatments and dosage rates are given in Tables 1 and 2. A randomized complete block design (single tree plots) with four replicates per treatment was used at each locality.

Treatments commenced at 20% flower. Two follow-up sprays were applied at fortnightly intervals, one at 60% flower and the other at 100% flower. All spraying was done with a high-volume applicator with hand guns. A pressure of 2,000 kPa was used, and trees were sprayed till run-off, approximately 20 L of spray mix per tree.

A follow-up experiment was conducted in the 1990–91 season at Constantia on 10-yr-old Tommy Atkins trees, and in the Letsitele Valley on 10-yr-old Keitt trees. Flood irrigation was used at the Constantia trial site and microirrigation at Letsitele.

Treatments and dosage rates are given in Tables 3 and 4. A randomized block design consisting of five replicates (double-tree plots) per treatment was used. Spraying commenced at 20% flower, and two follow-up sprays were applied as in the previous year.

Panicles were evaluated for the incidence of blossom diseases at 100% petal drop, and again when the fruit were marble size. Panicles were rated on a 0–4 scale for the incidence of powdery mildew, blight, and blossom spot, where 0 = panicle free of disease, 1 = 1–25% infected, 2 = 26–50% infected, 3 = 51–75% infected, and 4 = more than 75% infected.

Results are expressed in terms of infection index (32) and as the percentage of disease-free panicles. Average number of fruit per tree was determined 1 mo before harvest by counting the total number of fruit that had set on each tree. Average yield per tree was also determined for cultivars Keitt and Tommy Atkins by weighing the fruit from each tree after picking.

RESULTS

Disease incidence for 1989–90. Because of the similarity in the results between the first and second disease assessments, only results from the second assessment are presented (Tables 1 and 2). Disease incidence was high at both sites (0% disease-free panicles at Lisbon and 5% at Deer Park in nontreated controls). Powdery mildew was the major disease present, with the nontreated controls having an infection index of 99.2

at Lisbon and 78.5 at Deer Park. All fungicide treatments controlled powdery mildew ($P = 0.05$).

The high incidence of mildew in the nontreated controls made the rating of blight and blossom spot difficult. As a result, the incidence of blight and blossom spot was observed to be lower for nontreated controls than for many of the fungicide treatments, making the interpretation of these results difficult.

All fungicide treatments resulted in a significant increase in the percentage of disease-free panicles. Where irrigation was used (Lisbon Estates) the best treatments were iprodione, prochloraz manganese chloride, triadimenol, flusilazol, and the tank mix of copper oxychloride + mancozeb + chinomethionat. These treatments resulted in between 65 and 91% disease-free panicles (Table 1).

Under dryland conditions (Deer Park), all treatments performed poorly except flusilazol, which resulted in more than 60% of the panicles free of disease (Table 2). Chinomethionat was the least effective treatment at both sites.

Disease incidence for 1990-91. Powdery mildew incidence was generally lower for the 1990-91 season than for the previous season (Tables 3 and 4). All treatments controlled powdery mildew. Disease pressure on Tommy Atkins at the Constantia site was higher (infection index = 60.47) than on Keitt at the Letsitele Valley site (infection index = 38.6). Under these conditions, flusilazol alone or in combination with mancozeb, triadimenol, prochloraz manganese chloride, and calcium polysulfide performed significantly ($P = 0.05$) better than pyrazophos, iprodione, and chinomethionat, alone or in combination with copper oxychloride.

The incidence of blight was lowest with flusilazol, and of blossom spot was lowest with iprodione (Tables 3 and 4). The tank mix of flusilazol + mancozeb was significantly ($P = 0.05$) more effective against blossom spot than flusilazol alone in Keitt at the Letsitele Valley site (Table 3).

Flusilazol, flusilazol + mancozeb, triadimenol, and prochloraz gave above 60% disease-free panicles at both sites, the best overall treatment being flusilazol + mancozeb (Tables 3 and 4).

Fruit set for 1989-90. At the dryland site in Deer Park, the flusilazol treatment resulted in significantly ($P = 0.05$) higher fruit set than did the nontreated control (Fig. 1A), a 416% increase. No significant differences in fruit set between the treatments and the nontreated controls were obtained at the irrigated Lisbon site (Fig. 1B).

Fruit set for 1990-91. Flusilazol, alone and in combination with mancozeb, and pyrazophos alone resulted in a significant ($P = 0.05$) increase in fruit set above the nontreated controls at the site in Letsitele. Flusilazol and pyrazophos resulted

Table 1. The effect of fungicide treatments on the incidence of blossom diseases of mango, cultivar Irwin, at Lisbon Estates for the 1989–90 season

Treatments	Rate (g a.i./100 L)	Infection index[y] Powdery mildew	Infection index[y] Blight	Infection index[y] Blossom spot	Disease free panicles (%)
Iprodione	50	6.65 bc[z]	6.98 bc	0.0 c	68 b
Chinomethionat	6.25	8.31 bc	11.97 ab	0.33 bc	42 d
Prochloraz manganese chloride	12.5	0.33 c	3.66 c	0.0 c	89 a
Triadimenol	5	0.33 c	2.33 c	0.0 c	91 a
Flusilazol	2	0.0 c	12.96 ab	0.0 c	69 b
Copper oxychloride	255	1.33 c	17.6 a	1.0 ab	55 bc
Copper oxychloride + mancozeb	170+ 120	13.97 b	12.6 ab	0.33 bc	49 cd
Copper oxychloride + mancozeb + chinomethionat	170+ 120+ 6.25	3.99 c	8.31 bc	1.33 a	65 bc
Control	...	99.24 a	7.65 bc	0.0 c	0 e

[y] Infection index = (sum of individual ratings)/(number of panicles assessed) × 100/(max. disease class) (32).

[z] Values followed by the same letter in the same column are not significantly different according to Duncan's multiple range test ($P = 0.05$).

Table 2. The effect of fungicide treatments on the incidence of blossom diseases of mango, cultivar Irwin, at Deer Park (Tzaneen) for the 1989–90 season

Treatments	Rate (g a.i./100 L)	Infection index[y] Powdery mildew	Infection index[y] Blight	Infection index[y] Blossom spot	Disease free panicles (%)
Iprodione	50	13.63 bc[z]	29.62 abc	0.67 b	40.0 abc
Chinomethionat	6.25	7.65 c	49.6 a	9.31 ab	14 c
Prochloraz manganese chloride	12.5	9.31 c	38.9 ab	2.0 ab	28 bc
Triadimenol	5	4.99 c	38.9 ab	11.97 a	32 bc
Flusilazol	2	7.98 c	11.64 cd	1.0 b	63 a
Copper oxychloride	255	29.26 b	18.83 bcd	2.99 ab	32 bc
Copper oxychloride + mancozeb	170+ 120	20.53 bc	31.59 ab	6.32 ab	14 c
Copper oxychloride + mancozeb + chinomethionat	170+ 120+ 6.25	8.31 c	41.90 a	9.3 ab	31 bc
Control	...	78.50 a	1.66 d	0.0 b	5 d

[y] Infection index = (sum of individual ratings)/(number of panicles assessed) × 100/(max. disease class) (32).

[z] Values followed by the same letter in the same column are not significantly different according to Duncan's multiple range test ($P = 0.05$).

Table 3. The effect of fungicide treatments on the incidence of blossom diseases of mango, cultivar Keitt, in the Letsitele Valley for the 1990–91 season

Treatments	Rate (g a.i./100 L)	Infection index[y] Powdery mildew	Infection index[y] Blight	Infection index[y] Blossom spot	Disease free panicles (%)
Flusilazol	2	0.26 b[z]	1.83 c	5.60 cd	69.84 bc
Iprodione	50	1.23 b	2.53 bc	0.49 e	86.26 a
Chinomethionat	6.25	0.63 b	6.44 a	11.01 b	50.76 d
Calcium polysulfide	320	0.13 b	7.15 a	8.90 bc	53.64 d
Triadimenol	5	0.0 b	2.25 bc	6.34 cd	74.22 abc
Prochloraz manganese chloride	12.5	0.0 b	2.85 bc	1.5 e	83.28 ab
Pyrazophos	11.5	0.38 b	4.11 abc	8.38 bc	60.00 cd
Flusilazol + mancozeb	2+ 160	0.25 b	2.26 bc	1.54 e	87.28 a
Chinomethionat + copper oxychloride	6.25+ 255	0.48 b	4.05 abc	3.69 de	70.94 bc
Control	...	38.6 a	5.09 ab	15.48 a	7.0 e

[y] Infection index = (sum of individual ratings)/(number of panicles assessed) × 100/(max. disease class) (32).

[z] Values followed by the same letter in the same column are not significantly different according to Duncan's multiple range test ($P = 0.05$).

in the greatest increase in fruit set, a 61 and 65% increase, respectively, above the nontreated controls (Fig. 2A). The latter two treatments also increased fruit set at the site in Constantia (44 and 45% increase, respectively) above the nontreated controls (Fig. 2B).

Yield results for 1990-91. At the site in Letsitele, the flusilazol and pyrazophos treatments resulted in significant yield increases representing a 78 and 82% increase above the nontreated control (Fig. 2C).

At the site in Constantia (Fig. 2D), pyrazophos was the only treatment that gave a significant yield increase (39% above the nontreated control).

Table 4. The effect of fungicide treatments on the incidence of blossom diseases of mango, cultivar Tommy Atkins, at Constantia for the 1990-91 season

Treatments	Rate (g a.i./100 L)	Infection index[y] Powdery mildew	Infection index[y] Blight	Infection index[y] Blossom spot	Disease free panicles (%)
Flusilazol	2	0.84 d[z]	4.81 c	2.27 cd	72.68 a
Iprodione	50	6.4 bc	8.43 bc	0.0 d	51.40 bc
Chinomethionat	6.25	9.7 b	10.26 b	3.8 cd	35.28 d
Calcium polysulfide	320	0.24 d	8.25 bc	8.07 b	53.10 bc
Triadimenol	5	0.0 d	6.72 bc	3.12 cd	63.24 ab
Prochloraz manganese chloride	12.5	0.36 d	7.03 bc	0.12 d	71.68 a
Pyrazophos	11.5	4.91 c	9.86 b	5.29 bc	41.58 cd
Flusilazol + mancozeb	2+ 160	0.02 d	6.43 bc	0.13 d	74.38 a
Chinomethionat + copper oxychloride	6.25+ 255	8.67 bc	8.99 bc	2.09 cd	44.3 cd
Control	...	60.47 a	26.79 a	18.25 a	0.0 e

[y] Infection index = (sum of individual ratings)/(number of panicles assessed) × 100/(max. disease class) (32).

[z] Values followed by the same letter in the same column are not significantly different according to Duncan's multiple range test ($P = 0.05$).

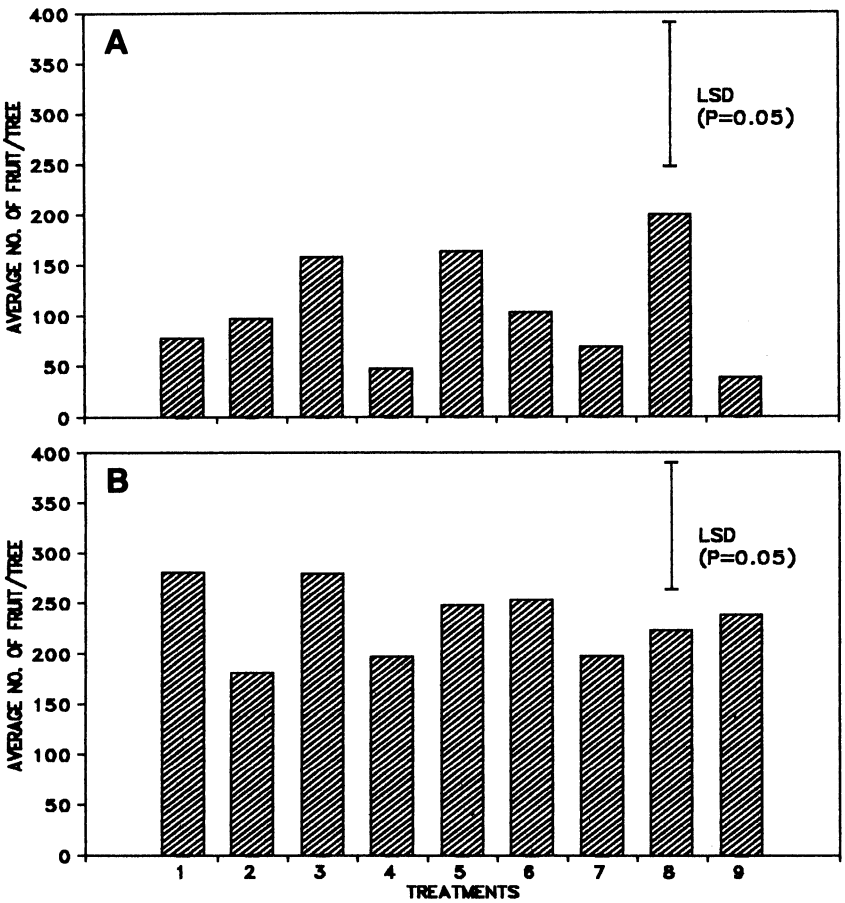

Fig. 1. The effect of various fungicide treatments on fruit set of mangoes, cultivar Irwin, on **(A)** dry land and **(B)** irrigated land. Treatments are represented by numbers: 1, iprodione; 2, chinomethionat; 3, prochloraz manganese chloride; 4, triadimenol; 5, chinomethionat + copper oxychloride + mancozeb; 6, copper oxychloride; 7, copper oxychloride + mancozeb; 8, flusilazol; and 9, control (nontreated).

DISCUSSION

In this study, all fungicide treatments controlled powdery mildew significantly on cultivars Irwin, Keitt, and Tommy Atkins. Flusilazol was the most effective treatment against blossom blight, and iprodione was the most effective against blossom spot. The tank mix of flusilazol + mancozeb gave better control of blossom spot than flusilazol alone.

In accordance with previous reports, mango blossom diseases resulted in poor fruit set and reduced yields (5,9,21, 23-26). The flusilazol and pyrazophos treatments gave the highest fruit set and yield overall. Although these fungicides provided good control of the mango blossom disease complex, many other fungicide treatments resulted in equal or better control. However, these other treatments did not result in equal or higher sets or yields, suggesting an inherent ability of flusilazol and pyrazophos to increase fruit set and yield in ways other than blossom disease control.

Flusilazol belongs to the triazole group of fungicides, and pyrazophos is an organophosphate pyrimidine (28); both therefore possess sterol-inhibiting properties (17). Sterol-inhibiting fungicides inhibit ergosterol biosynthesis in fungi and also interfere with the isoprenoid pathway in plants, thus shifting the balance of important plant hormones, including gibberellins, abscisic acid, and cytokinins (10). Hence, they have both fungicidal and plant-growth regulating properties. Certain sterol-inhibiting fungicides such as flusilazol and triadimenol are known to reduce the rate of transpiration in crops such as wheat, peas, and soybeans (11), and apple (1). One possible effect of reduced transpiration could be more efficient water use, and therefore higher yields, in plants growing under moisture stress conditions (1). It is unlikely, however, that the high fruit set and yield response observed in these trials with flusilazol and pyrazophos was due to protection from moisture stress during the flowering period; because one would have expected similar fruit set and yield increases with prochloraz, iprodione, and triadimenol, which are also sterol-inhibitors (17).

A more likely explanation for the consistently high set and yields obtained with the flusilazol and pyrazophos treatments may lie in the possible nontarget effects of these fungicides on other mango diseases and pests. Flusilazol applied as a postharvest treatment to mangoes has been shown to be highly effective in the control of soft brown rot (22), caused by *Hendersonia creberrima* (2), recently renamed *Nattrassia mangiferae* (27). The symptoms are virtually identical to those caused by *Dothiorella dominicana*

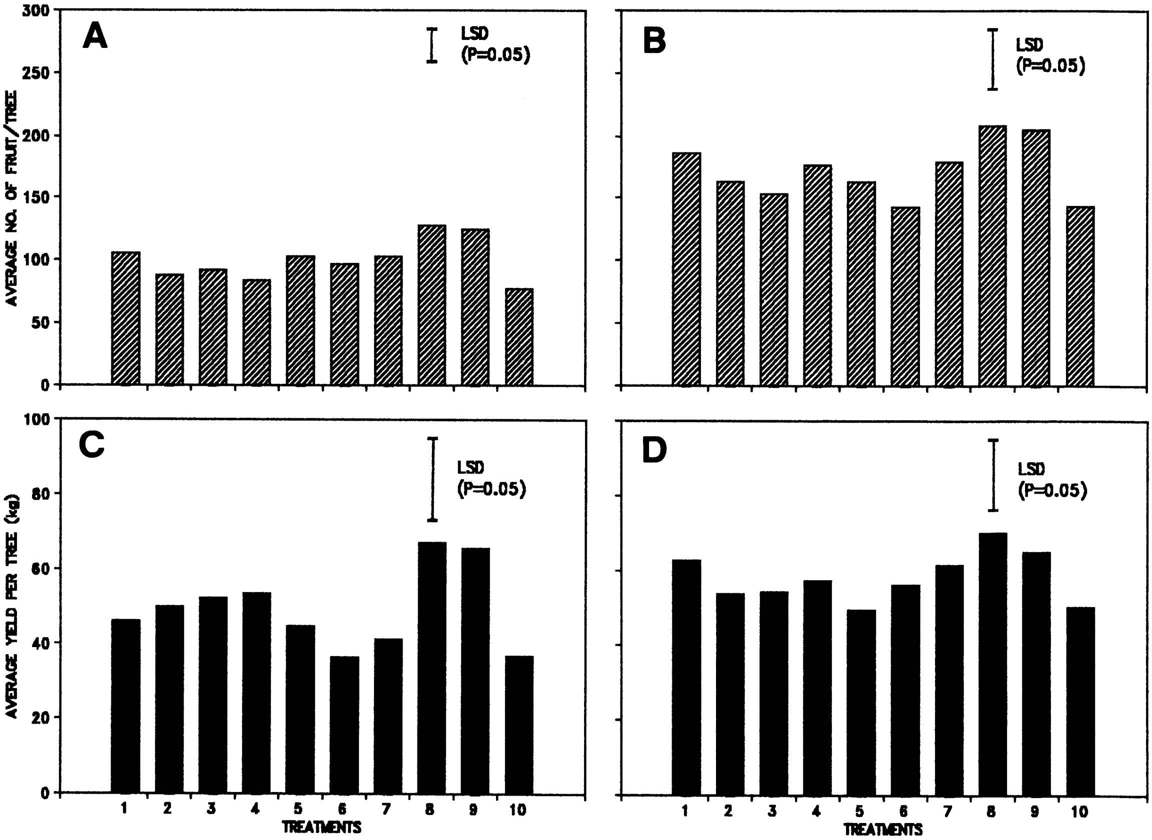

Fig. 2. The effect of various fungicide treatments on **(A)** fruit set of cultivar Keitt, **(B)** fruit set of cultivar Tommy Atkins, **(C)** yield of Keitt, and **(D)** yield of Tommy Atkins. Treatments are represented by numbers: 1, flusilazol + mancozeb; 2, iprodione; 3, chinomethionat; 4, calcium polysulfide; 5, triadimenol; 6, prochloraz manganese chloride; 7, chinomethionat + copper oxychloride; 8, pyrazophos; 9, flusilazol; and 10, control (nontreated).

Petrak et Cif. and *Lasiodiplodia theobromae* (Pat.) Griffon & Maubl.(16). It is possible that soft brown rot develops from endophytic colonization of mango peduncle tissue by *N. mangiferae* and that *N. mangiferae* is associated with premature fruit drop in South Africa, as is the case for *D. dominicana* and *D. mangiferae* (syn. *N. mangiferae*) (27), associated with stem end rot of mangoes in Australia (15). If so, applications of flusilazol during flower, particularly those towards the end of flower, may inhibit the colonization of *N. mangiferae* in peduncle tissue and thereby prevent fruit drop. The organophosphate content of pyrazophos may help to control certain pests such as the coconut bug (*Pseudotheraptus wayi* (Brown)), which also causes fruit drop in mango (29), thereby increasing fruit set and yield. While no work on the nontarget effects of pyrazophos and flusilazol has been conducted on mango, our results indicate that such effects may exist. It has been speculated that mango blossom blight develops because of systemic infection by *N. mangiferae* (19); further studies are warranted to establish the systemic nature of this pathogen and its involvement in fruit drop on mango in South Africa.

A fungicide formulation known as Punch C, SC, containing flusilazol (250 g/L) and carbendazim (125 g/L), has recently been registered for the control of mango blossom diseases in South Africa. However, iprodione, calcium polysulfide, and prochloraz manganese chloride are not yet registered in South Africa and may not be used commercially for the control of mango blossom diseases.

ACKNOWLEDGMENTS

We thank Lisbon Estates and H. van Dyk, G. van Veijeren, and J. van den Berg for allowing us to use their orchards to conduct these experiments. We also thank the South African Mango Grower's Association for the financial support that made this work possible.

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