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Evaluation of chlorothalonil and paraffinic oil alone and in combinations with registered fungicides for the control of yellow Sigatoka (*Mycosphaerella musicola*) of bananas in Northern Queensland, Australia

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ABSTRACT

The efficacy of chlorothalonil and paraffinic oil alone and in combinations with the registered fungicides propiconazole, tebuconazole, difenoconazole, epoxiconazole and pyrimethanil was evaluated in a field experiment over two cropping cycles in 2013 and 2014 in Northern Queensland, Australia, for control of yellow Sigatoka (caused by *Mycosphaerella musicola*) of banana. The predominantly applied by the banana industry treatment mancozeb with paraffinic oil was included for comparison. The results from the two cropping cycles suggested that all chemicals used with paraffinic oil were as effective or more effective than when applied with chlorothalonil, and chlorothalonil alone. Difenoconazole and epoxiconazole with paraffinic oil followed by propiconazole with paraffinic oil were the most effective treatments. Pyrimethanil and tebuconazole plus chlorothalonil were the least effective treatments. None of the chemical treatments was phytotoxic or reduced yield.

1. Introduction

Yellow Sigatoka (*Mycosphaerella musicola* Leach.) is considered the most serious foliar disease for the Northern Queensland banana industry, which depends exclusively on the highly susceptible banana cultivars in the Cavendish subgroup [Musa (AAA; Cavendish subgroup)] (Jones, 2000). Foliar necrotic lesions and reduced photosynthesis caused by yellow Sigatoka result in a reduction in bunch size, fruit number per bunch, and premature ripening in the field and post-harvest (Abadie et al., 2008; Chillet et al., 2009; Daniells et al., 1987; Marín et al., 2003). Control is largely dependent on fungicide applications supported by cultural practices (such as the removal of diseased leaves). Removing infected leaves helps reduce inoculum levels but does not provide satisfactory control and therefore chemical control is also required.

Currently, chemical control of yellow Sigatoka is achieved using spray programs consisting of protectant fungicides such as mancozeb, chlorothalonil, and pyrimethanil, and the systemic fungicides propiconazole, tebuconazole, epoxiconazole and difenoconazole (Marín et al., 2003; Vawdrey et al., 2005). It is also recommended that a petroleum-derived spray oil be used with all of these chemicals except chlorothalonil which is incompatible with paraffinic oil (Beattie et al., 2002). Oil has been shown to delay initial fungal infection and development as well as enhancing the performance of fungicides (Vawdrey et al., 2004, 2005). However, mineral oil formulations with unsulfonated residues of less than 92% are known to photodegrade to form phytotoxic products (Ploetz, 2000), which has raised a concern that the accumulation of oil might cause phytotoxicity and subsequent reduction in fruit yield (Israeli et al., 1993). Even though the possibility of photodegradation has been significantly reduced with the current highly refined oils (e.g. Biopest oil® with unsulfonated residues of not less than 98%), the large number of oil sprays needed to control leaf spot may result in flecking and eventual bronzing of older leaves (Beattie et al., 2002).

A recent survey of growers in North Queensland confirmed that there has been an increased use of chlorothalonil as a replacement for mancozeb and oil and interest in combining chlorothalonil with systemic fungicides to control yellow Sigatoka (Samuelian, 2014). This change has been largely due to the rising cost of paraffinic oil,

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anecdotal perception regarding the effectiveness of oil-based programs compared to chlorothalonil and chlorothalonil-based programs, and concerns that oil-based spray programs reduce yield. The aim of this study was to compare the efficacy of chlorothalonil and a paraffinic oil alone and in combinations with propiconazole, tebuconazole, epoxiconazole, difenoconazole, and pyrimethanil in controlling yellow Sigatoka in a field experiment over two cropping cycles. The phytotoxicity of the chemical treatments and possible effect of these treatments on yield, as time of bunching, average number of fruit, number of hands, and total bunch weight, and leaf number were also assessed.

2. Materials and methods

2.1. Site description and experimental design

The experiment was conducted at the Centre for Wet Tropics Agriculture (CWTA), South Johnstone, near the town of Innisfail (17°30′S, 146°00′E) (climatic data for South Johnstone: mean temperature 23.7 °C, 3337.3 mm year^{-1} rainfall, 136 days of rain ≥1 mm; soil: reddish brown light clay (Heiner and Smith, 1987); 17.3 m elevation). The experimental site was designed as a randomised complete block with four replications on bananas Musa (AAA, Cavendish subgroup) cv. 'Williams' irrigated by mini-sprinklers. The fertiliser program for each experiment consisted of applications of potassium nitrate (19.3% N, 0% P and 28.4% K) every 2 weeks at the rate of 35.7 kg/ha and urea (15.7 kg/ha) through the mini-sprinkler irrigation system. Datum plots contained a single row of 5 plants with 2 non-datum 'guard' plants separating each plot. Datum rows were separated by single 'guard' rows of unsprayed plants, which were deleafed every 4–6 weeks. Treatments commenced when plants had four to five fully expanded leaves with no visible Sigatoka lesions observed at this stage.

2.2. Treatment application

Eight chemicals were used in this study (Table 1). The systemic fungicides and pyrimethanil were mixed either with chlorothalonil or with paraffinic oil and these treatments were compared to mancozeb plus paraffinic oil, chlorothalonil alone, and paraffinic oil alone. Chemicals were delivered with a modified Jen-ell orchard sprayer (Silvan Pumps & Sprayers (Aust.) Pty. Ltd.) with spray volume calibrated by spraying 10 plants and adjusted to 250–285 L/ha. Chemicals were applied every two weeks during the wetter months (February–June), and every three weeks during the drier months from middle of June until December. For the first trial chemical sprays commenced on 30 January 2013 and a total of 10 treatment applications were made before disease assessment, which was conducted when 90% of the trees had bunched. The second trial commenced on 26 March 2014 and a total of 12 treatments were applied before disease assessment. Chemical applications continued until bunch measurements (average number of fruit, number of hands, and total bunch weight) were completed.

2.3. Disease assessment

Disease severity ratings were assessed on five fruiting plants using the rating scale of Stover (1971) when 90% of the trees had bunched. Rating grades were 0, leaves with no visible disease symptoms; 1, leaves with <1% of the leaf area covered with disease symptoms (10 spots per leaf); 2, 1–5% of leaf area were spotted; 3, 6–15%; 4, 16–33%; 5, 34–50%; and 6, >50% of leaf area spotted. An average leaf spot rating (ALR) was calculated for each plant as the sum of the disease severity ratings for each leaf divided by the number of leaves. A disease severity index (DSI) = [(Sum nb)/(N−1) × T], was calculated, where n = number of leaves in each grade, b = grade, N = number of grades used (total of 7), and T = total number of leaves graded on each plant. The DSI takes into account the location of yellow Sigatoka lesions on the plant, which is important when assessing the overall disease intensity (Stover and Dickson, 1970).

The total number of leaves per plant was also assessed.

2.4. Determining date of bunching, number of hands, fruit (finger) numbers/bunch, and bunch weight

Date of bunching was recorded at the 'first week of bunch emergence or week 1' when the bunch could be seen in a vertical position emerging from the top of the plant. Following established industry practices (Daniells, 1984) bunches were trimmed by removing hermaphrodite type flowers and the lower one or two hands, with two fingers left on the bottom hand. The male bud was broken from the stalk and the bunch bagged within one month of bunch emergence. Number of hands, fruit (finger) numbers on bunches were determined soon after bunching according to Turner et al. (1988) by counting the number of fruit on the third hand from the proximal (top) end (f_3) and the second hand from the distal (bottom) end (f_{n-1}) of the bunch. Total number of fruit was calculated as $(F_b) = n\,(f_3 + f_{n-1})/2$, where n was the total number of hands on the bunch. Any hand with less than 6 fingers was not taken into account.

Three to five bunches/plot were harvested from the second spray trial when two fingers in the middle of the outside whorl of the third hand from the proximal end of the bunch was ≥34.5 mm in diameter. Bunch weight was measured with a 300 kg hanging digital scale (Wedderburn).

2.5. Data analyses

All statistical analyses were performed with the GenStat 14th Edition software package (VSN International, 2011). Analysis of

Table 1
Formulation, rate of application and origin of the fungicides used in this study.

Common name	Formulation[a]	Application rate (ai/ha)	Product name	Supplier
Chlorothalonil	500 g/L, s.c.	1300 g	Elect 500	Nufarm
Paraffinic oil	–l.	5 L	Biopest oil®	Sacoa
Mancozeb	750 g/L, w.p.	1650 g	Penncozeb 750 DF	Nufarm
Propiconazole	500 g/L, e.c.	100 g	Throttle	Nufarm
Tebuconazole	430 g/L, s.c.	99 g	Folicur 430 SC	Bayer
Difenoconazole	250 g/L, e.c.	100 g	Digger	Nufarm
Epoxiconazole	125 g/L, s.c.	360 g	Soprano	FarmOz
Pyrimethanil	600 g/L, s.c.	396 g	Siganex	Bayer

[a] Type of formulation: e.c. – emulsifiable concentrate; l. – liquid; s.c. – suspension concentrate; w.p. – wettable powder.