CHAPTER 6

CHEMICAL CONTROL OF CASHEW POWDERY MILDEW (*OIDIUM ANACARDII* NOACK) IN MOZAMBIQUE

ABSTRACT

Triadimenol and hexaconazole are the two fungicides commercially used to control powdery mildew (*Oidium anacardii* Noack) on cashew (*Anacardium occidentale* L.) in Mozambique from 1998. Being both triazoles, the risk of the pathogen developing resistance is high. In addition, cost-benefit analysis becomes important taking the economic dynamics of the country into account. Thus, on-farm trials were conducted with a view to assess biological and economical effectiveness of a series of chemical fungicides against cashew powdery mildew. Two trials, in randomised block design, were conducted in two consecutive crop seasons. Four blocks with 13 elementary plots of five trees were considered. Treatments included two doses of the following fungicides: triadimenol (as positive control), trifloxystrobin, tetraconazole, triadimefon, spiroxamine and inorganic liquid sulphur. A negative (non-applied) treatment was also included. Fungicides were applied three times, using a motor blower at 21 d intervals. For treatment comparison, disease severity on cashew panicles, nut yield and percentage of scarified nuts were assessed. Results indicated higher bio-efficacy of triadimenol and trifloxystrobin followed by triadimefon and liquid sulphur at higher doses. Highest average nut yield of about 23 kg/tree was obtained from plots treated with trifloxystrobin at the higher rate. Economic returns of USD 0.75 to 1.00 per tree were obtained from triadimefon and trifloxystrobin treated trees/orchard respectively. However, equivalent financial benefits could be obtained from non-treated plots, suggesting that fungicides in use at prevailing circumstances had no additional quantitative benefits to the farmers.

INTRODUCTION

One of the cashew (*Anacardium occidentale* L.) production constraints in Mozambique since the 1970's has been powdery mildew (*Oidium anacardii* Noack) (Ohler, 1979; Dhindsa & Monjane, 1984; Milheiro & Evaristo, 1994; Nathaniels, 1996; Uaciquete; 1997). Today, yield reduction combined with industry policy related aspects, have led to more than 8000 direct job losses in Mozambique (Anon., 2003). To revert this scenario, integrated cashew powdery mildew management strategies are possible options. These include cultural practices such as sanitation, tree canopy size and shape modification either by pruning or top working susceptible plants with disease tolerant genotypes, field gap filling with tolerant material, and chemical control (Boma *et al.*, 1998; Maddison *et al.*, 1998; Waller *et al.*, 1992; Topper *et al.*, 2000). No information on biological control against cashew powdery mildew is available. Attempts of using biological control agents were made, but showed to be less effective when compared to chemicals such as Bayfidan for instance (Chapter 5). Furthermore, the viability of biocontrol product storage, and use for small-scale growers appears to be complicated.

An increase in the annual production of raw nuts in Tanzania has been achieved, mainly due to widespread use of sulphur to control the disease (Sijaona & Mansfield, 2001). Sulphur is a multisite inhibitor that interferes with electron transport along the cytochromes of the fungi (Delp, 1980; Agrios, 1988). In addition to sulphur, a number of systemic fungicides which operate as sterol biosynthesis inhibitors such as Bayfidan (triadimenol), Anvil (hexaconzole) and topas (penconazole) have been tested and recommended in Tanzania (Sijaona & Mansfield, 2001). Although sulphur appears to be of comparatively low cost and requires no water for application, its sustained use has been shown to cause soil acidification (Smith *et al.*, 1997). This is why sulphur was not adopted for cashew powdery mildew control in Mozambique. Currently, only Bayfidan and Anvil are in widespread use. However, both mentioned fungicides are triazoles, which pose a risk of potential build up of pathogen resistance. Site-specific inhibitors act on one or two metabolic sites and pathogen resistance is more common (Delp, 1980). On the other hand, a new generation of synthetic antifungal compounds (strobilurins), which inhibit mitochondrial respiration of the fungi by blocking the electron transfer at the cytochrome bc1-complex, has emerged (Leinhos *et al.*, 1997). Thus, the objective of this work was to screen chemical fungicides for powdery mildew disease control including a cost-benefit analysis of the spray program.

MATERIALS AND METHODS

Two trials were conducted in the Northern region of Mozambique for the crop season 2001/2002 at Itoculo, Monapo District and 2002/2003 at Nassuruma (Salimo area), Meconta District. The layout of the experiments was a complete randomised block design (Gomez & Gomez, 1984) with three and four blocks respectively for Monapo and Meconta Districts. Five trees per plot were assigned per treatment. Trees at Monapo were about five years old, vegetatively propagated but heterogeneous in shape and size and subjected only to normal cultural practices such as cleaning and pruning. At Meconta District, cashew trees were established by seed, and were more than 20 years of age and subjected to similar crop management systems as those at Monapo. At both sites, natural rainfall was the only way in which trees were watered.

Trees were sprayed with commercial concentrations of different fungicides (Table 6.1) over a 21 d interval, starting July 22 for the 2001/2002 crop season and July 16 for the 2002/2003 season. Chemical treatments were applied with a water-based motorised mist blower (Solo) at a rate of 1.0 l/tree (Topper *et al*., 2000). In both trials, a non-treated control was included to monitor the appearance of disease. The severity of powdery mildew on the control panicles (that is, no fungicides and no water applied) was not significantly different from that on the panicles which were treated with water (Masawe *et al*., 1997).

As shown in Table 6.1 for the 2002/2003 crop season, the number of treatments increased due to integration of other potential chemicals and the discontinuation of Stroby due to lack of supply.

In both experiments, fungicide applications were initiated at the critical point of 15% panicle emergence and 10% panicle diseased as determined by the scouting quadrat method described by Boma *et al.* (1998). Inflorescence disease severity was assessed using a six grade scale (0, 5%, 25, 50, 75 and 100%) representing different levels of mildew infection (Nathaniels, 1996) as determined at the beginning of nut set and the second assessment, three weeks later (Boma *et al.,* 1998; Topper *et al*., 2000).

Table 6.1 Chemical treatments per cashew crop season trial

Crop Season	Treatment	Formulation	Active ingredient	Chemical family	Rate (l/tree)
	Bayfidan	250EC	Triadimenol	Triazole	10.0 ml
2001/2002	Flint	500WG	Trifloxystrobin	Strobilurine	3.0 g
	Flint	50WG	Trifloxystrobin	Strobilurine	4.5 g
	Prosper	500EC	Spiroxamine	Spiroketalamine	15.0 ml
	Prosper	500EC	Spiroxamine	Spiroketalamine	20.0 ml
	Stroby		Kresoxim-methyl	Strobilurine	3.0 g
	Stroby		Kresoxim-methyl	Strobilurine	4.5 g
	Bayfidan	250EC	Triadimenol	Triazole	10.0 ml
	Bayfidan	250EC	Triadimenol	Triazole	15.0 ml
	Flint	50WG	Trifloxystrobin	Strobilurine	3.0 g
	Flint	50WG	Trifloxystrobin	Strobilurine	4.5 g
	Trical	250EC	Triadimefon	Triazole	10.0 ml
	Trical	250EC	Triadimefon	Triazole	15.0 ml
	Solfo Li	65%	Inorganic sulphur		100.0 ml
2002/2003	Solfo Li	65%	Inorganic sulphur		150.0 ml
	Eminent	40EW	Tetraconazole	Triazole	10.0 ml
	Eminent	40EW	Tetraconazole	Triazole	15.0 ml
	Prosper	500EC	Spiroxamine	Spiroketalamine	15.0 ml
	Prosper	500EC	Spiroxamine	Spiroketalamine	20.0 ml

Three different parameters were selected to determine the effectiveness of different fungicides and dose sprays: disease severity on panicles (Nathaniels, 1996), yield per canopy ground cover area (cgca) (Behrens, 1996; Topper *et al.*, 2000; Maddison *et al.*, 1997; Maddison *et al.*, 1998) and percentage of non-scarified nuts (clean nuts). In order to determine the percentage of clean nuts, a sample of 100 g of nuts per tree were collected at the beginning, middle and end of the harvesting season. The sampled nuts were separated into five categories of weight percentage: 0% scarified or clean nuts, 0-25% scarified nuts; 25-75%, 75-99% and 100% scarified (Fig. 6.3). Only the proportion of clean nuts was statistically analysed and presented in this report. Other categories which could not show significant differences between treatments were not processed for treatment comparison. The three parameters were chosen because they enabled assessment of the disease impact at three levels of cashew development:

Prior to nut formation, quantity and quality of produced nuts. Therefore, the parameters selected were complementary to one another.

Analysis of variance was performed for disease severity scores for each date and side of the tree, and the yield per cgca and transformed percentages (arcsin) of clean nuts were compared using Duncan's multiple range or Tukey's tests at 0.05 probability level.

Cost-benefit analysis was performed using a simplified model (Topper *et al*., 1999), which encompassed the cost of fungicide, petrol and oil for the mist blower, depreciation of the blower per application and labour costs for spraying (Table 6.2). Harvesting and seasonal management costs were not included. On the other hand, cashew apple and other tree benefits are excluded from this evaluation. The total margin of benefit was calculated subtracting the total cost of fungicide application from nut yield (kg) times the price per unit.

Table 6.2 A model of cost benefit analysis for spraying a cashew tree three times during the season

Item	Quantity used/application	Cost/unit (USD)	Cost/tree/season
Fungicide	X[a]	X[a]	X[a]
Petrol (l)	0.05	0.5156	0.02578
2 Times engine Oil (l)	0.002	4.0469	0.0081
Depreciation of blower/ application		0.08	0.08
Labour costs		0.05	0.05
Total Cost			Y

a = Variable, dependent on chemical ; Source: Topper *et al*. (2000).

RESULTS

None of the treatments were toxic to cashew trees. Fungicide treatment differences were not detected for control of cashew powdery mildew when data from two different sides of the tree were compared at each date of observation for the crop season 2001/2002 (Table 6.3). Similarly, means of yield per area of canopy ground area coverage from all fungicide sprayed treatments were not significantly different, P>0.5779 for 2001/2002 crop season at Monapo District (Table 6.3). From this 2001/2002 trial, it is evident that the percentage of clean nuts from Stroby treated plots was significantly higher (70.6%) than that obtained from Flint 4,5 g/tree/application and Prosper 15 ml/tree/application treated plots, (Table 6.3).

For the 2002/2003 crop season, powdery mildew severity in both assessments and sides of the tree were significantly higher on untreated (negative control) plots than on treated ones (Table 6.4). Disease severity on Flint and Trical high dose treated plots was not statistically different from Bayfidan (positive control) sprayed plots (Table 6.4). The northern side of the tree, in both assessments, showed no statistical differences for all fungicide treated plots (Table 6.4). As in the previous season, yield means per area of canopy ground coverage from all fungicide sprayed treatments were not significantly different, P>0.0757 for the 2002/2003 crop season in the Meconta District (Table 6.4). For the percentage of clean nuts, treatment means were statistically different P>0.0057 (Table 6.4). The highest percentage of clean nut (25.5%) was obtained from plots sprayed with Flint 3g/tree/application. But it was not significantly higher than that obtained from other treatments (Table 6.4).

Chemical treatments on young trees at a rate of 1 l/tree showed to be uneconomical except for Flint, 3 g/tree per application and Prosper 20 ml/tree/application, which resulted in a small marginal benefit (less than USD 0.21 per tree). No treatment resulted in a much higher economic benefit to the farmer than that obtained from untreated plots (about USD 0.63 per tree) (Fig. 6.1). However, the use of fungicides on adult trees, at Meconta district, 2002/2003 crop season, resulted in economic benefits ranging from USD 0.21 to 0.83 per tree. The fungicide Prosper showed to be uneconomical at both dosages, while liquid sulphur (Solfoli) was uneconomical at 150 ml/l (Fig. 6.2). For Trical, Tetraconazole and Flint treatments an increased dosage resulted in a respective increase in economic benefits. However, this tendency was contrary for Bayfidan and Solfoli (Fig. 6.2).

Table 6.3 Performance of fungicide spray programs at 21-day intervals for control of cashew powdery mildew (*Oidium anacardii* Noack) during the 2001/2002 crop season in Monapo District, Mozambique

	Yield (g/m^2)	Powdery mildew severity (%)		Proportion of clean nuts (%)
		First assessment		
Tree side		North	South	
Grand Mean		7.3 (0.235)	14.6 (0.362)	
CV(%)		60	46	
Control Means		39.3	46.3	
Treatments				
Bayfidan 10		18.2 (0.412)	20.7 (0.465)	
Flint 3		12.5(0.351)	24.7 (0.497)	
Flint 4.5		7.7(0.253)	7.8 (0.265)	
Prosper 15		3.9(0.194)	16.0 (0.411)	
Prosper 20		4.9(0.197)	18.5 (0.392)	
Stroby 3		3.4(0.164)	9.4 (280)	
Stroby 4.5		0.8(0.071)	5.2 (0.223)	
Ftreat:Prob>F		0.1415 NS	0.3573 NS	
FBloc:Prob>F		0.8816 NS	0.2317 NS	
		Second assessment		
Grand Mean	116.3	2.1 (0.100)	14.8 (0.353)	56.8 (0.854)
CV(%)	25	89	59	10
Control Means	56.3	64	72.7	36
Treatments				
Bayfidan 10	142.2	6.7 (0.202)	24.4 (0.484)	63.4 (0.921 ab)
Flint 3	119.6	2.5 (0.141)	28.0 (0.549)	61.4 (0.901 ab)
Flint 4.5	101.6	0.9 (0.089)	7.9 (0.257)	47.8 (0.762 b)
Prosper 15	125.4	0.3 (0.030)	7.1 (0.264)	41.3 (0.696 b)
Prosper 20	102.7	3.3 (0.162)	19.7 (0.378)	54.5 (0.831 ab)
Stroby 3	103.7	0.9 (0.076)	7.0 (0.250)	58.5 (0.871 ab)
Stroby 4.5	119.2	0.00 (0.000)	9.7 (0.292)	70.6 (0.998 a)
Ftreat:Prob>F	0.5779 NS	0.1448 NS	0.4691 NS	0.0120*
FBloc:Prob>F	0.0042**	0.0680 NS	0.3761 NS	0.8816 NS

Legend of Fisher Test: NS = Non-significant at 5%; (* ** ***) significant at 5%, 1%, 1%0).

Means followed by the same letter do not differ significantly by Tukey's test at P = 0.05; numbers in ( ) are transformed data.

Table 6.4 Performance of fungicide spray programs at 21-day intervals for control of cashew powdery mildew (*Oidium anacardii* Noack) during the 2002/2003 cashew season in Meconta district, Mozambique

	Yield (g/m^2)	Powdery mildew severity (arcsin transformed %)		Proportion of clean nuts (%)
		First assessment		
Tree side		North	South	
Grand Mean		0.097225	0.1911	
CV(%)		138.8	98.0	
Control Means		0.670 a	0.9918 a	
Treatments				
Bayfidan 10		0.01532 b	0.323 c	
Bayfidan 15		0.00075 b	0.0093 c	
Flint 3		0.00175 b	0.0451 c	
Flint 4.5		0.02552 b	0.0594 c	
Trical 10		0.02998 b	0.0634 c	
Trical 15		0.00972 b	0.0322 c	
Solfoli 100		0.12054 b	0.1861 bc	
Solfoli 150		0.01824 b	0.1026 c	
Eminent 10		0.19504 b	0.2550 bc	
Eminent 15		0.00650 b	0.0986 c	
Prosper 15		0.08306 b	0.4075 b	
Prosper 20		0.8692 b	0.2011 bc	
Ftreat:Prob>F		0.0001***	0.0001***	
Fbloc:Prob>F		0.1140	0.0097	
		Second assessment		
Grand Mean	107.2	0.2174	0.434128	14.2 (0.356)
CV(%)	65	86	59.39	35
Control Means	75.5	1.2738 a	1.3909 a	4.1 (0.158)
Treatments				
Bayfidan 10	113.7	0.0157 b	0.0884 de	14.6 (0.356 ab)
Bayfidan 15	140.1	0.0055 b	0.0235 e	23.3 (0.500 a)
Flint 3	165.5	0.0110 b	0.1747 cde	25.5 (0.517 a)
Flint 4.5	184.1	0.0310 b	0.1110 de	20.8 (0.470 ab)
Trical 10	55	0.2225 b	0.4686 bcd	6.2 (0.243 ab)
Trical 15	82.1	0.1363 b	0.3210b cde	9.1 (0.268 ab)
Solfoli 100	68.8	0.2210 b	0.5543 bc	13.6 (0.338 ab)
Solfoli 150	190.7	0.0589 b	0.3218b cde	18.9 (0.417 ab)
Eminent 10	69	0.2505 b	0.6318 b	10.2 (0.315 ab)
Eminent 15	104.9	0.0782 b	0.3158b cde	18.6 (0.436 ab)
Prosper 15	73.2	0.3068 b	0.5929 bc	12.8 (0.359 ab)
Prosper 20	70.9	0.2156 b	0.6492 b	6.7 (0.255 ab)
FTreat:Prob>F	0.0757 NS	<0.0001***	<0.0001****	0.0057 **
Fbloc:Prob>F	0.3137 NS	0.0160	0.0003	0.0032 **

Legend of Fisher Test: NS = Non significant at 5%; (* ** ***) significant at 5%; 1%, 1%0)

Means followed by the same letter do not differ significantly by Duncan's (powdery mildew severity) or Tukey's test at P = 0.05; numbers in brackets are transformed data.

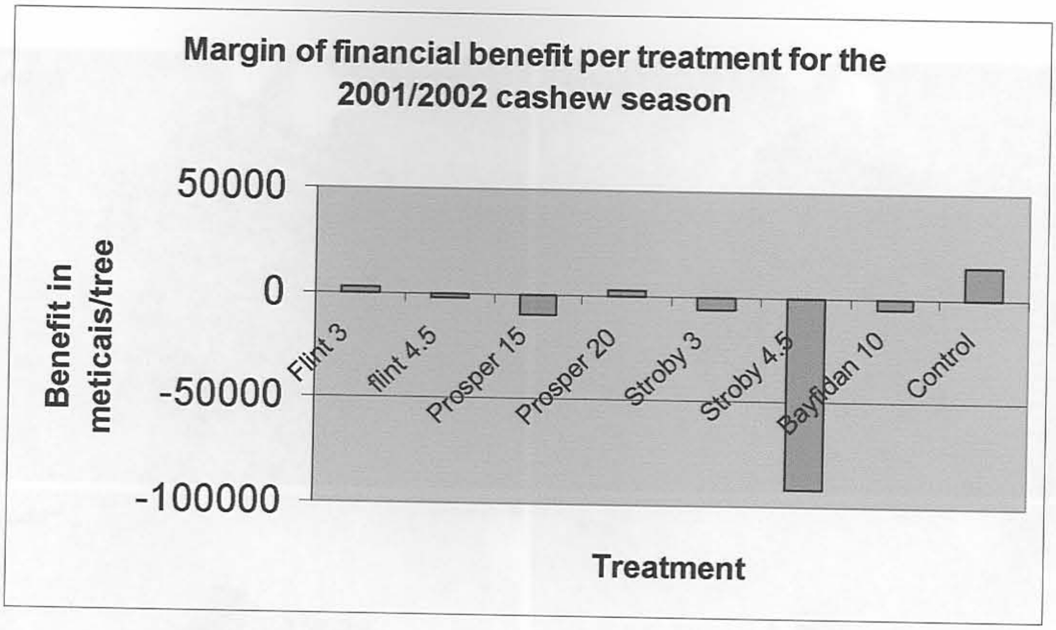

Figure 6.1 Treatment effects after fungicide spray programs for the control of cashew powdery mildew (*Oidium anacardii* Noack) during the 2001/2002 crop season in Monapo district, Mozambique; 24 000.00 Meticais = 1 USD.

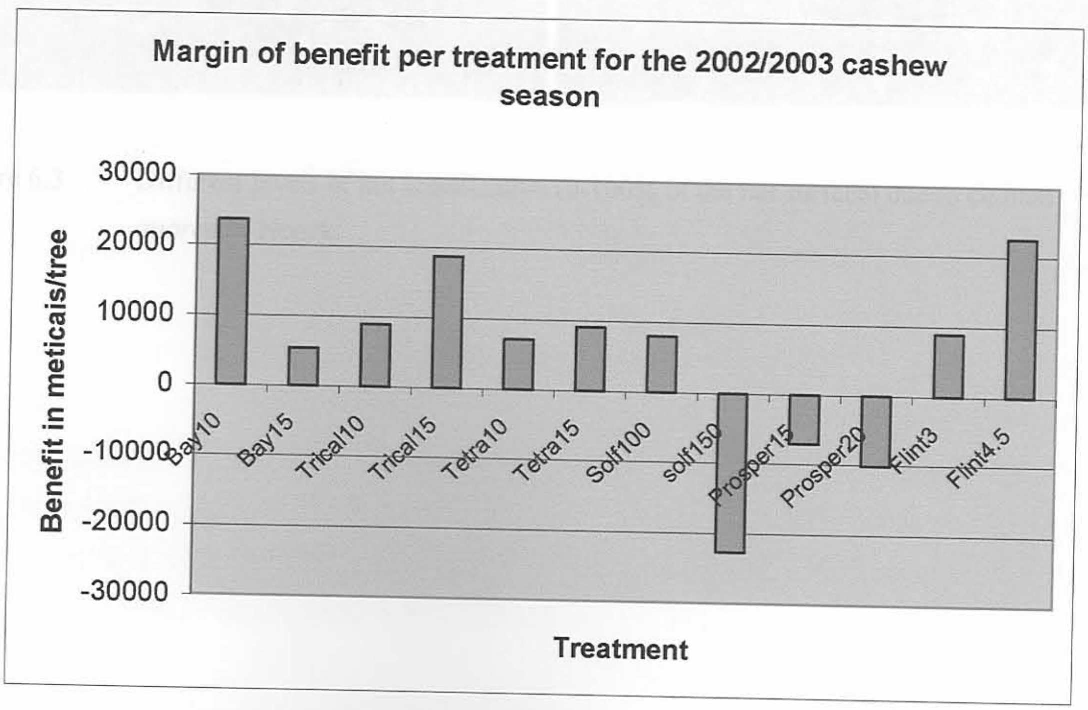

Figure 6.2 Treatment impact of fungicide spray programs for the control of cashew powdery mildew (*Oidium anacardii* Noack) during the 2002/2003 crop season in Meconta district, Mozambique; 24 000.00 Meticais = 1 USD.

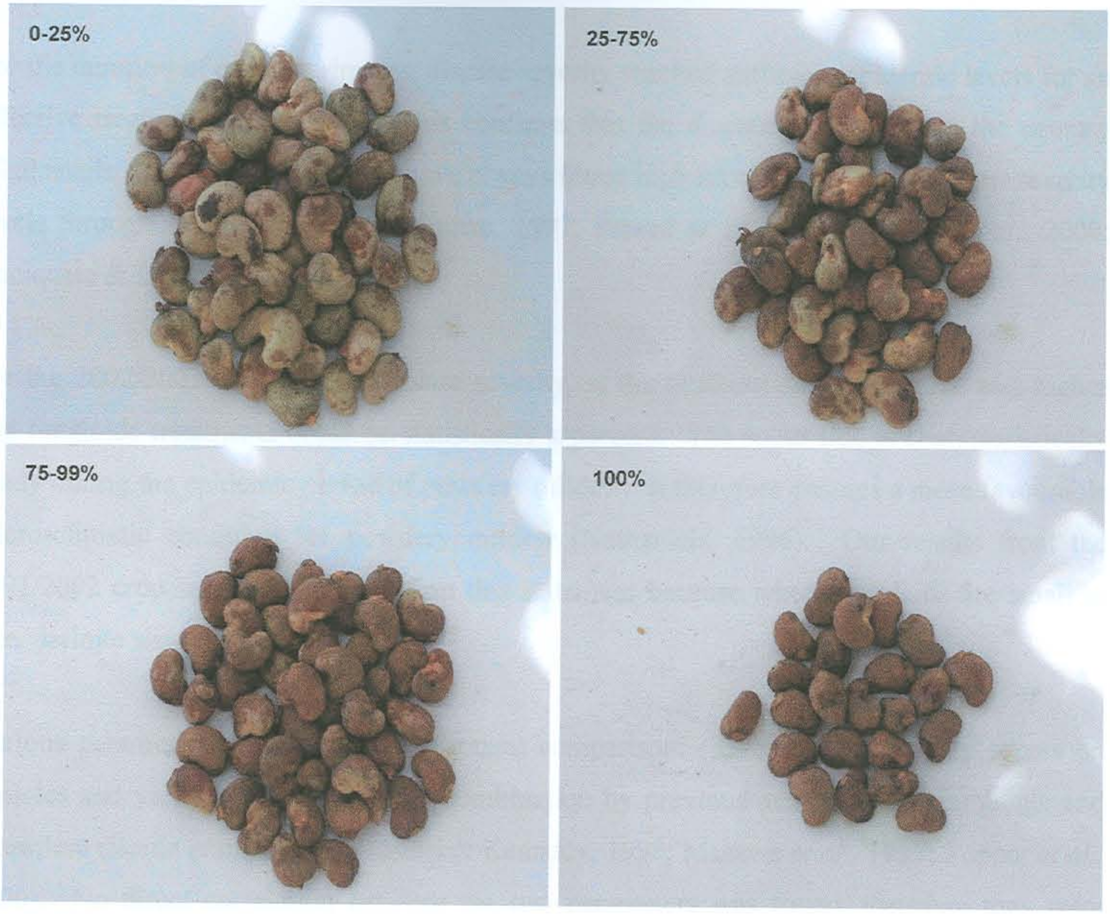

Figure 6.3 Different levels of nut scarification (0-100% of the nut surface) due to *Oidium anarcadii* Noack.

DISCUSSION

For the duration of our experiments, disease severity reached sufficient epidemic levels for an effective treatment comparison. This confirms that the disease is endemic in the country (Nathaniels, 1996). Other workers have always found high levels of powdery mildew severity levels throughout the country (Uaciquete, 1997; Prasad *et al.*, 2000; Topper *et al.*, 2000; Uaciquete & Lyannaz, 2002a,b).

For the 2002/2003 crop season, disease severity on the southern side of the tree was higher and fungicide treatments could be statistically separated. The south side is characteristically shady during the epidemic period of powdery mildew. It therefore ensures a more favourable micro-climatic condition for powdery mildew (Nathaniels, 1996). Our results from the 2001/2002 crop season cannot confirm this statement because when the plants are small in size, definite shady sides do not exist.

Various parameters were used for treatment comparison: Two disease severity scores on panicles and yield have been used in combination by previous authors in Mozambique and elsewhere (Boma *et al.*, 1998; Shomari & Kennedy, 1998; Masawe *et al.*, 1997; Topper *et al.*, 2000). No direct correlation between the two parameters was found, therefore they were considered to be complementary to one another (Boma *et al.*, 1998). In this experiment, a third parameter of nut quality (% of clean nuts) was introduced, providing additional information on assessing the impact of fungicide treatment on the marketable product.

For the most effective fungicides, disease severity did not reach beyond 10%, while untreated plots showed more than 90% damage on the panicles. The findings are in accordance with previous studies: In 14 trials conducted on-farm, Topper *et al.* (2000) obtained less than 30% disease severity with Bayfidan or Anvil treated plots against 80 to 90% damage on untreated plots. Similarly, Gibberd (2002) observed, with a fungicide testing trial at Monapo district, a maximum of 20% disease severity with fungicides compared to 90% on untreated cashew.

Recommended minimum dose for sulphur application against cashew powdery mildew is 125 g a.i./tree/spray (Topper *et al.*, 1999; Topper *et al.*, 2000). In our trial, liquid sulphur (65%) was applied at maximum dose of 150 ml/tree/round. This implies that only 97.5 g of active ingredient was deposited per tree/round.

Average nut yield per tree on untreated plots were 2.4 kg at the Monapo trial and 4.0 kg at Salimo. National nut yield average from untreated plots is between 3 and 4.3 kg (Machungo, 2002). Our results are therefore in accordance with other findings.

Working with systemic fungicides (Anvil and Bayfidan) Topper *et al.* (2000) obtained an average of 27 kg/tree from sprayed plots. Our results at Salimo indicated a range between 5 and 23 kg/tree depending on the dosage and fungicide applied. Bayfidan treated plots increased yield from 4 to 10 kg/tree. Topper's data were estimated as nut counts on the tree and not mature harvested nuts. This may explain the difference of nut yield average on Bayfidan treated plots. Extensive use of systemic fungicides on farmer's fields has increased yield from 3 to 12 kg/tree (Machungo, 2002). This finding appears to be more realistic, although low efficacy may be associated with inefficient use by extension workers.

High yields obtained from Bayfidan (triadimenol) and Flint treated plots may be related to the effect of both chemicals against cashew, and anthracnose (*Colletotrichum gloeosporioides* Penz.) (Smith & Manicom, 1999; Freire *et al.*, 2002) which may occur in conjunction with powdery mildew (Lopes *et al.*, 1993).

Percentage of clean nuts from Flint and Bayfidan treated plots suggest that there are no direct relationships between this and the severity of disease on panicles. It is possible the genetic precocity of some cashew clones and timing of applications may have higher influence on the percentage of clean nuts harvested than severity of the disease on panicles.

From our findings, the percentage of clean nuts on fungicide treated plots is consistently higher than on untreated ones. This supports the statements by Topper *et al.* (2000) who analysed the kernel turn-out from both treated and untreated nuts and found a significant reduction on turn-out of about 22% from diseased nuts, thus affecting the quality of nuts.

An increase in the rates of Flint, Trical and Eminent resulted in corresponding increases on yield and thus the benefit of USD 2.5, 0.5 and 0.083 respectively. This suggests that more trials with an increased dose for Flint and Trical would be necessary before a final recommendation.

In our experiment, the highest margin of economic benefit was USD 1.04, 1.00 and 0.75 per tree for Bayfidan (10 ml); Flint (4,5 g) and Trical (15 ml) respectively. These results are surprisingly low. Prior to our study, Topper *et al.* (2000) estimated the benefit from the use of Bayfidan or Anvil to be between USD 9 and 12 per tree. The author over-estimated the price of nuts (USD 0.5/kg) against the current USD 0.24/kg and under-estimated the cost of organic fungicides USD 32/l against the actual USD 37/l for Bayfidan. In addition, the author based his calculation on the potential yield estimated by nut counting, a method that may have over-estimated the yield. The nut counting method used in this study was especially developed because nuts were frequently stolen from the experimental plots. No cases of nut stealing or hiding were reported from our study.

Our study has highlighted the low benefits that farmers get from the use of systemic fungicides in general (USD 0.75-1). In fact, such yield benefits could also be obtained without the use of fungicides. Approximate value (USD 0.96) could be obtained from untreated plots yielding 4kg/tree on average.

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