BICARBONATE SALTS AND CALCIUM CYANAMIDE SUPPRESS APOTHECIAL PRODUCTION BY *CIBORINIA CAMELLIAE*

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ABSTRACT

Apothecia of *Ciborinia camelliae* arise from soil-borne sclerotia that are often located at the base of camellia bushes and release ascospores that infect camellia flowers. To suppress the production of apothecia as a strategy to control camellia flower blight, granule formulations of potassium bicarbonate (Armicarb 100SR) at 300 kg/ha, ammonium bicarbonate (Armicarb 300) at 300 kg/ha and calcium cyanamide at 500 and 1000 kg/ha were applied to soil beneath camellia bushes. After 16 days, potassium bicarbonate, ammonium bicarbonate and calcium cyanamide, at both rates, reduced the numbers of apothecia from 32.1/m^2 in untreated plots to 4.6, 3.0, 0.8 and 0.3/m^2, respectively. This level of control continued for the duration of apothecial production. Calcium cyanamide at 500-1000 kg/ha and the bicarbonate salts at 300 kg/ha offer potential for cultural control of camellia flower blight. The optimum rate for bicarbonate salts to achieve complete suppression of apothecia still needs to be determined.

Keywords: camellia blight, *Ciborinia camelliae,* apothecia, calcium cyanamide, ammonium bicarbonate.

INTRODUCTION

The fungus *Ciborinia camelliae* Kohn causes camellia flower blight, which results in premature browning and drop of flowers. The disease has been found in most regions throughout New Zealand, except south of Christchurch (Taylor & Long 2000). Controlling ascospore infection of flowers with frequent applications of fungicides has provided limited success (Taylor & Long 2000). Removal and burning of fallen camellia flowers, which may harbour developing sclerotia, is effective but labour intensive. Repeated application of fungicides to soil under camellia bushes during spring is reported to suppress apothecial production from over-wintering sclerotia (Fullerton et al. 1998), but camellia growers have not adopted the strategy.

Since many growers of camellias have expressed reluctance to rely on fungicides, this study investigated the potential of soil-applied nitrogen-based compounds to suppress apothecial production in spring. The nitrogenous fertiliser, calcium cyanamide, has been shown to inhibit *C. camelliae* apothecial production by 82-98% when applied to soil at 224-896 kg/ha (Haasis & Nelson 1953). When applied as soil amendments, urea and ammonium bicarbonate completely inhibited sclerotial germination of *Sclerotium rolfsii* (Tu et al. 1991). In another study, ammonium sulphate, ammonium nitrate and ammonium chloride also inhibited germination, while sodium nitrite, potassium nitrite, urea and calcium cyanamide killed sclerotia of *S. rolfsii* (Fang et al. 1988).

In this study, calcium cyanamide, potassium bicarbonate and ammonium bicarbonate were applied to soil under camellia bushes and evaluated for their ability to inhibit apothecial production by sclerotia of *C. camelliae* under field conditions.

METHODS

On 3 September 2001, at the onset of the main apothecial production period, a bare area of ground 10x10 m, which was surrounded by camellia bushes naturally infested with *C. camelliae* in the camellia gardens of the Wellington Botanic Gardens, was prepared for the trial. The few existing apothecia, from the current season's germinating soil-borne sclerotia, were removed by hand hoeing. Surface debris of twigs and senescent flowers, which may have hidden emerging apothecia, were raked off. The treatments comprised an untreated control, potassium bicarbonate ($KHCO_3$) (Armicarb 100SR) and ammonium bicarbonate (NH_4HCO_3) (Armicarb 300) granules (Church & Dwight Co., New Jersey, USA) at 300 kg/ha, and calcium cyanamide ($CaCN_2$) powder (Aldrich Chemical Company, Milwaukee, USA) at 500 and 1000 kg/ha. The test products were broadcast by hand onto the soil in pre-marked plots, 0.6 x 0.6 m. The treatments were replicated nine times in a randomised block design. They were arranged in five treatment rows of six blocks in one group, and five treatment rows of three blocks in an adjacent group, to accommodate the space available between camellia bushes.

The apothecia that developed within the central area (0.5 x 0.5 m) of each plot were counted on 19 September and 10 and 19 October 2001, 16, 37 and 46 days after treatment application. At the first two assessments, the apothecia were removed from the plots after being counted, to prevent them being recounted in subsequent assessments. For the duration of the trial, the soil temperatures between 0-30 mm depth in two sites at opposite edges of the trial were measured at 3-hourly intervals with two Tinytag probes (Gemini Data loggers UK, West Sussex, England).

Data on density of apothecia were analysed using GenStat 2000 Release 4.22 by analysis of variance using a $\log_e$+0.5 transformation to stabilise the error variance and allow analysis of zero data. Treatment means were compared at P=0.05.

RESULTS

At trial completion (19 October 2004), the total density of apothecia in the untreated plots averaged 43 apothecia/m^2, with most apothecia produced by 19 September, 16 days after treatment. The $KHCO_3$ and NH_4HCO_3, and $CaCN_2$ at 500 and 1000 kg/ha, suppressed apothecial production by 76, 88, 98 and 99%, respectively (Table 1).

TABLE 1: The number of apothecia/m^2 emerged at 16, 37 and 46 days after treatment of soil containing *C. camelliae* sclerotia with three fertilisers.

Treatment	Application rate (kg/ha)	16 days	37 days	46 days	Total[2]
Untreated		32.1 (3.48)[1]	6.7 (1.98)	1.2 (0.54)	43.3 (3.78)
$KHCO_3$	300	4.6 (1.63)	3.0 (1.27)	0.0 (-0.69)	10.3 (2.38)
NH_4HCO_3	300	3.0 (1.24)	1.9 (0.86)	1.3 (0.58)	5.4 (1.78)
$CaCN_2$	500	0.8 (0.22)	0.0 (-0.69)	0.1 (-0.45)	0.8 (0.29)
$CaCN_2$	1000	0.3 (-0.22)	0.0 (-0.69)	0.0 (-0.69)	0.3 (-0.20)
LSD(P<0.05)		(1.13)	(0.91)	(0.84)	(1.10)

[1]Data are back transformed means, with $\log_e$ + 0.5 transformed values in parentheses.
[2]Since the back transformed means are geometric means, the data in the rows do not add up arithmetically.

The effects of the soil amendments on suppression of apothecial production were significant (P<0.001) for all assessments. The white granules of $KHCO_3$ and NH_4HCO_3 were visible on the soil immediately after application, but had disappeared by the first assessment on 19 September. In contrast, the dark grey powder of $CaCN_2$ remained visible in plots treated with the higher rate for the full 46 days of the trial. Mean, minimum and maximum soil temperatures were 11.3°C (SEM=0.10), 7.0°C and 16.7°C, respectively.

DISCUSSION

Both bicarbonate compounds at 300 kg/ha suppressed populations of apothecia by 76-88% at 46 days after application. At higher rates, both products may provide total suppression of apothecia, and this warrants further investigation.

$CaCN_2$ applied at 500 and 1000 kg/ha almost completely inhibited production of apothecia of *C. camelliae*. Thus $CaCN_2$ may provide effective control of the disease by reducing the amount of primary inoculum, thereby limiting infection. However, $CaCN_2$ is generally considered a hazardous substance because it liberates ammonia and highly flammable acetylene gas when in contact with water. The calcium and hydrogen compounds associated with its breakdown in moist soil can induce irritation to severe dermatitis in sufferers, causing an erythematous or macular rash (Canadian Centre for Occupational Health and Safety 2001). Therefore, precautions would need to be adopted to prevent $CaCN_2$ coming into contact with the skin, eyes and respiratory system of garden staff. In the dust formulation currently available in New Zealand, the fertiliser would need to be applied using gloves and a full-face chemical respirator. $CaCN_2$ is available in the USA as a granule fertiliser under the trade name Perlka™. This formulation is less hazardous than the dust form, and home gardeners may use it with care to control camellia blight. Nitrolim™ (57% $CaCN_2$) is another relatively safe formulation that is available outside New Zealand. It has been shown to be efficacious as a soil dressing in pea crops, where it completely inhibited carpogenic germination of buried and surface sclerotia of the closely related pathogen *Sclerotinia sclerotiorum* (Jones & Gray 1973).

In wet soil, $CaCN_2$ is transformed to urea, producing dicyandiamide, guanylurea sulphate and hydrogen cyanamide (H_2CN_2) in the process (Fink & Borner 1985; Kruger 1980), and it is these intermediary products that appear to inhibit apothecial production. Fink & Borner (1985) showed that dicyandiamide applied directly to sclerotia of *S. sclerotiorum* in 10.2 M solutions significantly inhibited production of apothecia, and guanylurea sulphate added in 10.3 M solutions completely inhibited production of stipes and apothecia. However, $CaCN_2$ was not inhibitory in these doses. Kruger (1980) found that $CaCN_2$ applied to soil containing sclerotia of *S. sclerotiorum* was effective in suppressing apothecial production, which he concluded was due to the presence of dicyandiamide found in the top 30 mm of soil at 10-18°C, 60 days after application of $CaCN_2$. At the Wellington trial site the 7-17°C soil temperature range was similar to that in Kruger's trial, suggesting that the intermediary breakdown products of $CaCN_2$ may also have been present for a similar duration.

Huang & Janzen (1991) found that urea was also an active compound since surface application of urea to soil at 50-100 kg/ha inhibited carpogenic germination of *S. sclerotiorum* sclerotia. Since the treatment was ineffective in sterile soil, which has no urease, they concluded that ammonia released from decomposition of the urea might have been the key toxic agent responsible for the inhibition of germination. The use of urea may also contribute to a long-term decline in numbers of *C. camelliae* sclerotia. In laboratory assays in which urea was applied at 217 kg/ha to soil containing sclerotia, the proportion of firm (viable) small *C. camelliae* sclerotia was reduced by 19%, after incubation for 6 months (van Toor 2002). This reduction was postulated to be due to the stimulation by urea of microbial activity in the soil.

The application of bicarbonate salts and $CaCN_2$ in late winter to suppress apothecial production offers potential to control camellia blight. The results from this study suggest that these compounds should be applied once a year at the onset of apothecium emergence (early August). Further investigation is needed into the timing of application and the long-term effect of these compounds on the survival of soil-borne sclerotia and on enhanced parasitism by opportunistic micro-antagonists in the soil.

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