Potential Sources for Initial Inoculum and Dispersal Pattern of Cashew Powdery Mildew Disease

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Abstract

Investigations to identify major sources for initial inoculum of cashew powdery mildew disease caused by the fungus ***Oidium anacardii*** *were carried out in southern Tanzania. Sexual stages of O. anacardii were not observed. Surveys conducted in Mtwara, Newala, Nachingwea and Tunduru districts indicated that active infections occurring on immature shoots and flowers produced within tree canopies were the major sources for cashew powdery mildew initial inoculum. However, numbers of immature shoots varied between districts with more in Mtwara and Newala than Nachingwea and Tunduru. Dispersal gradients of* ***O. anacardii*** *showed that conidial concentrations decreased with increasing distance from a single tree and isolated block of cashew trees. Approximately 6.3% of the initial conidial concentration was recovered 16 metres away from a single tree source. Even from a block of infected cashew trees, about 3.8% of initial conidial concentrations were trapped at a distance of 180 metres from the source. This shows that sanitary measures alone can not be effective in managing the disease in southern Tanzania. At sites in Nachingwea and Tunduru districts, however, where initial inoculum appeared to be generally lower than other areas, sanitary practices during non-flowering season could delay the onset of cashew powdery mildew epidemics. With proper scouting on mildew development to determine the timing of first round of fungicide application, it may be possible to reduce the number of applications from the recommended six rounds of sulphur to three or four at sites in these districts. Further studies to determine the impact of off-season immature shoots and flowers on the build-up of initial inoculum at different locations are necessary.*

Key words: *Oidium anacardii*, initial inoculum, conidia, cleistothecia, sanitation.

Introduction

Cashewnut is a major cash crop in Southern Tanzania (Northwood, 1962; Ellis, 1980). It is estimated that about 280,000 families are involved in cashew farming with approximately 390, 000 hectares of land under production (Shomari, 1990).

In Tanzania, cashew nut has been an increasingly important economic crop since 1945 when approximately 300 tonnes were produced and exported (Ellis, 1980). There were further rapid increases in annual production after this time and the crop became an important source of foreign exchange. During the 1973/74 season, production had reached 145,000 tonnes (Brown *et al.*, 1984), and it was expected that there would be further increases in annual production. After mid 1970s, however, cashewnut production began to decline to the extent that only 16,500 tonnes were produced in 1986 season (CATA, 1987).

Various reasons have been identified for this decline in cashewnut production (Anonymous, 1991), however powdery mildew caused by the fungus *Oidium anacardii* (Castellani and Casulli, 1981; Intini and Sijaona, 1983) was singled out as the main contributory factor with losses of 50 to 70% being reported (Sijaona and Shomari, 1987).

The pathogen infects immature leaves, inflorescences, developing nuts and apples

(Castellani and Casulli, 1981; Casulli, 1981). Severe infections on leaves may cause necrosis and defoliation. When young nuts are severely infected they become shriveled and damaged (Shomari, 1996) resulting in downgrading and reduced market value. Inflorescences are very susceptible to infection and may be attacked at the bud stage. Severely infected buds fall before anthesis thereby significantly reducing the potential for nut set (Masawe, 1994).

At present sulphur dust is widely used to control cashew powdery mildew in Tanzania. Application of 0.25 kg of sulphur dust per tree at a three-week interval on five or six rounds during the season has been recommended (Anonymous, 1987). This treatment provides adequate control, however, there are some problems associated with sulphur usage. First there is a problem of transportation of large quantities of sulphur and machines required for its application over extensive and remote areas. Secondly there is an economic problem relating to purchase by the resource-poor community. In addition there may be environmental hazards associated with applying relatively large quantities of sulphur, particularly the likely long term effect on soil acidity (Ikerra *et al.*, 1995; Majule *et al.*, 1997).

Considering the need for reducing the large amounts of sulphur used in farmers fields, investigations were carried out to determine the potential sources of initial inoculum and dispersal parttens of *O. anacardii* conidia. The information generated from these investigations will help in the formulation of strategies for managing cashew powdery mildew disease and in minimising sulphur applications.

Materials and Methods

Monitoring the presence of cleistothecia

During the period of three months from October to December 1992, cashew leaves infected with powdery mildew were collected at regular intervals from various sites in southern Tanzania. These leaves were maintained under field conditions at a Progeny Test Trial block, Agricultural Research Institute, Naliendele, Mtwara. At two-week intervals twenty leaves were removed and examined on both the adaxial and abaxial leaf surfaces using a binocular microscope at x 20 magnification for the presence of any fruiting bodies.

Monitoring off-season survival of *O. Anacardii* on living cashew tissues

Surveys were conducted during the wet periods (March/April) of 1993 and 1994 in the Mtwara, Newala, Nachingwea and Tunduru in southern Tanzania to assess the effect of tree growth on the survival of cashew powdery mildew. In each district two fields were selected. In each field, sixty trees were randomly selected for assessment of cashew growth and powdery mildew infection. Shoots were grouped into four different categories depending on their location on the tree as follows:

(i) Shoots from peripheral branches of the tree canopy (PB);
(ii) Shoots produced from upper minor branches (more than 4m above ground) within the tree canopy (UMB);
(iii) Shoots produced from lower minor branches (less than 4m above ground) within tree canopy (LMB);
(iv) Shoots produced from main branches within the tree canopy (MB).

The peripheral areas of the tree canopy were sampled at a height of between 2-4m from the ground on the North, South, East and West sides of the tree using a m^2 quadrat area within which shoot numbers were recorded. Fewer shoot numbers were present on the main and minor branches, therefore, all shoots produced on these areas were included in the observations. Assessment of shoot developmental stage was carried out using a cashew growth key (Nathaniels, 1991b). Shoots with red flushes and those with green orange leaves were grouped together as immature shoots. Observations were made of mildew absence, presence and activity (active, clear whitish to grey-white mildew colour maintained; non-active, clear whitish to grey-white mildew colour lost).

Monitoring conidial dispersal gradients from a single and a block of infected cashew trees

Method used to sample conidia from the air

Rotorod traps developed by Perkins (1957) were used to monitor conidial dispersal from different types of inoculum sources. A rotorod trap consisted of a pair of vertical metal arms which were rotated by an electric motor. The rods were assembled to form a trapping unit which comprised of five traps placed at 1m intervals on an aluminium bar. In each experiment, four trapping units were used. In all experiments, the rotorods were operated from 0900 to 1300h (period of maximum release and dispersal of *O. anacardii*). In the field, conidia were impacted on a sticky cellotape strip mounted on the leading edge of the rotating arms.

Conidial counts

Two strips on each rod were removed and each cut into eight units. The tape strips were mouted on microscope slides, and stained with 1% lactophenol cotton blue. Conidia on each strip unit were counted using a light microscope at x 200 magnification. The number of conidia on each of the eight tape fragments was added and represented the total number of conidia trapped on each rotorod trap. The number of conidia (C) sampled by each rod from a cubic metre of air was determined by the formula:

$C = N/V$

Where:

N = Total number of conidia counted

V = Volume of air sampled by the rod (2 arms) during the time (minute) of exposure

$V = 2 \times 22/7 \times 0.16 \times 4.5 \times ((4+5)/2) \times 3100 \times 2 \times 240/10^6$

Where:

0.16 = width of the rod (cm)

4.5 = length of the strip (cm);

4 = radius of the arm of the rod when stopped (cm);

5 = estimated radius of the arm of the rod when rotating (cm);

3100 = revolutions of the rod per minute;

240 = time (in minutes) the rod was exposed in the field; $10^6 cm^3 = m^3$.

Assessment on dispersal of *O. anacardii* conidia from a single infected tree

Measurements on the dispersal of *O. anacardii* conidia from a single infected tree was conducted from an isolated 30-year-old cashew tree which was 12 metres high located at the Agricultural Research Institute, Naliendele, Mtwara. Four trapping units were aligned vertically with the first unit 1m from the edge of the tree canopy and others arranged at 5m intervals. The experiment was repeated on three separate occasions.

Assessment on dispersal gradient of *O. anacardii* conidia from an infected block of cashew trees

Monitoring of the dispersal of *O. anacardii* conidia from an infected area source of inoculum was carried out from an isolated cashew block comprising of 62 ten-year-old trees of approximately 9m in height at Chambezi Agricultural Research Substation, Bagamoyo. During the study mildew development on the panicles was scored and found to be approximately 60%. The nearest significant exterior inoculum source was a cashew block 1750 m away. Assessment of the horizontal dispersal of *O. anacardii* conidia from a block of infected cashew trees was conducted by positioning horizontally the four trapping units with the first unit 5/100m. These were placed from the edge of the cashew block in a straight line at 20 m apart and 2 m from the ground. The experiment was repeated three times and at each time the trapping units were aligned approximately from the middle and at perpendicular to the edge of the cashew tree block.

Data analysis

Estimates of the rates at which conidial concentrations in the air (y) decreased with distance (x) from the inoculum source were obtained by applying linear regression analysis on the natural logarithm transformed values of (x) and (y) using the following regression equation:

$\ln(y) = a + b \ln(x)$

ln (y) = natural logarithms of conidial numbers

Where:

ln (x) = natural logarithms of the distances from inoculum source

b = a measure of steepness of the ln (y) gradient, (the rate at which conidial numbers decrease with distance).

a = conidial numbers at zero distance from inoculum source.

Results

Presence of cleistothecia active powdery mildew on cashew living tissues

Presence of cleistothecia was not observed on all the sampled cashew leaves. In all the surveyed sites the number of immature shoots were lower in comparison to mature shoots in all types of cashew branches (Tables 1 and 2). Higher numbers of immature shoots were present on trees in the Newala and Mtwara districts compared to Nachingwea and Tunduru. Large numbers of these immature shoots were observed on the main branches in all sampled areas (Tables 1 and 2).

Active cashew powdery mildew was observed at higher levels on immature than mature shoots in all sampled fields on all types of cashew tree branches. There were some panicles (inflorescences) in peripheral parts of the tree and 4.2 to 30.4% of these were infected with active powdery mildew. Immature shoots produced from the main branches were a significant source of active powdery mildew in all districts. Active powdery mildew was also observed on considerable proportions of immature shoots on minor branches within cashew tree canopies and also on some peripheral branches on large trees in Newala and Mtwara in both years. Minor branches and peripheral shoots were an insignificant source of active mildew in Tunduru district.

Dispersal of *O. anacardii* conidia from an infected single tree source

Numbers of trapped conidia of *O. anacardii* one metre above ground decreased with increasing distance from a single infected cashew tree (Table 3). At a distance of 16m from the tree, approximately 6.3% of the initial conidial concentration was trapped. Concentrations of *O. anacardii* conidia trapped from a single tree decreased at a rate of –1.022 as shown in Figure 1.

Dispersal of *O. anacardii* conidia from a block of infected cashew trees

Concentrations of *O. anacardii* conidia trapped in a horizontal plane at 2 m above the ground declined with increasing distance from the cashew block source (Table 4). About 3.8% of the initial conidial concentration was trapped 180 m from the source. The results show that concentrations of *O. anacardii* conidia from a block source decreased at a rate of –0.922 (Figure 2).

Discussion and Conclusions

In the present study no sexual stages of *O. anacardii* were observed. This is in agreement with the findings of other workers (Yarwood, 1957; Gupta, 1988; Munshi *et al.*, 1988) that cleistothecial structures are rarely formed by powdery mildews under tropical conditions. Formation of resistant fruiting bodies by cashew powdery mildew would appear unnecessary as weather conditions during the non-flowering seasons are favourable and host tissues are available to support active survival of the pathogen.

In this work surveys were conducted in four districts in southern Tanzania to determine the ability of *O. anacardii* to survive and produce vi-

Table 1: Incidence of cashew powdery mildew at sites in southern Tanzania in March/April 1993.

Site	Immature Shoots NM	Immature Shoots IN	Immature Shoots ACT	Mature Shoots NM	Mature Shoots IN	Mature Shoots ACT	Panicles NM	Panicles IN	Panicles ACT
Mtwara									
PB	663	1	1 (0.0)[a]	1473	111	0 (0.0)	53	7	26 (30.2)[b]
MB	640	26	38 (5.4)	2875	246	11 (0.4)	0	0	0 (0.0)
LMB	88	3	1 (1.0)	14056	500	1 (0.0)	0	0	0 (0.0)
UMB	161	0	3 (1.8)	13888	201	0 (0.0)	0	0	0 (0.0)
NEWALA									
PB	510	0	40 (7.3)	15522	1116	54 (0.3)	39	3	11 (20.8)
MB	670	11	342 (33.4)	2552	815	77 (1.7)	0	0	0 (0.0)
LMB	62	0	16 (20.5)	9837	1750	44 (0.4)	1	0	0 (0.0)
UMB	91	0	14 (13.3)	9917	1963	22 (0.2)	0	0	0 (0.0)
N'GWEA									
PB	363	0	40 (9.9)	20131	199	13 (0.0)	30	0	9 (22.5)
MB	121	5	61 (32.6)	1813	277	4 (0.2)	0	0	0 (0.0)
LMB	72	0	23 (24.2)	8145	298	4 (0.0)	0	0	0 (0.0)
UMB	68	0	6 (8.1)	8804	220	3 (0.0)	1	0	0 (0.0)
TU'DURU									
PB	56	0	0 (0.0)	16666	41	0 (0.0)	0	0	0 (0.0)
MB	43	2	13 (22.4)	1993	313	1 (0.0)	0	0	0 (0.0)
LMB	2	0	0 (0.0)	9408	77	1 (0.0)	0	0	0 (0.0)
UMB	1	1	0 (0.0)	9124	48	0 (0.0)	0	0	0 (0.0)

[a] Percentage of total shoots with active powdery mildew in that branch category; [b] percentage of total panicles with active powdery mildew in that branch category; NM shoots with no powdery mildew; IN shoots with inactive powdery mildew; ACT shoots with

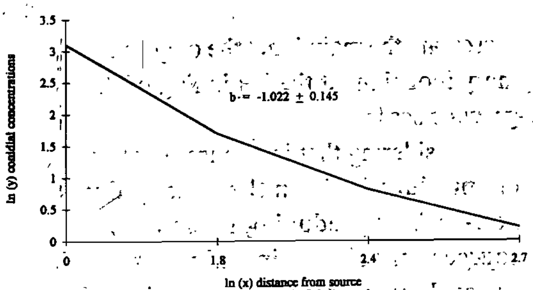

Figure 1: Vertical dispersal regression of *Oidium anacardii* conidia with a distance from a single infected tree

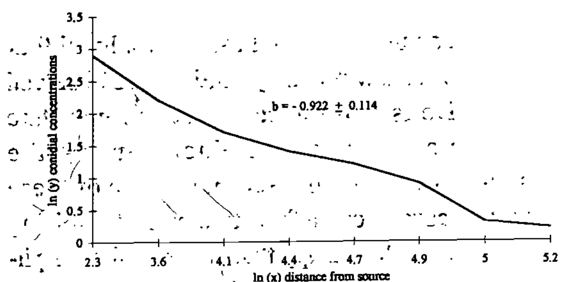

Figure 2: Horizontal dispersal regression of *Oidium anacard* conidia with a distance from a block of cashew tre

Table 2: Incidence of cashew powdery mildew at sites in southern Tanzania in March/April 1994.

Site	Immature Shoots NM	IN	ACT	Mature Shoots NM	IN	ACT	Panicles NM	IN	ACT
Mtwara									
PB	515	0	4(0.8)[a]	16899	1007	7 (0.0)	124	80	9 (4.2)[b]
MB	215	3	94(30.1)	1430	301	0(0.0)	1	0	0 (0.0)
LMB	67	0	17(20.2)	11747	6843	1 (0.0)	2	0	0 (0.0)
UMB	43	0	0(0.0)	12010	874	1 (0.0)	104	0	0 (0.0)
Newala									
PB	981	35	24(2.4)	16783	1823	21 (0.1)	393	4	8(17.8)
MB	649	3	432(66.6)	3034	1028	9(0.2)	0	0	0 (0.0)
LMB	582	2	235(40.3)	11639	1915	6 (0.0)	8	0	0 (0.0)
UMB	476	0	165(34.7)	11635	1403	1 (0.0)	0	0	0 (0.0)
N'gwea									
PB	69	0	0 (0.0)	17907	599	0 (0.0)	75	29	20 (16.1)
MB	285	13	155(34.2)	2547	867	10 (0.2)	0	0	0 (0.0)
LMB	6	4	0(0.0)	12294	825	5 (0.0)	0	0	0 (0.0)
UMB	3	0	0(0.0)	12391	514	0 (0.0)	0	0	0 (0.0)
Tu'duru									
PB	68	0	0(0.0)	18378	2253	0 (0.0)	8	8	0 (0.0)
MB	340	12	21(5.6)	2754	913	6 (0.0)	0	0	0 (0.0)
LMB	7	00	0 (0.0)	12242	1966	0 (0.0)	3	0	0 (0.0)
UMB	4	0	0 (0.0)	12580	1529	0 (0.0)	0	0	0 (0.0)

[a] Percentage of total shoots with active powdery mildew in that branch category; [b] percentage of total panicles with active powdery mildew in that branch category; NM shoots with no powdery mildew; IN shoots with inactive powdery mildew; ACT shoots with active mildew; PB periphery branches; MB main branches; LMB lower minor branches; UMB upper minor branches

Table 3: Vertical dispersal gradients of *Oidium anacardii* conidia from an infected cashew tree.

Distance (x) from source	In (x)	Numbers of conidia (y)	In (y)	% Conidial concentration
0	0	-	3.2[a]	-
1	0	22.5	3.1	96.9
6	1.8	5.7	0.8	53.1
11	2.4	2.4	0.2	25.0
16	27	2.7		6.3

[a] Value at zero metres from inoculum source is an intercept from linear regression analysis. Conidial concentrations are means of five traps over three days catch

able inoculum on living host tissues. In all four districts cashew powdery mildew was observed to survive as active infections on few immature shoots and flowers produced during the non-cashew growing seasons. More of these were recorded on cashew tree branches arising from within the canopy than those on the peripheral areas of the tree. In the absence of other known mildew survival mechanisms during the non-flowering season it is logical to assume that immature shoots and flowers which occur out of season are the main if not the only source for primary inoculum at the beginning of the cashew growing season.

Considering that immature shoots and flowers produced within the canopy during the non-cashew producing season are the main sources for primary inoculum. It may be assumed that their destruction may delay the onset of cashew powdery mildew disease. Cashew powdery mildew, however, is a polycyclic disease which takes just 4 days for a germinating

Table 4: Dispersal gradients of *Oidium anacardii* conidia from a block of infected cashew trees.

Distance (x) from source	In (x)	Numbers of conidia (y)	In (y)	% Conidial concentration
0	0	-	5.3[a]	
10	2.3	17.3	2.9	54.7
35	3.6	8.9	2.2	141.5
60	4.1	4.8	1.7	32.1
85	4.4	4.1	1.4	26.4
105	4.7	3.2	1.2	22.6
130	4.9	2.4	0.9	16.9
155	5.0	1.4	0.3	5.7
180	5.2	1.2	0.2	3.8

[a] Value at zero metres from inoculum source is an intercept from linear regression analysis. Conidial concentrations are means of five traps over three days catch.

conidia to sporulate (Shomari, 1996). The present investigations on dispersal gradients indicated that the of conidia *O. anacardii* can be trapped even at a distance of 16 m from a single tree source and 180 m from a cashew field. The maximum existing spacing between cashew trees in Tanzania is 12 x 12 m and the distance between two adjacent fields is hardly 20 metres. This shows that the disease develops rapidly and spreads over greater distances than the existing spacing between trees. The likelihood of sanitary measures alone being effective in managing the disease are low given the amount of unattended cashew trees in Tanzania. These unattended cashew trees ensure that initial inoculum will always be available except in some isolated areas.

The present study has shown that there was great variation in numbers of immature shoots produced in different districts. Higher numbers of immature shoots were present on trees in the Newala and Mtwara districts than in Nachingwea and Tunduru districts. High numbers of immature shoots provide more sites for powdery mildew development and build-up of inoculum at the beginning of the growing season. This suggests that in districts such as Newala and Mtwara with higher production of immature shoots, there is greater potential for high initial inoculum of *O. anacardii*. In contrast, however, other areas such as Nachingwea and Tunduru districts with relatively lower numbers of immature shoots produced during off-season, initial production of initial inoculum will be reduced.

Due to differences in the production of immature shoots on cashew in various locations, it may be possible to exploit such variations to develop more effective control measures of cashew powdery mildew disease. In Nachingwea and Tunduru districts, for example, where survival is more restricted, initial inoculum may be considerably reduced by adopting sanitation practices. Such control measures could result in delaying the onset of cashew powdery mildew epidemics. Effective eradication of initial inoculum would greatly supplement chemical control using sulphur, possibly reducing the number of applications per season.

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