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Evaluation of chemical control measures for termites in maize

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Field trials were conducted from the 1994/95 to 2000/2001 growing seasons to evaluate various insecticides for preventative and corrective control of the fungus-growing termites, *Microtermes* sp., *Odontotermes* sp. and *Allosternonotermes* sp. in maize. The incidence of lodged maize plants was used as criteria for insecticide efficacy. Carbofuran GR, imidacloprid WS, chlorpyrifos GR and fiponil GR were evaluated as preventative treatments. Corrective treatments in the form of spray applications of the systemic insecticides carbosulfan EC, benfuracarb EC and imidacloprid SL were also evaluated. Treatments were applied to the basal 25 cm of maize stems and to the soil surface surrounding plants. Imidacloprid spray applications generally provided good control of termites. The optimum plant growth stage for imidacloprid application was during the pre-flowering stage, 6 to 10 weeks after plant emergence. Pre-flowering applications were usually more effective in limiting damage than post-flowering applications. The granular insecticide, fiponil, showed promise for termite control. Chlorpyrifos granules, applied as a side dressing four weeks after plant emergence, significantly reduced lodging. Two novel control methods (fishmeal and diesel fuel) on the soil surface resulted in suppression of termite damage and subsequent reduction in lodging of plants. In the majority of trials total yields (lodged and upright plants) did not differ over insecticide treatments. However, the proportion of the total yield that had to be hand-harvested from lodged plants ranged from 0 to 41%, and was significantly higher in ineffective treatments. This resulted in increased production costs and uneconomic maize production.

Key words: insecticides, maize, *Microtermes*, termites

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Introduction

The fungus-growing termites, *Microtermes* spp., *Macrotermes* spp. and *Odontotermes* spp. (Macrotermitinae), are among the most important constraints in maize production in sub-Saharan Africa (Wood & Cowie, 1988; Munthali *et al.*, 1999; Sekamatte, Ogena-latigo & Russell-Smith, 2001a). They cause damage to roots and stems of plants from seedling to mature stages (Wood, Johnson & Oiaagu, 1980; Van den Berg & Riekert, 2003).

Although non-chemical methods such as host plant resistance (Pearce, 1997), biological control (Logan, Cowie & Wood, 1990) and cultural control methods (Black & Wood, 1989; Sekamatte *et al.*, 2001a; Smit & Van den Berg, in press) can contribute to reduction of damage, these methods are still being developed (Pearce, 1997). As a result, control measures are dependent on the prophylactic use of persistent organochlorine insecticides (Cowie & Wood, 1989; Gold, Wightman & Pimbert, 1991).

Seed dressing insecticides or furrow application of insecticides in maize can provide extended protection through the growing season (Wood & Cowie, 1988). The use of highly persistent organochlorine insecticides developed in the 1940's largely prevented termite damage to maize (Harris, 1971; Logan *et al.*, 1990) and resulted in 43% to 100% yield increases in wheat (Sands, 1977). However, the persistence of these chlorinated insecticides has led to it being banned in many countries (Prasad & Rao, 1995), including South Africa. Research to develop alternative chemical control methods has centered on newer, less persistent insecticides (Wood, Bednarzik & Aden, 1987) such as imidacloprid.

Imidacloprid is reported to disrupt social behaviour and to kill *Reticulitermes flavipes*, a wood feeding termite species

(Boucias *et al.*, 1996; Ramakrishnan *et al.*, 2000). It became available in South Africa in 1991 for control of coleopteran soil pests of maize (Vermeulen *et al.*, 1991). The soluble concentrate (SL) formulation of imidacloprid is applied as a corrective treatment for the control of *Macrotermes mossambicus* (Hagen) and *Odontotermes* spp. in maize crops in Namibia (Anonymous, 1998) and termites in maize and tobacco in Zimbabwe (E. Robbertse, Bayer, South Africa, personnel communication).

In South Africa no insecticide is registered for control of fungus-growing termites in maize (Nel *et al.*, 1999). Termite damage to maize commences at seedling stage and increases at the onset of senescence, approximately 10 weeks after crop emergence (Van den Berg & Riekert, 2003). Therefore, insecticides other than persistent organochlorides that could be applied correctively at relatively late plant growth stages, or preventative treatments will contribute towards economic production of maize in termite prone areas.

The aim of this study was to evaluate chemical insecticides for use in preventative and corrective control strategies for fungus-growing termites and to evaluate methods and times of application of insecticides to reduce termite damage in maize crops.

Materials and methods

Field trials were conducted at Ramatlabama (S25°38'; E25°35'), a locality with high termite infestation levels in the North West Province of South Africa (Van den Berg & Riekert, 2003) from the 1994/95 to 1998/99 growing seasons. During the 2000/2001 season a field trial was conducted near Lichtenburg (S26°35'; E26°07') in the North West province. The soil type at both localities was a Hutton with a clay con-

tent of 15%. The mean annual rainfall is 400 to 450 mm at both localities.

Soil was cultivated by means of a deep chisel plough to a depth of 0.30 m before planting. Fertilizer was applied as 200 kg of 3:2:3 (ratio of nitrogen: phosphate: potassium) according to soil analyses. Maize was planted with an inter-row spacing of 2.2 m and an inter-plant spacing of 0.35 m. Plots were hand weeded. Insecticide spray treatments were applied with a knap-sack spray to the basal 0.25 m of maize stalks, unless otherwise indicated, e.g. granular and seed dressing insecticides. Sprays were applied using a hollow-cone nozzle directed at a 45° angle towards the stalk base. Stalks were sprayed until small drops appeared on the surface. Since the swath width was approximately 0.20 m, insecticides were applied to stalks as well as the surrounding soil surface.

Various systemic insecticides were evaluated in a field trial during the 1994/95 season to determine their efficacy against termites when applied as corrective treatments onto maize plants during the growing season. The optimum time of application of insecticides identified as effective during the 1994/95 season was further investigated in field trials during the 1995/96, 1996/97 and 1997/98 seasons. The times evaluated were either before flowering (5 to 9 WAE), during flowering (10 WAE) or after flowering (11 to 13 WAE). Eight insecticide treatments using carbosulfan EC, benfuracarb EC and imidacloprid SL at the various times were evaluated during the first two seasons while six were evaluated during the latter two seasons. An upper check treatment that was sprayed with imidacloprid at weekly intervals from 6 to 12 WAE was included in trials during the 1996/97 and 1997/98 seasons. Insecticides were applied at similar rates throughout the study (Table 1).

A randomized block experimental design was used and an untreated control treatment was included in all trials. Each trial had three replicates. Plots consisted of single rows 45 m in length during the 1994/95 season, 30 m in length during the 1995/96 and 1996/97 seasons and 50 m in length during the 1997/98 season.

During the 1998/99 season, experimental procedures differed in that two granular insecticides and one seed dressing insecticide were evaluated with imidacloprid SL sprayed at different plant growth stages. Plots consisted of single 40 m rows.

The trial site was changed to Lichtenburg during the 2000/2001 season since results indicated that termite infestation levels at Ramatlabama were extremely high and could mask differences between insecticides. Experimental procedures were changed after addition of treatments.

The trial at the Lichtenburg site consisted of ten treatments that included a granular insecticide, two novel control methods and spray applications of imidacloprid at various times after crop emergence. Imidacloprid SL spray treatments were applied at weekly intervals from 9 to 13 WAE. Contrary to other seasons, sprays were directed at the soil surface in a 0.20 m band at both sides of the maize row and not onto maize stems. Chlorpyrifos (GR 15) was applied either at planting or as a side-dressing at a dosage rate of 5 g m⁻¹ (675 g a.i. ha⁻¹). The side-dressing application was done 4 WAE, in a shallow furrow, 20 mm deep, 0.10 m from the plant row. The furrow was covered with soil after application.

Two novel control methods included the application of diesel fuel and fishmeal. Diesel fuel, an old remedy for the con-

trol of termites, was applied to the soil surface adjacent to the plant row at a rate of 40 ml m⁻¹, 5 WAE. Fishmeal was applied by hand onto the soil surface in the plant row at a rate of 4 kg 100 m⁻¹, 5 WAE. Treatments were replicated four times with each replicate consisting of a 40 m row.

Data were collected at harvest. The number of lodged plants was determined in all trials. The number of ears plant⁻¹ and grain yield were determined during the 1995/96 season. Yield and gross value of grain were determined during the 1998/99 and 2000/01 seasons. Grain yield of upright and lodged plants were determined separately during the 2000/01 season. Data were subjected to analyses of variance.

Results

Termites collected at Ramatlabama were identified as *Microtermes* sp. and *Allodoterme*s sp. while those at Lichtenburg were *Microtermes* sp. and *Odontotermes* sp. The level of termite infestation was higher at the Ramatlabama than at the Lichtenburg trial site as shown by the number of lodged plants (Tables 1 to 5).

Lodging

Results from the initial evaluation conducted during the 1994/95 season indicated that, compared to the untreated control, applications of imidacloprid both 8 WAE and 10 WAE (flowering) and benfuracarb 8 WAE resulted in a significant reduction in the incidence of lodging (Table 1). During the 1995/96 season a tendency was observed for imidacloprid spray treatments applied during the pre-flowering period to reduce lodging compared to the untreated control. However, differences were not significant (Table 2). Applications of imidacloprid 8 WAE during the 1996/97 season and 6 WAE during the 1997/98 season resulted in a significant reduction in lodging compared to the untreated control. The lowest incidence of lodging in both the 1996/97 and 1997/98 seasons was observed in the upper check treatments, whereas the highest incidence of lodging occurred in the untreated control (Table 3).

Table 1 Incidence of lodging in maize at harvest following treatment with insecticides for termite control (1994/95 season)

Treatment/time of application (WAE**)	Formulation	Dosage rate (g a.i. 100 l water ⁻¹)	Application rate (ml 100 m row ⁻¹)	Lodging* (%)
Imidacloprid - 8	350 SL	1.75	5	12.0 a
Imidacloprid - 10	350 SL	1.751	5	28.3 a
Benfuracarb - 8	200 EC	2	10	57.0 b
Carbosulfan - 10	480 EC	24	50	69.5 bc
Carbosulfan - 8	480 EC	24	50	69.7 bc
Carbosulfan - 5	480 EC	24	50	70.9 bc
Benfuracarb - 10	200 EC	2	10	73.5 bc
Benfuracarb - 5	200 EC	2	10	74.0 bc
Untreated control	-	-	-	74.4 c

* Means within columns followed by the same letter do not differ significantly at P = 0.01 (LSD)

**WAE = weeks after crop emergence

Table 2 Incidence of lodged maize plants 23 weeks after emergence, the number of ears per plant and grain yield following treatment with insecticides at different times after crop emergence (1995/96 season)

Treatment/ time of application (WAE**)	Lodging(%) 23 WAE	Grain yield (t ha ⁻¹)
Imidacloprid SL - 6	2.7 a	2.082 b
Imidacloprid SL - 9	6.0 ab	1.993 ab
Imidacloprid SL - 11	6.4 ab	1.919 ab
Untreated control	7.3 ab	1.495 a
Carbosulfan EC - 6	8.4 ab	1.821 ab
Carbosulfan EC - 9	11.4 ab	1.924 ab
Imidacloprid EC - 13	13.0 ab	1.824 ab
Carbosulfan EC - 11	14.8 b	1.742 ab

*Means within columns followed by the same letter do not differ significantly at P = 0.01 (LSD)

**WAE = weeks after crop emergence

Table 3 The effect of imidacloprid SL application at different times after crop emergence on termite damage to maize during the 1996/97 and 1997/98 seasons

Treatment	Lodged plants (%)	
	1996/97 season	1997/98 season
Upper check	29.0 a	10.7 a
8 WAE**	45.0 a	45.3 bc
10 WAE	46.3 ab	62.7 c
6 WAE	54.9 ab	26.7 ab
12 WAE	56.1 ab	60.7 c
Untreated control	70.5 b	64.0 c

* Means within columns followed by the same letter do not differ significantly at P = 0.05 (LSD)

**WAE = weeks after crop emergence

The incidence of lodging was high with all treatments used during the 1998/99 season (Table 4). Fipronil resulted in a significant although inadequate reduction in lodging compared to all other treatments.

At the Lichtenburg site (2000/01 season), all insecticides as well as diesel and fishmeal resulted in significant (P<0.001) reductions in lodging (Table 5). The reduction in lodging that resulted from the last two treatments was, however, lower than that provided by the insecticide treatments. Application of chlorpyrifos as a side-dressing 4 WAE and all imidacloprid treatments provided similar control.

Grain yield

Grain yield of plants sprayed with imidacloprid 6 WAE was significantly higher than the untreated control during the 1995/96 season (Table 2). During the 1998/9 season grain yields were low and no treatment prevented large-scale yield loss (Table 4). The gross value of grain was low during this season and ranged from R64 to R124 ha⁻¹ with various treatments.

Table 4 The effect of preventative insecticide treatments and imidacloprid application at different times after crop emergence on maize lodging, yield and gross value of grain (1998/99 season)

Treatment/ time of application (WAE**)	Lodging (%)	Yield (t ha ⁻¹)	Gross value ha ⁻¹ at R650 t ⁻¹
Carbofuran GR - 0	98.7 b	0.192	124.15
Fipronil GR - 0	94.4 a	0.173	112.45
Imidacloprid WS - 0	99.6 b	0.099	64.35
Imidacloprid SL - 6	99.8 b	0.123	79.95
Imidacloprid SL - 7	99.4 b	0.199	129.35
Imidacloprid SL - 8	99.8 b	0.178	115.70
Imidacloprid SL - 9	100 b	0.164	106.60
Imidacloprid SL - 10	100 b	0.184	119.60
Untreated control	100 b	0.093	60.45

* Means within columns followed by the same letter do not differ significantly at P = 0.05 (LSD)

During the 2000/01 season significant differences were observed over treatments as indicated by yields of upright plants, ranging from 0.862 to 2.012 t ha⁻¹ (Table 5). Only treatment with chlorpyrifos as side dressing and application of imidacloprid 13 WAE resulted in significantly higher yields on upright plants compared to the untreated control. Yields of lodged plants that received imidacloprid treatments ranged from zero to 0.719 t ha⁻¹ and were significantly lower than those of the control and chlorpyrifos treatments. Total yield ranged from 0.903 to 2.030 t ha⁻¹ and although it differed significantly over some of the insecticide treatments, none of the treatments differed from the control. The gross value of harvested grain ranged from R587 ha⁻¹ to R1367 ha⁻¹ with various treatments.

Discussion

Results from initial evaluations of systemic insecticides indicated that post-emergence application of imidacloprid onto maize plants held promise as a corrective treatment. The general tendency in subsequent evaluations was that applications of imidacloprid during the pre-flowering stages improved protection against termites, compared to post-flowering applications. Application of the non-systemic insecticide, chlorpyrifos, 5 WAE, also resulted in a significant reduction in lodging and could be a viable option for termite control in maize.

Chlorpyrifos is effective against termites in groundnut (Logan *et al.*, 1992) but has reduced persistence in cultivated soil in the tropics (Wood *et al.*, 1987; Logan *et al.*, 1992). The efficacy of systemic insecticides and chlorpyrifos applied during the pre-flowering period could be attributed to the insecticide still being present and active during the period when termite activity in the root zone started to increase. Although lodging usually commences with plant senescence, termites damage plants from the seedling stage onwards. Termite damage to plants at Ramathhabama was observed to increase sharply between 6 and 10 WAE (Van den Berg & Riekert, 2003).

Table 5 The effect of insecticides on lodging, yield response and gross value of maize at Lichtenburg (2000/2001 season)

Treatment/time of application (WAE**)	Lodging (%)	Yield of upright plants (t ha ⁻¹)	Yield of lodged plants (t ha ⁻¹)	Total yield (t ha ⁻¹)	Gross value ha ⁻¹ at R650 t ⁻¹
Imidacloprid SL - 13	0.9 a	2.012 d	0.058 a	2.030 b	1320
Imidacloprid SL - 12	1.1 a	1.006 abc	0.000 a	1.006 a	645
Imidacloprid SL - 10	1.8 a	1.322 abc	0.144 ab	1.446 ab	953
Imidacloprid SL - 11	2.6 a	0.862 a	0.040 a	0.903 a	587
Imidacloprid SL - 9 E	4.9 a	1.092 abc	0.040 a	1.236 a	803
Chlorpyrifos GR side dressing	11.3 ab	1.523 cd	0.489 cd	2.013 b	1367
Chlorpyrifos GR at planting	21.6 bc	1.443 bcd	0.546 cd	1.989 b	1293
Fishmeal - 5	29.1 cd	0.949 ab	0.316 bc	1.265 a	822
Diesel fuel - 5	36.2 d	1.236 abc	0.719 d	1.955 b	1271
Untreated control	65.5 e	0.920 ab	0.632 d	1.553 ab	1009

* Means within columns followed by the same letter do not differ significantly at P = 0.05 (LSD)

The efficacy of diesel fuel could possibly be ascribed to a repellent effect on foraging termites around the bases of plants. However, this method of termite control may have a negative effect on the environment if applied over an extended period. The reduced incidence of lodging in plots treated with fishmeal may be ascribed to an increase in the incidence of predatory insects such as ants. Although the incidence of ants and ant nests was not monitored in this study, increased activity of ants has been reported following application of fishmeal to maize, resulting in reduced termite damage in Uganda (Sekamatte *et al.*, 2001a, b). Although the application of fishmeal holds no promise for termite control in large-scale farming systems, this method could be used effectively by small-scale farmers (Sekamatte *et al.*, 2001a, b).

Although yields were similar over treatments, the effect of reduced lodging following imidacloprid treatment should not be underestimated. Van den Berg & Riekert (2003) observed that grain yield and quality *per se* were not always significantly influenced by termite damage or lodging, but that the additional cost of harvesting grain from lodged plants resulted in uneconomical maize production in termite prone areas.

Yield data indicated that maize production is not viable under conditions of severe termite infestation. The highest income per hectare during the 2000/2001 season at Lichtenburg was R1367 and resulted from the chlorpyrifos side dressing (Table 5). This was below the approximately R1450 to R1650 needed for economic maize production in the region.

Conclusions

This study indicates that termite damage to maize can be suppressed by applications of systemic or granular formulations of insecticides after crop emergence. Some of these insecticides may however be too expensive, especially in marginal crop production areas where termite infestations usually occur. Since termites require prophylactic treatment, future studies need to focus on the development of technologies addressing formulation of insecticides that provide protection throughout the pre-flowering period.

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