Evaluation of Bitertanol and Triadimefon for the Control of Gladiolus Rust Caused by *Uromyces transversalis*

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ABSTRACT

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Weekly applications of bitertanol or triadimefon gave significantly better control of gladiolus rust caused by *Uromyces transversalis* than did fenarimol and the control and performed better than oxycarboxin, penconazole, EDTA, CuEDTA, and DTPA. There was a direct relationship between the number of applications and the incidence of rust. Corm yield was adversely affected by rust, and weekly applications of bitertanol or triadimefon were necessary to ensure a reasonable yield. Marketable gladiolus inflorescences were harvested only from plots treated weekly with either of these two fungicides. Internode lengths on flower spikes were closely related to the intervals between applications of bitertanol or triadimefon.

Gladiolus (*Gladiolus* L.) rust is a serious disease caused by *Uromyces transversalis* (Thüm.) Winter. The causal organism was originally named *Uredo transversalis* by Thümen in 1876 and was renamed in 1884 by Winter (9) based on his investigation of diseased gladiolus samples from Somerset East, South Africa. The disease has since spread to eastern and northern Africa, Malta, Italy (8), and South America (4). Under conditions conducive to the disease, i.e., temperatures between 16 and 23 C and 1–2 days of fog (Ferreira, *unpublished*), the disease can reach epidemic proportions and inflict heavy losses. In the province of Natal, South Africa, outbreaks of gladiolus rust can cause losses of up to 100% and make the production of gladiolus cut flowers almost impossible without the use of a fungicide. In drier areas, rust is considered a problem only during exceptionally wet seasons. The disease is characterized by bright orange pustules forming across the leaf blade. Spores from leaf pustules may infect the inflorescence and render the flower spike unmarketable. The presence of pustules on any part of the flower spike precludes export to other countries. The mere fact that gladiolus rust occurs in the Republic of South Africa has resulted in an export ban on corms as well as flowers to the United States.

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Garibaldi and Aloj (2) evaluated the fungicidal control of gladiolus rust in a plastic glasshouse and concluded that dithiocarbamates gave poor control but that weekly sprays of benodanil (Calirus 50WP) or oxycarboxin (Plantvax 75WP) prevented rust development. Magie (5) conducted glasshouse trials on two artificially inoculated gladiolus cultivars and found that oxycarboxin and three sodium salts of chelates gave good control.

In this study, bitertanol and triadimefon are compared with other fungicides and chelates in field trials, with special reference to the timing of the applications.

MATERIALS AND METHODS

The field trials were conducted under mist belt conditions at Cedara in Natal, a locality known to be conducive to outbreaks of gladiolus rust. The trials were laid out in a randomized block design with either four or five replicates and protected by a hail shelter. The 0.02-ha field (Hutton soil type with pH[KCl] of 4.4) was prepared with a rotavator and fertilized with 900 kg/ha of 2-3-2(22). Weeds were controlled before planting with linuron (Afalon 45SC at 1.5 kg/ha). Corms (average diameter 4.5 cm) were planted either in spring (September) or in midsummer (January) at a depth of 4 cm and spaced 15 × 15 cm, with 36 (6 × 6) corms per 0.81-m^2 plot. A wire mesh that could be raised as plant height increased was placed over the plots to provide plant support and prevent shoots and inflorescences from breaking off during thunderstorms or very windy conditions. After planting and before watering, the soil was treated with disulfoton (Disyston 5G), 1 g per 15 × 15 cm, to prevent thrips.

Before spraying, rust incidence was assessed (according to the scale in use during that particular season) to establish the uniformity of rust infection. The fungicides and chelates were applied to runoff with a knapsack sprayer equipped with a flat fan nozzle (Spraying Systems, Brass 8002E) at 2.07×10^5 Pa after the first sign of rust. Portable plastic screens were used to limit drift between plots with different treatments. The control plots were sprayed with water containing an adjuvant.

1984 Trial. Thirty-six corms of each of the gladiolus cultivars Day Dream, Fire Chief, Goldfield, Green Isle, and Spectacular were planted in midsummer (January). Rust appeared 6 wk after planting, after which plants were treated to runoff weekly for 6 wk with 15 g of bitertanol (Baycor 30EC), 12.5 g of triadimefon (Bayleton 25EC), 12.5 g of oxycarboxin (Plantvax 25EC), 12 g of fenarimol (Rubigan 12EC), or 10 g of penconazole (Topas 10EC) per 100 L of water. In view of the wax layer on the leaves, an adjuvant, Agral 90 (ICI

Plant Protection Ltd.) at 25 ml/100 L of water was added throughout. Two rows of four plants each in the center of the plot were rated according to a 0–5 scale, where 0 = no visible pustules, 1 = very slight infection, 2 = slight infection, 3 = moderate infection, 4 = moderately severe infection, and 5 = severe infection. Two disease assessments (in addition to that before spraying) were made, the first 9 wk and the second 12 wk after planting. Results were analyzed according to the methods outlined in Table 1.

1985 Trial. Thirty-six corms of Goldfield were planted in spring (September). At the first sign of rust, 6 wk after planting, the trial was sprayed to runoff weekly with triadimefon (12.5 g/100 L) or bitertanol (15 g/100 L) or with one of the commercially available chelates: 7 g of ethylenediaminetetraacetic acid (EDTA) containing 14% copper (Librel Cu 14WP), 13 g of EDTA (Tetralon A 40EC), or 13 g of diethylenetriamine pentaacetic acid (DTPA) (Tetralon B 40EC) per 100 L of water. The adjuvants were added as indicated in Table 2 at a rate of 25 ml/100 L. The incidence of rust was assessed 8 wk after planting by employing the Horsfall and Barratt (3) scale and converting the figures according to the tables of Redman et al (6). Results were analyzed according to the methods outlined in Table 2.

Table 1. Incidence of gladiolus rust, caused by *Uromyces transversalis*, in a field spraying trial at Cedara, South Africa, in 1984

Fungicide[y]	Rate (g)/100 L of water	Disease incidence[z]	
		Assessment 1	Assessment 2
Bitertanol	15	1.2 c	1.8 c
Oxycarboxin	12.5	2.9 abc	3.5 abc
Triadimefon	12.5	1.1 c	1.5 c
Fenarimol	12	3.8 a	4.3 ab
Penconazole	10	2.2 abc	3.2 abc
Control	0	3.5 ab	4.6 a

[y] Fungicides were applied weekly with knapsack sprayer to runoff with 25 ml of Agral 90 per 100 L on four replicates (randomized block design) of 36 plants for 6 wk after the first sign of rust (6 wk after planting).

[z] Average disease incidence rated according to a 0–5 scale, where 0 = no infection and 5 = severe infection. Assessments 1 and 2 were made 9 and 12 wk respectively, after planting. Means in a column followed by the same letter did not differ after analysis with Kruskal-Wallis; all differences were significant at $P = 0.01$ except the difference between bitertanol and fenarimol in assessment 2, which was significant at $P = 0.05$.

Fig. 1. Inflorescences of gladiolus cultivar Goldfield 6 wk after initiation of triadimefon treatment at the first sign of rust caused by *Uromyces transversalis*. Triadimefon was applied (left to right) every week, every 2 wk, every 3 wk, and once. Note the long internodes on the inflorescence at right and the progressively shorter internodes toward the inflorescence at left. Fewer applications resulted in more rust, which caused the flowers to abort. (Left to right): No abortions and fully opened flowers, first two flowers partially opened before abortion and higher flowers opened further, first five flowers aborted after emergence without opening and higher flowers partially opened, and first five flowers aborted and sixth flower partially opened.

1986 Trial. Four weeks before the corms for the trial of bitertanol and triadimefon were planted, Goldfield corms were planted in rows 1.5 m apart, peripherally and between plots; to ensure uniform spread of rust, these rows were not sprayed. In spring (September), 24 corms of Goldfield were planted per plot, and bitertanol (15 g/100 L of water) and triadimefon (12.5 g/100 L of water) were applied to runoff; 25 ml of Agridex 90 (Bayer S.A.) and 25 ml of Agral 90 per 100 L of water, respectively, were added. The first sign of rust appeared 6 wk after planting. Both fungicides were applied once as follows: 1 wk before the first sign of rust, after the first sign of rust, every 3 wk, every 2 wk, and weekly for 6 wk. An assessment similar to that done during the 1985 trial was conducted 10 wk after planting. In addition, two assistants made individual assessments, and the means of the three assessments were used for analysis. The corm yield from each plot was determined 9 wk after planting, and the results were analyzed. Polynomial analysis with BMDP statistical software (1) and regression analysis were

Table 2. Disease assessments of gladiolus rust, caused by *Uromyces transversalis*, in a field trial at Cedara, South Africa, in 1985 after weekly treatments with bitertanol and triadimefon (with both adjuvants, Agridex and Agral 90) and chelates

Treatment[y]	Rate (g)/100 L of water	Disease incidence (%)[z]
Bitertanol + Agridex	15	0
Bitertanol + Agral 90	15	0
Triadimefon + Agridex	12.5	0
Triadimefon + Agral 90	12.5	0
Control + Agral 90	0	37.3 b
EDTA + Agral 90	13	2.7 a
DTPA + Agral 90	13	29.7 b
CuEDTA + Agral 90	7	5.3 a

[y] Treatments were applied weekly with a knapsack sprayer to runoff for 6 wk after the first sign of rust (6 wk after planting) with 25 ml of Agral 90 or Agridex per 100 L of water.

[z] Average disease incidence of each treatment (four replicates of blocks with 36 plants in a randomized block design) was rated according to the Horsfall and Barratt (3) scale and converted with tables by Redman et al (6) 8 wk after planting. Analysis disregarded zero disease incidences. Means in a column followed by the same letter did not differ significantly at $P = 0.05$ after analysis with the Friedman test.

performed on the disease incidence and corm yield in relation to the application intervals of bitertanol and triadimefon.

RESULTS

During 1984–1986, gladiolus rust appeared in the trials 6 wk after planting. The assessments shortly before spraying were not used in the final analysis because no significant differences in disease incidence were found among plots.

1984 Trial. Significant (P = 0.01) control was obtained with bitertanol and triadimefon (Table 1). These fungicides were significantly more effective than fenarimol. Control of gladiolus rust in this trial was evident at the time of the first assessment (9 wk after planting) and remained similar for the second assessment (12 wk after planting) except that the difference between the bitertanol and fenarimol treatments was less significant (P = 0.05).

1985 Trial. There were no significant differences between fungicides. The infection pressure was lower in this season than in the previous or following seasons, apparently because of drought conditions (*personal observation*) in the Natal region. No rust was observed in the plots sprayed with bitertanol or triadimefon. These treatments were not included in the statistical (Friedman) analysis. This analysis showed significant (P = 0.05) differences between chelates EDTA or CuEDTA and DTPA or control treatments (Table 2).

1986 Trial. Very high infection pressure prevailed under field conditions. Treatment of gladioli for 6 wk with triadimefon resulted in a shortening of internodes of the flower spikes (Fig. 1). The internodes of inflorescences treated only once with triadimefon were considerably longer than those treated weekly with triadimefon; intermediate application intervals showed a marked progressive shortening. The fewer the applications of triadimefon, the higher the disease incidence (Fig. 2). This in turn caused more flowers to abort, so that in the control treatment, no flower spikes developed or no flowers on the spike opened. With one treatment in 6 wk, the basal flowers aborted and the sixth acropetal flower opened partially. With two applications, the basal flowers developed but aborted before opening and the sixth acropetal flower opened partially. With three applications, the basal flowers aborted after opening partially, but the third acropetal flower opened partially and those above opened in a progressively increasing manner. Weekly applications resulted in inflorescences without aborted or partially opened flowers (Fig. 1).

Differences between applications of triadimefon every week or every 2 wk and the control were significant (P = 0.05). Weekly applications of triadimefon were significantly (P = 0.05) different from the control and one application before the onset of gladiolus rust. Differences between applications of bitertanol every week or every 2 wk and the control were significant (P = 0.05). Weekly applications of bitertanol were significantly (P = 0.05) different from the control and one application after the first sign of rust. Disease incidence was, therefore, closely related to the lengths of the intervals between applications of bitertanol or triadimefon (Fig. 2).

Polynomial analysis of the disease incidence compared with application intervals for bitertanol and triadimefon (Fig. 2) resulted in polynomial equations of the first degree or a linear relationship (Table 3). Therefore, the more regularly

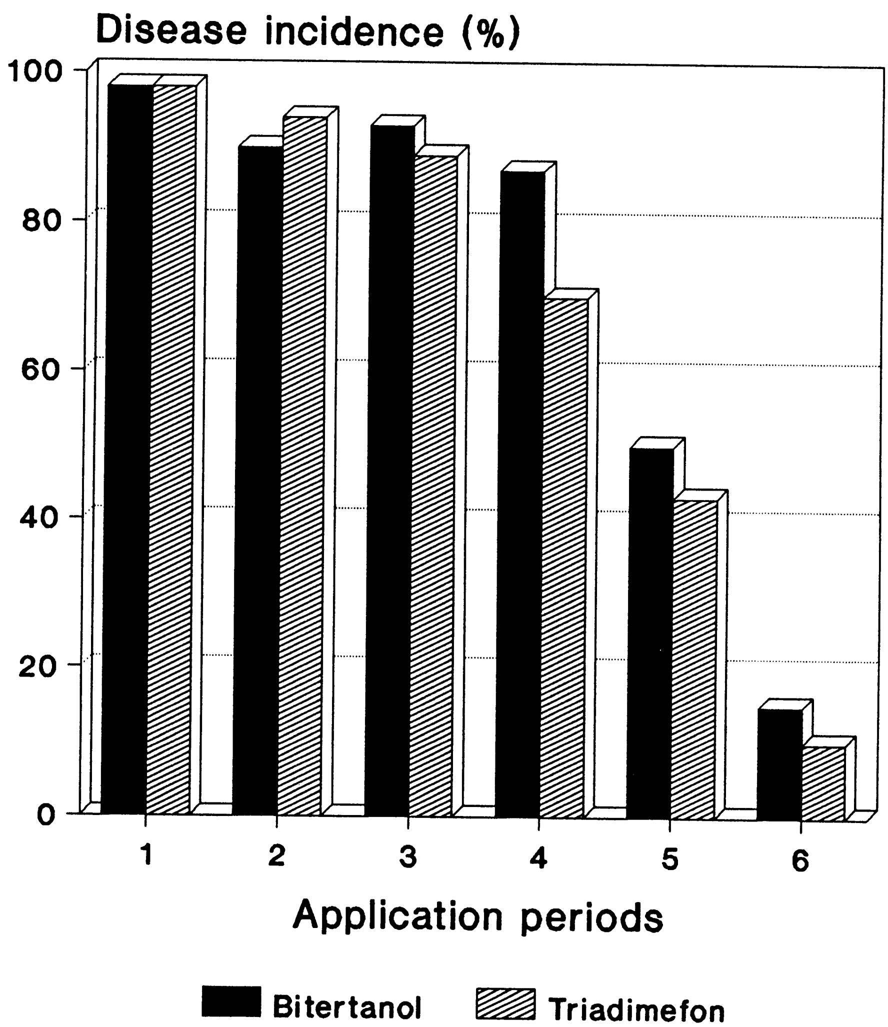

Fig. 2. Incidence of gladiolus rust, caused by *Uromyces transversalis*, 6 wk after commencement of spray applications of triadimefon and bitertanol. Applications: 1, no treatment; 2, one before first sign of rust; 3, one after first sign of rust; 4, two at 3-wk intervals; 5, three at 2-wk intervals; and 6, weekly. According to a Friedman analysis, applications 5 and 6 of triadimefon differed significantly from application 1 and application 6 differed significantly from applications 1 and 2 (P = 0.05). For bitertanol, applications 5 and 6 differed significantly from application 1 and application 6 differed significantly from applications 1 and 2 (P = 0.05).

Table 3. Percentage fit[w] of polynomial equations to disease incidence/application intervals and corm yield/application intervals for bitertanol and triadimefon in the control of gladiolus rust, caused by *Uromyces transversalis*, at Cedara, South Africa, in 1986

	Disease incidence[y]	Corms harvested[z]	
Fungicide[x]	First degree	Second degree	Third degree
Bitertanol	85%	91%	93%
Triadimefon	80%	82%	82%

[w] Percentage fit of first-, second-, and third-degree polynomial equations were calculated with BMDP for disease incidence and corms harvested.

[x] Bitertanol and triadimefon were applied with a knapsack sprayer to runoff once before the first sign of rust (5 wk after planting), once after, every 3 wk, every 2 wk, and weekly for 6 wk at 15 and 12.5 g, respectively, per 100 L of water, plus Agral 90 with triadimefon and Agridex with bitertanol, both at 25 ml per 100 L of water.

[y] Determined 10 wk after planting and rated according to the Horsfall and Barratt (3) scale and converted with tables by Redman et al (6) for each treatment.

[z] Based on average number of corms harvested from each treatment.

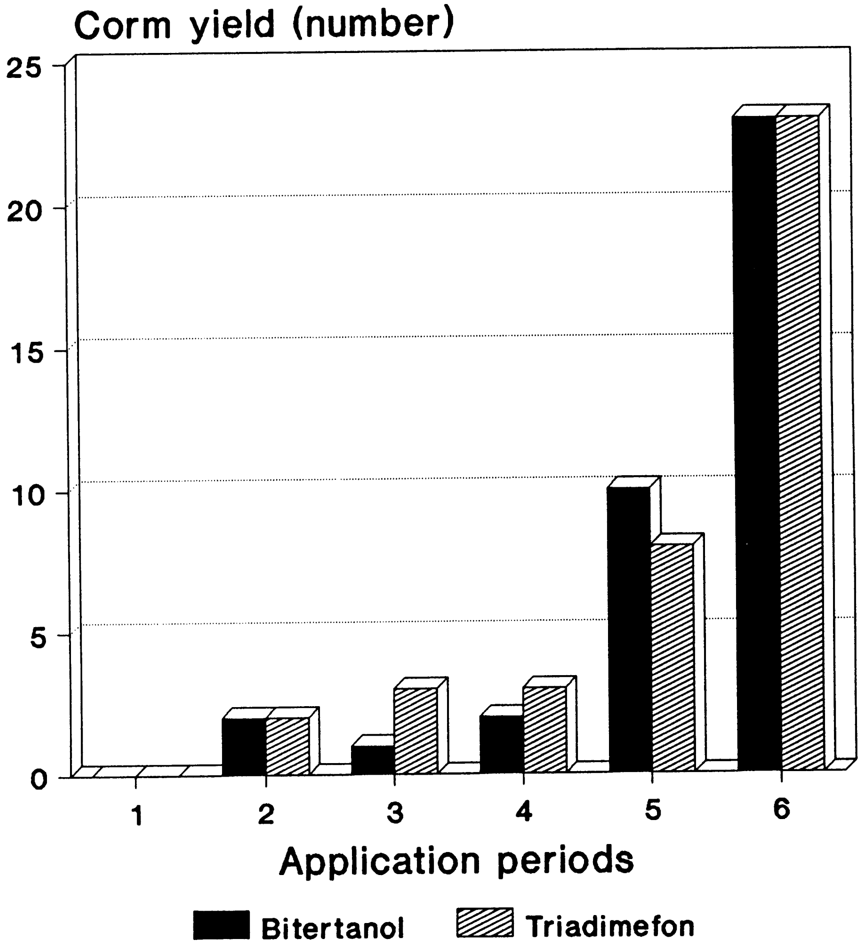

Fig. 3. Corm yield per plot and application of triadimefon and bitertanol for gladiolus rust caused by *Uromyces transversalis*. Applications: 1, no treatment; 2, one before first sign of rust; 3, one after first sign of rust; 4, two at 3-wk intervals; 5, three at 2-wk intervals; and 6, weekly. According to a Friedman analysis, application 6 of triadimefon differed significantly from applications 1 and 2 ($P = 0.05$). According to the Student-Newman-Keuls test, applications 5 and 6 of bitertanol differed significantly from applications 1, 2, 3, and 4 ($P = 0.05$).

either triadimefon or bitertanol was applied, the better the control. Regression analysis of disease incidence vs. application intervals for triadimefon and bitertanol showed that one fungicide did not give significantly better control than the other over the range of intervals.

The average corm yield from plots treated with weekly applications of triadimefon differed significantly ($P = 0.05$) from the yield of the controls or those that were sprayed before the first sign of gladiolus rust (Fig. 3). Applications of bitertanol every week or every 2 wk yielded significantly ($P = 0.05$) more corms than the control treatment, the treatments once before or once after the first sign of rust, or the treatment every 3 wk (Fig. 3). The complete absence of cormels in all the treatments with bitertanol or triadimefon was particularly noticeable. Polynomial equations were calculated from the results for corm yield after different application intervals with triadimefon and bitertanol. Table 3 shows that second- or third-degree equations fit the data reliably. Therefore, there is no direct linear relationship between the application intervals and the corm yield per plot. Theoretically, there is an exponential increase in corm yield with the shortening of application intervals, if the intervals are shorter than 2 wk.

DISCUSSION

The trials conducted during 1984–1986 clearly show the differences in disease incidence. In the spring of 1986, the infection pressure reached the highest level for the three seasons under review. In treatments other than weekly applications of triadimefon and bitertanol, no marketable flowers were harvested. To market gladiolus flowers when infection pressure is high, therefore, weekly sprays of either bitertanol or triadimefon are essential. A direct relationship between the application interval and disease incidence was found. Magie (5) found three chelates that gave significant control of gladiolus rust under glasshouse conditions. The results of our study substantiate his conclusion that EDTA controls the disease. In contrast with his findings, however, DTPA did not control rust caused by *U. transversalis* under field conditions. This is possibly due to lower infection pressure in glasshouse trials.

The cormels produced in addition to the new corm are commercially used for corm production. It is likely that the lack of cormel production in the treated plots was due to the use of these fungicides and in the untreated plots to the rust infection. Weekly applications of bitertanol and triadimefon resulted in the development of the new corm only; no cormels were formed.

The two triazoles used in these field trials caused a shortening of the internodes on the flower spike compared with those on the control. A similar observation on the reduction in the length of flower spikes was made by Garibaldi and Aloj (2) after spraying gladiolus plants with triadimefon. This may be rectified with gibberellic acid treatments, as suggested by Siegel (7). Another possibility is the marketing of short-internode gladiolus inflorescences as an attractive alternative to the longer spikes. The control of gladiolus rust is of benefit not only to the producer of gladiolus flowers and corms but also to importers for quarantine treatment in countries that do not have *U. transversalis*, such as the United States. The continued use of triazoles may possibly result in resistant strains of *U. transversalis*, and it would therefore be desirable to use mixtures of the triazoles and protectant fungicides.

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