Variation in the response of cashew genotypes to the targeted application of fungicide to flower panicles for control of powdery mildew disease

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Application of the fungicide triadimenol (Bayfidan) directly to inflorescences of cashew was investigated as a means of controlling powdery mildew disease caused by *Oidium anacardii*. Disease development and nut production were studied in 12 cashew genotypes that differed in their susceptibility to mildew. Panicle colonization by *O. anacardii* reached 100% coverage in all genotypes without fungicide treatment, but rates of infection differed significantly. Triadimenol sprays reduced mildew to less than 9%, even in panicles of highly susceptible genotypes. In the absence of disease, particularly good yield responses with more than nine times more nuts set than untreated controls were achieved by AM6 and AC1, which were categorized as highly susceptible and intermediate, respectively, in reaction to powdery mildew. By contrast, the partially resistant genotypes AZA2 and AC6 both produced yield response ratios of less than 3·0. The targeted treatment of flower panicles to control mildew is recommended, rather than the current practice of wastefully treating whole trees on which all mature leaves are naturally immune to infection.

Keywords: cashew, fungicide, powdery mildew, yield response

Introduction

Powdery mildew of cashew (*Anacardium occidentale*), incited by *Oidium anacardii*, is controlled by the application of fungicides (Sijaona, 1987; Topper & Boma, 1994). Increase in the annual production of raw nuts in recent years in Tanzania is mainly due to widespread use of sulphur to control the disease. In addition to sulphur, a number of systemic fungicides which operate as sterol biosynthesis inhibitors, such as Bayfidan (triadimenol), Anvil (hexaconazole) and Topas (penconazole), have been tested and recommended for control of powdery mildew in cashew in Tanzania (Topper & Boma, 1994). Cashew genotypes respond variably to fungicide application. Working on the efficacy of fungicide application to six cashew clones, Millanzi (1991) noted a lack of correlation between mildew severity and nut yield. Similar observations were reported by Maddison (1994). However, despite the lack of correlation with infection levels, nut yield has traditionally been used as a selection criterion for resistance to mildew in cashew because of the endemic nature of the disease (Faenza *et al.*, 1982).

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Due to the lack of detailed information on yield potential in the absence of disease, experiments were designed to examine the response of 12 cashew genotypes to fungicides known to control mildew. Fungicide treatments are usually applied to whole trees by blower (for sulphur) or misting (Waller *et al.*, 1992; Topper & Boma, 1994). Such an application strategy is extremely inefficient because only immature shoots, including leaves and inflorescences, are susceptible to colonization by *O. anacardii* (Shomari & Kennedy, 1999; Sijaona *et al.*, 2001). In the present study, the effect of local application to individual panicles was tested in an attempt to target the susceptible tissues directly responsible for nut production. Excellent control and yield increases were achieved; the possibility of applying targeted fungicides to inflorescences on a field scale is discussed.

Materials and methods

Location

The experiment was conducted in the progeny test trial field block at the Agricultural Research Institute, Naliendele, Mtwara, Tanzania, in the 1995/96 season. The area of the field block used for this experiment was established clonally by air-layering vegetative

propagation (Ohler, 1979). The block comprised 12 cashew genotypes, planted in 1983, at a spacing of 12×12 m. Each clone was planted in a row across the field, with a maximum of 16 trees per row.

Genotypes (clones)

The 12 genotypes were originally selected on the basis of overall yield (Faenza *et al.*, 1982). Subsequently, they have been categorized directly by their reaction to powdery mildew on detached leaves, seedlings and inflorescences, AC43, AC6 and AZA2 being regarded as partially resistant; AIN62, AM6 and ATA19 as highly susceptible; and AC1, AC4 AC10, AC22, AC28 and AZA17 as intermediate (Sijaona *et al.*, 2001).

Fungicide treatment

The treatments compared were: the fungicide triadimenol, formulated as Bayfidan (250 g a.i. L^{-1}), which was applied in water at a rate of 10 mL L^{-1}; water as a sprayed control; and an untreated control. Two trees from each clone were selected. Each cashew tree canopy was divided into two sides. From each side of the tree, 15 panicles at growth stage 4/5 (Conticini, 1982), without visible mildew, were selected and tagged with numbered plastic labels. A sisal cord ≈ 1 m in length was attached to the branch bearing a labelled panicle and left hanging down for ease of location. Tagging was colour-coded according to the treatment. The sample size was therefore five panicles per treatment per side of tree, i.e. 10 panicles per tree and 20 panicles per clone for each of the three treatments.

Fungicide and water spraying was carried out early in the morning when the wind was not strong, to avoid chemical drift. Spraying was done using a manual pump-action sprayer (1 L capacity) at 2-week intervals, starting 1 day after panicle tagging. During spraying a panicle was held and sprayed ≈ 40 cm away from the nozzle; one spray jet per panicle was adequate to achieve good cover.

Mildew assessment and data processing

Starting as soon as the first disease symptoms appeared on inflorescences, each tagged panicle was assessed for mildew infection at weekly intervals. At each assessment the percentage of flowers and flower buds affected by mildew was estimated using the 0–6 disease severity key (Nathaniels, 1996; Sijaona *et al.*, 2001). Mildew infection was indicated by the presence of mycelial growth and sporulation on the tissue surface, and was clearly distinguished from tissue discoloration due to physiological decay. Assessments were made on the four lowermost laterals, giving a total of four units of observation per panicle. Scoring continued throughout

the epidemic and terminated when mildew infection levels on all genotypes reached 100% without fungicide application. Data obtained from each day of scoring were compiled in a frequency table of scores occurring in each class. Mean percentage mildew infection per unit of observation was then estimated by multiplying each of the percentage range mid-points by the frequency of the observation units scored in the class relating to that range, summing the products so obtained and dividing the total by the number of observation units scored in the sample. Mildew progress curves were constructed for each data set for comparative studies between all test clones. Concurrent with assessment of mildew severity, the number of nuts that had set on each tagged panicle was also recorded. Note that set nuts reach maturity and fall from the tree throughout the season. The mean number of nuts set and the maximum number of nuts formed per panicle were used as yield parameters. Nut weights were not recorded, as the nut is enclosed in a shell of variable size. Once set, most nuts reached maturity with or without fungicide treatment. Analysis of variance was used to compare data on nut formation.

Results

Mildew development on panicles

Progress curves for mildew infection on treated and untreated panicles of four representative genotypes (AIN62 and AM6 as susceptible, and AC28 and AZA2 as partially resistant clones) are presented in Fig. 1. Untreated panicles showed a typically sigmoidal curve for mildew development, which began during the second week in July. As expected from earlier experiments on disease development, marked differences were observed between genotypes in their rate of mildew colonization. The disease increased rapidly on AM6, ATA19 and AIN62, reaching 100% by the end of July, whereas on AZA2, AC28, AC22, AC43 and AC6, 100% infection was reached only by the second week of September (Fig. 1). Intermediate infection rates were observed on the other genotypes.

Mildew progress on the water-sprayed treatment followed much the same course as the untreated control. Although there was slightly more infection on the latter, differences were not statistically significant. The development of disease on the fungicide-treated panicles was very slow in all genotypes; none exceeded 9% mildew infection. Panicles on AM6, ATA19, AIN62 and some replicates of AC28 were kept completely free of mildew throughout the season. There were no clear differences in mildew levels on fungicide-treated panicles of susceptible and partially resistant clones (Fig. 1). The lack of differentiation confirmed that the fungicide treatment was highly effective in controlling powdery mildew under high inoculum pressure.
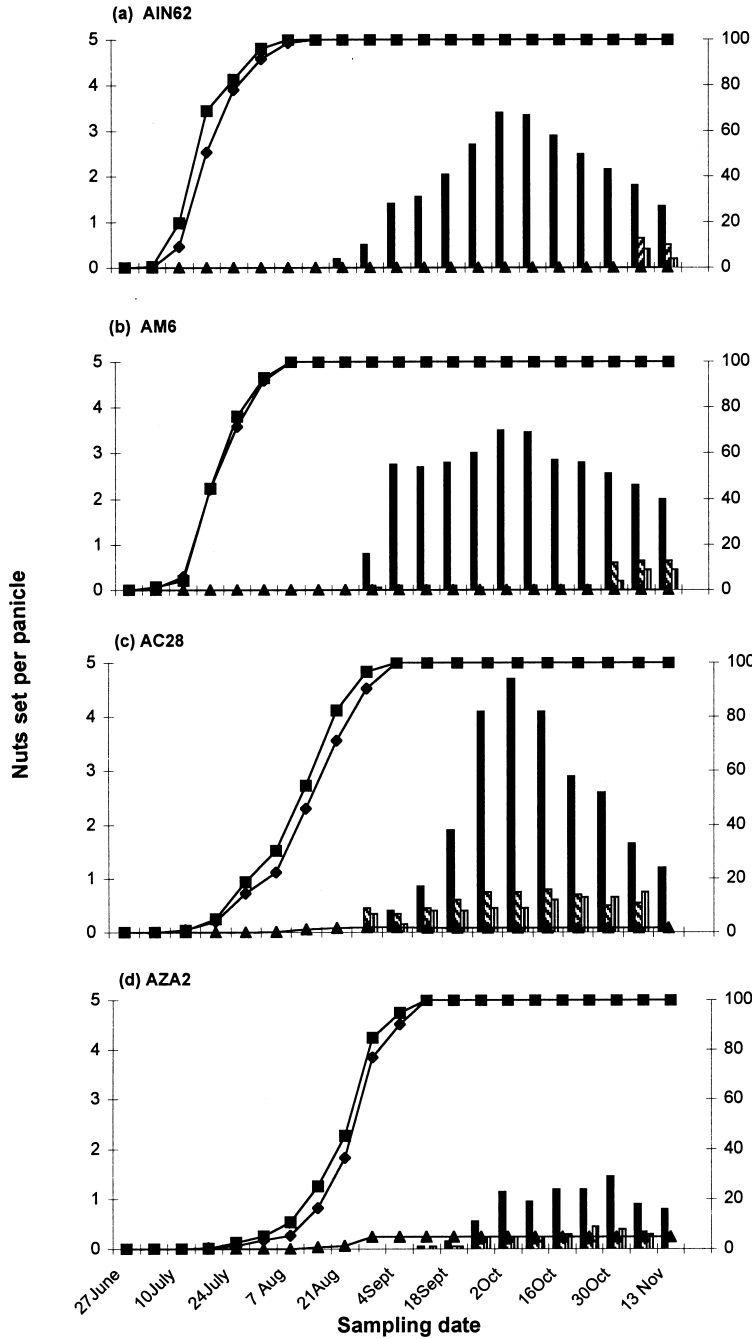
Fig. 1 **Mildew** progress curves (line graphs) and the numbers of nuts set (bars) on panicles of four representative cashew genotypes. Panicles were treated with Bayfidan (▲, solid bars) or water (◆, hatched bars), or were untreated (■, vertically striped bars).

Nut setting on panicles

The number of nuts set per panicle was greatly increased by fungicide application (Figs 1 and 2). The maximum number of nuts set (calculated as the mean of the highest number of nuts set per panicle from each treatment replicate), and the ratio between numbers of nuts on fungicide-treated panicles and untreated controls, are presented in Table 1.

Some of the more susceptible clones, for example AM6 and ATA19, gave excellent yields after fungicide

treatment, as shown by high response ratios. By contrast AZA2, the most resistant clone, produced comparatively poor yields with and without fungicide. There was no significant difference ($P < 0.05$) in the number of nuts set per panicle on water-sprayed panicles and untreated controls.

It was clear that mildew infection had a profound effect on nut development. Control of the disease by fungicide treatment therefore allowed the inherent timing of nut set to be examined more closely. ATA19, an early flowering clone, had the earliest nut set,
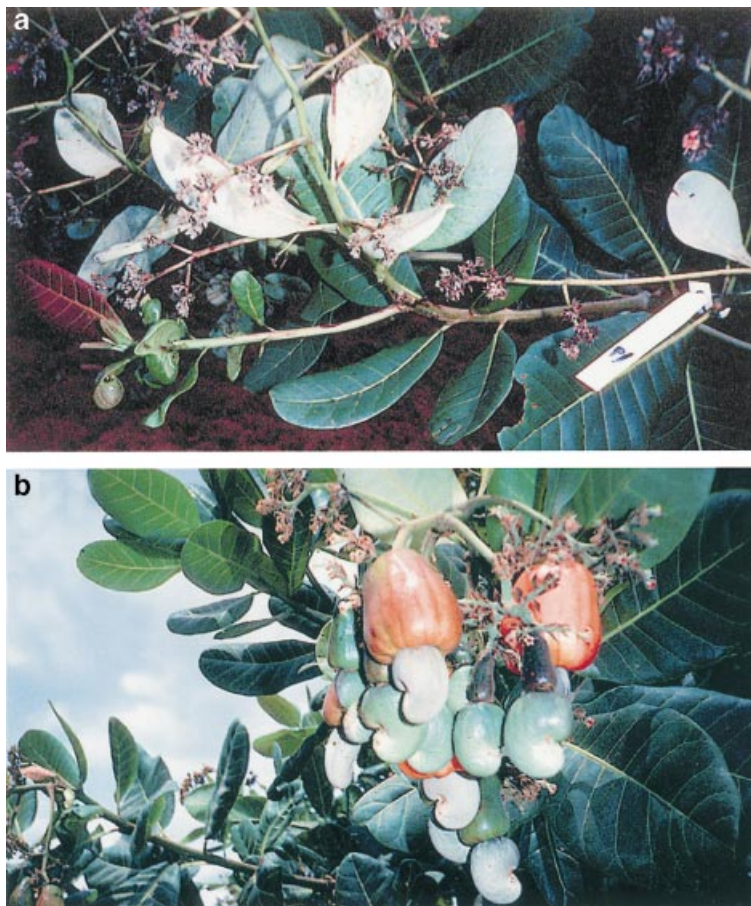
Fig. 2 Comparison of mildew and nut development on (a) untreated and (b) fungicide-treated inflorescences of AM6. Note the typically severe mildew on flowers in (a). No more than two nuts set on the untreated panicles of this highly susceptible genotype.

beginning in the third week of July, but AC6, another early flowering clone, did not set nuts until mid-August. Despite the fungicide treatment, AC43, AC28, AC22 and AZA2 took much longer to set nuts than did the other genotypes. In general, disease progress delayed nut set (Fig. 1), an exception being clone AC4, on which fruiting started at almost the same time with or without fungicide treatment.

Discussion

The experiment confirmed the efficacy of Bayfidan fungicide in controlling powdery mildew of cashew (Topper & Boma, 1994). Disease development on fungicide-treated panicles was very low; none of the clones exceeded 9% mildew infection and in some genotypes treated panicles were kept completely free from disease (Fig. 1). The complete control of mildew observed on some clones was not expected, simply because routine chemical applications rarely reduce disease to zero (Wheeler, 1976; Fry, 1982). Wheeler (1976) noted that partial control is normally obtained in fungicide treatments because it is virtually impossible to obtain complete coverage of the chemical on the plant. However, the level of control is often more dramatic with systemic fungicides such as Bayfidan. The present

Table 1 Effect of fungicide treatment and cashew genotype on maximum number of nuts set per panicle[a]

Cashew genotype	Treatment			
	Bayfidan	Water spray	Untreated control	Response ratio[b]
AC1	10·1 (1)	1·0 (2)	1·1 (2)	9 (2)
AM6	5·9 (2)	0·7 (5)	0·5 (9)	12 (1)
AC28	5·6 (3)	1·0 (2)	1·0 (3)	6 (5)
AZA17	5·4 (4)	0·0 (11)	0·9 (5)	6 (5)
AC22	4·9 (5)	0·5 (7)	1·0 (3)	5 (7)
AC10	4·7 (6)	0·5 (7)	0·7 (8)	7 (4)
AIN62	4·1 (7)	0·7 (5)	0·8 (7)	5 (7)
ATA19	3·6 (8)	0·2 (10)	0·4 (11)	9 (2)
AC6	3·4 (9)	1·1 (1)	1·4 (1)	2 (12)
AC43	2·6 (10)	0·0 (11)	0·0 (12)	3 (10)
AC4	2·4 (11)	0·9 (4)	0·9 (9)	3 (10)
AZA2	1·8 (12)	0·4 (9)	0·5 (9)	3 (9)
Mean	4·5	0·6	0·7	
LSD (0·05)	2·8			

[a]Means were obtained from the highest number of nuts set per panicle as some fell during the course of the experiment. Figures in parentheses are rank orders. [b]Response ratio calculated between Bayfidan and untreated control.

field observations suggest that Bayfidan is not translocated effectively from panicle tissues. The localization of control was demonstrated by the fact that untreated adjacent and surrounding panicles were always heavily infected by the disease. Lack of translocation and dilution by rapid panicle growth are two factors which suggest that repeated applications of fungicide will be necessary for effective control of mildew in the field.

There were clear variations between clones in the rates of infection on untreated panicles. Mildew development was particularly rapid on susceptible clones such as AM6 and AIN62, while the partial resistance as described by Sijaona *et al.* (2001) was observed on clones such as AZA2 and AC28. Most of the clones considered to be susceptible to mildew responded well to fungicide application. Fungicide-treated panicles on AM6, ATA19 and AIN62 were kept virtually free from mildew throughout the season and achieved high responses in terms of successful nut setting, with up to nine times more nuts after treatment. These results demonstrate clearly that certain genotypes that are highly susceptible to mildew are also potentially high yielding. Their failure to produce good yields in commercial plantations is directly linked to their extreme susceptibility and the devastating effect of the disease on nut development. Measures to incorporate resistance genes into some of these clones may prove beneficial in boosting nut yield. Lower responses were noted on partially resistant clones such as AC6, AC4 and AZA2, which overall did not yield well. However AC1, which was included as a partially resistant clone, ranked highly in response to fungicide application. This clone is a good example of a cashew genotype with partial resistance that can perform well without, but even better with the use of fungicide, indicating potentially synergistic interactions between partial resistance and the effect of the fungicide.

Genotypes such as AM6 yielded almost nothing without fungicide, but yield was increased more than ninefold following treatment. A key feature for economic control on a field scale may be targeting fungicide applications directly to inflorescences. Such direct application of fungicide to susceptible immature tissues would avoid wasteful deposition of expensive chemicals onto mature leaves, which are inherently resistant to the disease (Shomari & Kennedy, 1999; Sijaona *et al.*, 2001). Spraying with a long lance should allow a high proportion of flowers to be reached, particularly if trees are restricted to a manageable size. Given the availability of manpower and the low numbers of cashew trees grown in most smallholdings, direct spraying onto inflorescences has emerged as a viable option that should be critically assessed for cost-effective disease control.

Acknowledgements

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