Triadimefon, a Systemic Fungicide Against *Uncinula Necator* (Oïdium) on Wine Grapes: Disease Control, Residues and Effect on Fermentation and Wine Quality

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The efficacy of the systemic fungicide triadimefon (1-(4-chlorophenoxy)-3,3-dimethyl-1-(1H-1,2,4-triazol-1-yl)-2-butanone as a wettable powder spray was evaluated against oïdium in field trials. At a high level of infection (86,2% infection), treatment of the grapes with vine sulphur was inadequate (65% infection), while the triadimefon treatment controlled the disease excellently (10,5% infection). Residues recovered from grapes were low, in the order of 0,245 mg/kg on grapes harvested immediately after the final application of the fungicide. Addition of 200 mg triadimefon (active ingredient)/ ℓ to grape juice had no significant effect on either onset or rate of fermentation. Fermentation of must from triadimefon-treated grapes was also similar to that of must from untreated grapes, and no effect on wine quality could be observed.

Uncinula necator Burr. (Oïdium, powdery mildew) is a very important wine grape pathogen affecting both the quantity and quality of the crop, and consequently also the quality of the wine made from infected grapes. According to Matthee & Beukman (1972), there was a sharp increase in the incidence of powdery mildew in South African vineyards since 1968. They attributed this to inadequate application, as well as inefficiency of available fungicides.

Wettable sulphur, sulphur dust, dinocap and benomyl are the fungicides that have been used to date. Vine sulphur dusts have two distinct disadvantages: it is responsible for sulphur burn on grapes, and it can only be used up to six weeks before time of harvest, leaving the crop unprotected in the stage of ripening where damage due to powdery mildew may be very severe. This safety period of six weeks is necessary because sulphur has a detrimental effect on fermentation and wine quality (Marais, 1977). Dinocap is effective against powdery mildew but may also cause burning on the grapes of some cultivars such as Pinotage, Riesling and Muscat d'Alexandrie (Marais, 1977). The systemic fungicide benomyl is effective in controlling oïdium but has to be used in combination with and alternating with other fungicides, since its continued application has been reported to cause build-up of resistance and eventual ineffective control of fungi (Schroeder & Provvidenti, 1969; Wicks, 1974; Bolay & Rochaix, 1975).

In some important viticultural areas in South Africa warm humid conditions may prevail close to harvest, with consequent increased incidence of powdery mildew. The choice of fungicides which can be used at such a late stage is limited, because of the detrimental effects of residues of certain fungicides on alcoholic fermentation (Ehrenhardt & Jakob, 1968b; Rágala & Minárik, 1971). A new systemic fungicide, triadimefon[a] (1-(4-chlorophenoxy)-3,3-dimethyl-1-(1H-1,2,4 triazol-1-yl)-2-butanone), which can be used shortly before harvest was therefore evaluated in field and laboratory trials under South African conditions.

[a] Registered in South Africa as "Bayleton" and kindly supplied for experimental purposes by Bayer South Africa (Pty) Ltd.

MATERIALS AND METHODS

Disease control: During the 1978/1979 season a Chenin blanc vineyard in the Somerset West area and a Riesling vineyard in the Stellenbosch area were treated with five applications of triadimefon: the first when the bunches were flowering, followed by 4 subsequent sprays at 14 day intervals. The fungicide was applied as a 5% wettable powder (WP) formulation at 625 g/ha (31 g a.i./ha) for the first two sprays, and at 1 250 g/ha (62 g a.i./ha) for the subsequent three applications (500 and 1 000 ℓ/ha of a 125 g 5% triadimefon WP/100 ℓ suspension, respectively). Two reference plots were included in every replicate. The one was left untreated, while the other was treated with wettable vine sulphur (30 g/ ℓ) at 1 000 ℓ/ha (2 400 g a.i./ha) in the case of the Somerset West trial, and was dusted with vine sulphur at 20 kg/ha in the Stellenbosch trial at the same times as mentioned above. Sprays were applied with a motorized knapsack sprayer, and the dusting with a hand-operated rotary knapsack duster. Each plot comprised five vines with four replications per treatment. The extent of powdery mildew infection on the bunches were assessed visually seven days after the last fungicidal application, using the following scoring system:

0 = clean (no infection)
1 = light (1–3 berries per bunch infected)
2 = medium (up to 25% berries infected)
3 = heavy (more than 25% berries infected)

The mean percentage bunch infection for each replicate of each treatment was calculated by means of the following formula (Unterstenhöfer, 1963):

$$\%\text{infection} = \frac{(n^0 \times o) + (n^1 \times 1) + (n^2 \times 2) + (n^3 \times 3)}{T \times N} \times \frac{100}{1}$$

where T = Total number of bunches (berries, bunch stalks) assessed in each replicate.
N = Highest infection group (in this case three)
$n^0, n^1 \ldots n^3$ = Number of infected bunches (berries, bunch stalks) in each infection group.

Residue studies: A chenin blanc vineyard in Paarl, Western Cape, was dusted with 1% triadimefon (sulphur base) at a rate of 20 kg/ha application (200 g a.i./ha), employing a hand-operated rotary knapsack duster. The first application was made on 1976.09.27, followed by five subsequent applications at 21 day intervals. Representative grape samples were subsequently picked 0, 3, 7, 14 and 21 days after the final application, as well as from an unsprayed control, and analysed for triadimefon by the South African Bureau of Standards.

Wine quality studies: Chenin blanc grapes in the Stellenbosch area, Western Cape, were treated with three applications of a 1% triadimefon dust (sulphur base), applied with a hand-operated rotary knapsack duster at 20 kg/ha per application (200 g a.i./ha). The three applications were made at 14 day intervals in the four weeks preceding harvest. Grapes were harvested immediately after the third application so as to induce the maximum effect (if any) on wine quality.

Untreated control grapes were harvested at the same time. Wines were made as follows: the grapes were destemmed and crushed with the addition of *ca* 75 mg sulphur dioxide/ℓ, dejuiced and allowed to settle overnight at 5 °C with addition of 0,25 g Wyoming bentonite/ℓ juice. The clear juice was then inoculated with 3% (v/v) pure culture yeast (*Saccharomyces cerevisiae*, strain WE 14), and allowed to ferment to dryness in 20 ℓ containers at 12°C. The wines were subsequently racked, cold stabilized, filtered, bottled and sensorily evaluated by a panel of judges as described by Tromp & Conradie (1979).

Fermentation studies: The same must used in the wine quality study was employed for a fermentation study. A portion of the must from both treated and untreated grapes was drawn after bentonite addition (before settling), and divided into 4 aliquots of 100 mℓ each in 250 mℓ Erlenmeyer flasks. Fermentation was initiated by the addition of 3% (v/v) actively fermenting pure culture yeast (*Saccharomyces cerevisiae*, strain WE 14). Fermentation locks were placed on the flasks, which were then incubated at 15 °C. Fermentation activity was determined by measuring daily mass loss due to the evolution of CO_2.

Laboratory fermentations were also carried out by employing the methods of Ehrenhardt & Jakob (1968a). Triadimefon (5% WP) was added to 100 mℓ aliquots of autoclaved Chenin blanc grape juice in 250 mℓ Erlenmeyer flasks to yield final concentrations of 1, 10, 100 and 200 mg a.i./ℓ, while control samples of the same juice were left untreated. The flasks were subsequently inoculated with 3% (v/v) actively fermenting pure culture yeast (*Saccharomyces cerevisiae*, strain WE 14) incubated at 25 °C, and fermentation activity determined by measuring daily mass loss. All fermentations were done in quadruplicate.

TABLE 1

Bunch infection by *Uncinula necator* after application of different fungicides to two grapevine cultivars

Cultivar	Treatment	Dose g a.i./ha	Mean infection (%) bunches
Chenin blanc	triadimefon	31–62	10,5
	Vine sulphur (WP)		65,0
	Control		86,2
	D value (P = 0,05)		38,2
Riesling	triadimefon	31–62	3,6
	Vine sulphur (dust)	20 000	38
	Control		62
	D value		26,4

The application rates were: 625 g/ha (31 g a.i./ha) for the first two sprays and 1 250 g/ha (62 g a.i./ha) for the subsequent three for both the Chenin blanc and Riesling trials.

In the case of the Chenin blanc trial, the triadimefon gave statistically significant lower bunch infection than the treatment with wettable vine sulphur, while the wettable vine sulphur did not differ significantly from the untreated control.

In the case of the Riesling trial, the triadimefon gave significantly better control than the vine sulphur dust, while dusting with vine sulphur did not differ significantly from the untreated control.

Data of residues of triadimefon on Chenin blanc grapes are shown in Table 2. Scores (%) for wine quality of the two wines made from treated and untreated Chenin blanc grapes, are shown in Table 3.

TABLE 2

Triadimefon residues recovered from Chenin blanc grapes at progressive intervals after the final application

Days after final application[a]	triadimefon residues (mg/kg)[b]
0	0,245
3	0,085
7	0,035
14	0,020
21	0,015
Control	0,000

D value (P = 0,05) = 0,02

[a] 200 g a.i./ha applied at 20 kg triadimefon (sulphur base) dust/ha.

[b] Mean of two determinations.

TABLE 3

Wine quality ratings for wines made from triadimefon treated and untreated Chenin blanc grapes

Treatment[a]	Dose g a.i./ha	Wine quality rating (%)
triadimefon (1%)	200	66,3
Control	—	54,3

LSD = 9%

[a] Treated three times on 0, 14 and 28 days before harvest with 20 kg triadimefon (1%) dust/ha per treatment.

RESULTS

Level of control of *Uncinula necator* on Chenin blanc and Riesling grapes is shown in Table 1.

The significance of differences between treatments was tested by Duncan's multiple range test. In both trials triadimefon gave statistically significant lower bunch infections than the untreated control.

Results indicate that the wine made from the treated grapes was significantly higher in quality than the wine made from untreated grapes. The effect of dusting Chenin blanc grapes with triadimefon, as well as the addition of 200 mg a.i. triadimefon/ℓ to sterilized grape juice on the alcoholic fermentation of the juice, is shown in Figures 1 and 2 respectively. Similar curves were obtained with additions of 1, 10 and 100 mg a.i. triadimefon/ℓ.

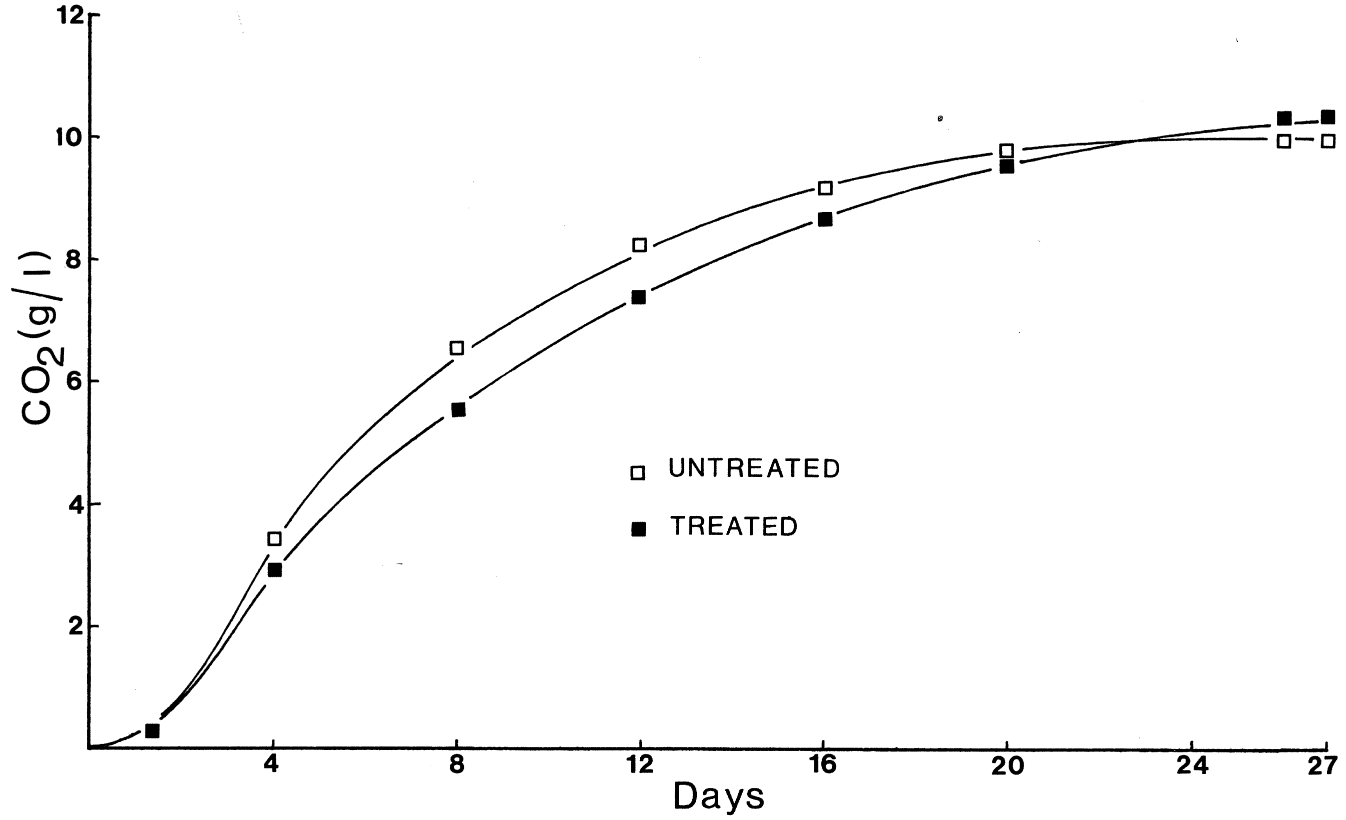

FIG. 1

Fermentation curves at 15°C of must from Chenin blanc grapes treated with three applications of 1% triadimefon (Sulphur base, 200 g a.i./ha) and of must from untreated grapes.

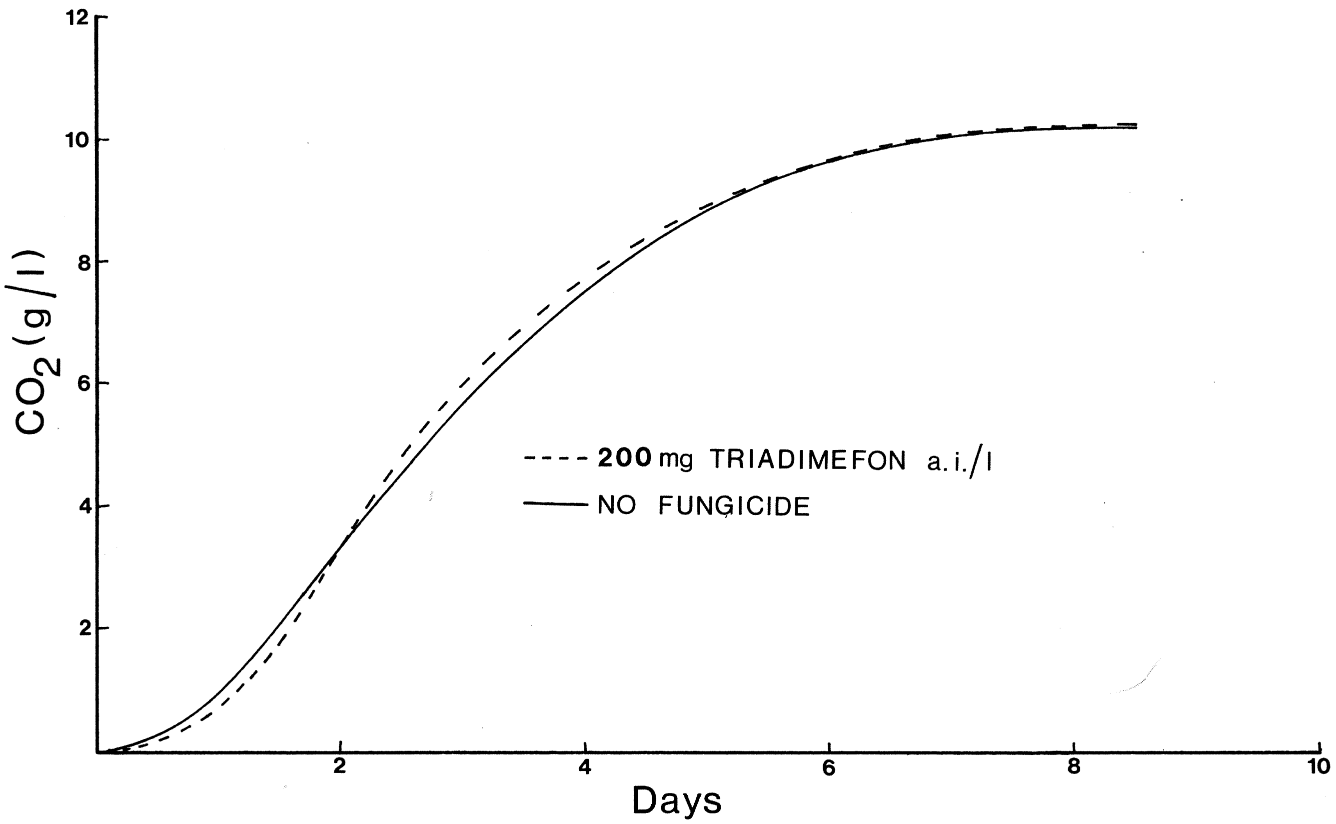

FIG. 2

Fermentation curves at 25°C of Chenin blanc must containing no fungicide and 200 mg triadimefon (a.i.)/ℓ.

DISCUSSION AND CONCLUSIONS

Triadimefon gave excellent control of *Uncinula necator* infection in field trials on grape vines. In the case of heavy infection in these trials, vine sulphur proved quite inadequate to control the disease, while triadimefon was still effective. This is in accordance with the findings of Braun (1974); Piglionica, Tarantini & Ferrara (1977) and Mancini & Cotroneo (1978), who also found Triadimefon an effective fungicide for the control of powdery mildew.

As far as the toxicity of triadimefon is concerned, the acute oral LD_{50} for rats was found to be 1 000–15 000 mg/kg body mass, while the chronic oral toxicity, no effect level (determined over a two year period) was 50 mg/kg and 500 mg/kg for female and male rats respectively (Anon., 1979). Triadimefon should therefore have no toxic effect if residues on grapes are kept under the 0,05 mg/kg tolerance level laid down by law in South Africa. Residues on grapes dusted with double the prescribed amount necessary for the protection of the crop, decreased to under this 0,05 mg/kg tolerance level within seven days after the final application of the fungicide.

Wine quality was not adversely affected by treating the grapes with triadimefon. The opposite is in fact evident from the data in Table 3. This could possibly be explained by the fact that the grapes of the control were infected with powdery mildew at time of harvest, while the grapes treated with triadimefon were not. Treating grapes with triadimefon thus had no detrimental effect on wine quality. According to Bayer South Africa (Personal communication 1979), triadimefon was found to have no effect on the quality of wine in experiments conducted with this fungicide at Geisenheim, Western Germany. Neither could any effect of triadimefon on the rate of fermentation of grape must be found. This is in agreement with the results of this study: the addition of up to 200 mg/ℓ of triadimefon to sterilized grape must had no effect on the rate of fermentation (Fig. 1). The 200 mg triadimefon/ℓ is approximately 800 times the amount of residue found on grapes when the last application was made immediately prior to harvesting of the grapes. The fermentation rate of must from grapes treated with triadimefon immediately before harvest also did not differ from the fermentation rate of must from control grapes (Fig. 2).

No phytotoxic effects could be seen in any trial where either a triadimefon WP spray or dust was employed.

It is concluded that triadimefon, applied as a spray at 30, 45, 60 and 90 g a.i./ha for four consecutive sprays, as recommended by the manufacturers, is very effective in controlling powdery mildew (*Uncinula necator*) infection on grapes. Furthermore, the low residues of triadimefon on grapes have no phytotoxic effect on the vine or detrimental effect on alcoholic fermentation or the quality of the resulting wine. Triadimefon has the further advantage that it can be applied up to seven days prior to harvest.

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