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Prevalence of Cashew Powdery Mildew Disease in Western Province of Zambia

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***Abstract*— *Cashew powdery mildew disease (PMD) is the most devastating disease of cashew nuts lowering nut yields and quality in Zambia and the rest of the world. Information on prevalence patterns and timing of disease onset is vital to manage the disease in any country effectively. Cashew powdery mildew disease incidence and severity were assessed from 160 farmers randomly chosen from all agricultural camps in eight of the ten cashew-growing districts of the Western province of Zambia in April, May, June and July 2020. A two-way ANOVA was used to compare disease severity by month and district. Results showed significant differences ($P < 0.001$) in both PMD incidence and severity among different districts, with the highest incidence in Limulunga (55.88 %) and the least in Sikongo District (36.49 %). Disease severity was highest in Nalolo (57.49 %) and lowest in Sioma district (27.87 %). July registered the highest (61.89 %), and April had the lowest (20.08%) incidence of the disease. PMD severity was highest in July (51.69 %). The current study indicates that one of the best strategies to control PMD in this cashew-growing province of Zambia is to include control measures such as the removal of water shoots beginning February through March for all districts, chemical control beginning in April in Limulunga district and delayed to May for the rest of the districts. The study has also identified the hotspots of PMD that should be priority targets for disease management to maximize the use of limited resources.*

Keywords*— *Anacardium occidentale, powdery mildew disease, incidence, severity

I. INTRODUCTION

Cashew (*Anacardium occidentale* Linn.) is an evergreen perennial nut crop in the flowering family *Anacardiaceae* (Majune *et al*., 2018; Ohler, 1979). It is native to northeastern Brazil but is widely grown in tropical climates, including Zambia. The plant was introduced to Africa in the 16th century (Ohler, 1979) and to Zambia in the 1940s (NA, 2016). Cashew is an important crop for nutrition and income generation worldwide (Majune *et al*., 2018; Mange *et al.*, 2014).

The current cashew yield in Zambia stands at 0. 850 MT/ha despite having a potential of 1.3 MT/ha (NA, 2016). This low yield is due to various abiotic and biotic factors that severely constrain cashew production in Zambia (ZARI, 2018). Some of the biotic humpers include pests and diseases such as *Helopeltis* and powdery mildew, respectively. Although the relative extent of damage is by far unknown, powdery mildew is probably the most devastating biotic factor in cashew production in Zambia. The disease was first detected in Zambia in 1979 (Uaciquete *et al*., 2003; Zhongrun & Masawe, 2014), and it is known to be the major constraint to cashew production worldwide (Sijaona *et al.*, 2006), associated with crop losses of 70 to 100% (Shomari & Kennedy, 1999; Sijaona & Shomari, 1987). The disease affects all young parts of the shoot, including leaves, inflorescences, apples, and nuts, reducing the visual quality and yield of cashew apples and nuts (Glawe, 2008; Sijaona & Shomari, 1987) as well as the nutritional status (Uaciquete *et al*.,2017).

Although smallholder farmers have reported the occurrence of PMD in Zambia, the extent of the damage has not been quantified (ZARI, 2018 Unpublished). In addition, incidence and severity patterns and hotspots of PMD have yet to be systematically assessed, thereby hindering the deployment of appropriate control strategies for this disease in Zambia. In addition, knowledge of the timing of disease onset in Zambia remains largely unknown, yet such information is vital in triggering the deployment of control measures. Currently, cashew farmers in Zambia use chemical control in a haphazard manner, a situation that has resulted in the excessive use of dangerous chemicals, engendering humans and the environment. Therefore, the current study sought to assess the incidence and severity of cashew powdery mildew disease to generate information for improved management of the disease in the cashew-growing region of Zambia.

II. MATERIALS AND METHODS

3.1.1. Study Locations

The survey was conducted in 8 districts of the western province, namely, Kalabo, Limulunga, Lukulu, Mongu, Nalolo, Senanga, Sikongo and Sioma (Figure 1). The districts were purposively selected because they are the cashew-growing districts of the province. Both commercial and family cashew orchards were assessed in the study.

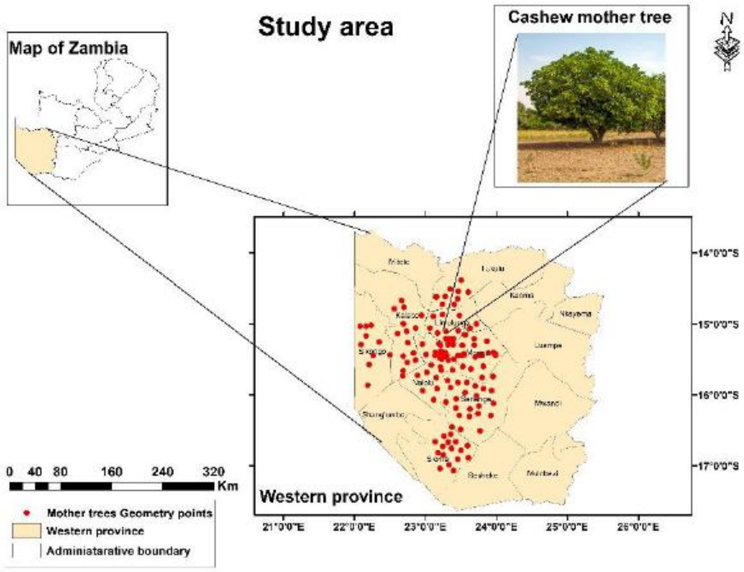


Fig.1: Sampling sites in 8 cashew-growing districts of the Western Province of Zambia.

Map developed using the software ArcGIS version 10.7.1 from the GPS coordinates recorded during the survey.

Disease incidence and severity Assessment

Disease incidence and severity were assayed on 160 trees at the first flash, flowering and panicle initiation stages of cashew from April to July 2020, as done previously (Sijaona *et al*., 2006). Depending on the size of the plantation, the zigzag or transact-walk sampling method was used to pick at least 20 cashew trees in each farmer's field (Gomez & Gomez, 1984). PMD incidence and severity were assessed per field and sampling date, based on the previously standardized scale (Nathaniels, 1990; 1996; Sijaona & Mansfield, 2001) as shown in table 1 below;

Table 1: Powdery mildew disease severity standard used in the study (modified from Nathaniels, 1990)

Infection Scale	Infection
0	No lesions
1	Powdery mildew fungus covering less than 5% of the leaf
2	Powdery mildew fungus covering 5% - 15% of the leaf
3	Powdery mildew fungus covering 15% - 25% of the leaf
4	Powdery mildew fungus covering 25% - 35% of the leaf
5	Powdery mildew fungus covering more than 35% of the leaf

The north and south sides of the tree canopy were scored based on the above standard (Table 1) using a 1 m x 1 m quadrant (Majune *et al.*, 2019). Four rounds of scoring, one month apart, corresponding with the phenological stages indicated previously (Adiga *et al*., 2019), were conducted for both PMD incidence and severity. Severity scores were converted to percentages for ease of presentation. Tree means were used to perform the statistical Analysis for PMD severity.

III. DATA ANALYSIS

Data were checked for normality, and where necessary, arcsine transformed prior to Analysis (Gomez & Gomez, 1984). However, only actual means are presented for clarity. A 4 x 8 two-way analysis of variance (ANOVA) was used to assess variability in incidence and severity among districts and months and to check for the presence of interaction between district or location and month of sampling. Means were separated using the Bonferroni test at a 5% significance level because of its advantage of allowing the comparison of several variables to avoid false data appearing statistically significant.

IV. RESULTS

Cashew Powdery mildew disease incidence across districts and months

There were significant differences ($P < 0.001$) in PMD incidence and severity among the different districts and months (table 2). The incidence and severity in districts depended on the month of assessment.

Table 2.0 Mean squares for Analysis of variance of cashew powdery mildew disease incidence and severity across districts evaluated from Western Province.

Source of variation	d.f	MS PMD Incidence	MS PMD everity
District	7	2287.5***	9081.854***
Month	3	63463.6***	41741.4***
District x Month	21	1157***	3097.08***
Error	608	113.7***	55.04***
Total	639		

*** Data significant at $P = 0.01$; d.f- degree of freedom, ms- mean square

The highest severity was recorded in Nalolo (57.48%), followed by Sikongo (50.61%), while Sioma had the lowest severity (27.84%). The district with the highest incidence was Limulunga (55.88 %, table 3), followed by Senanga (49.14%), while Sikongo had the least (36.49 %).

District	Severity (%)	Incidence (%)
Sioma	27.84[a]	47.15[b]
Limulunga	29.45[ab]	55.88[c]
Lukulu	31.53[b]	36.49[a]
Senanga	31.89[b]	49.14[b]
Mongu	37.58[c]	44.51[b]
Kalabo	38.73[c]	47.23[b]
Sikongo	50.61[d]	46.32[b]
Nalolo	57.48[e]	46.12[b]
Mean	**37.102**	**46.61**

Table 3.0: PMD severity and incidence by the district in the Western Province of Zambia in 2020

[a]Means followed by the same letter within the column are not statistically different by Fisher's protected least significant difference test performed at P = 0. 05

The highest severity was recorded in July (51.69%, table 4), followed by June (50.9%), while April had the lowest severity (18.27%). The months with the highest incidence of PMD were June (61.89%) and July (61.96%), followed by May (42.49%), while April had the least (20.08 %).

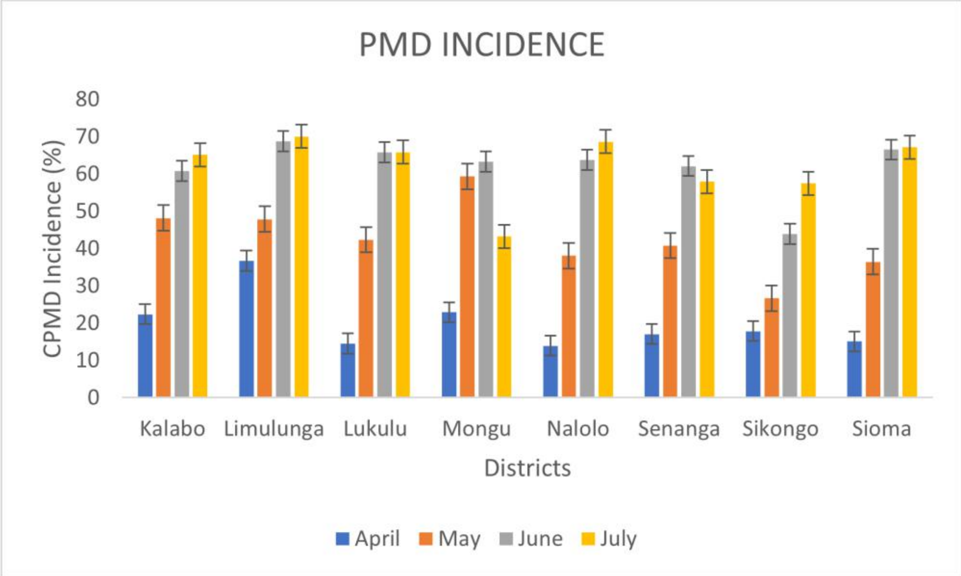
Table 4.0: PMD severity and incidence by month in the Western Province of Zambia in 2020

Months	Severity (%)	Incidence (%)
April	18.27[a]	20.08[a]
May	31.69[b]	42.49[b]
June	50.9[c]	61.89[c]
July	51.69[d]	61.96[c]
Mean	**38.14**	**46.6**

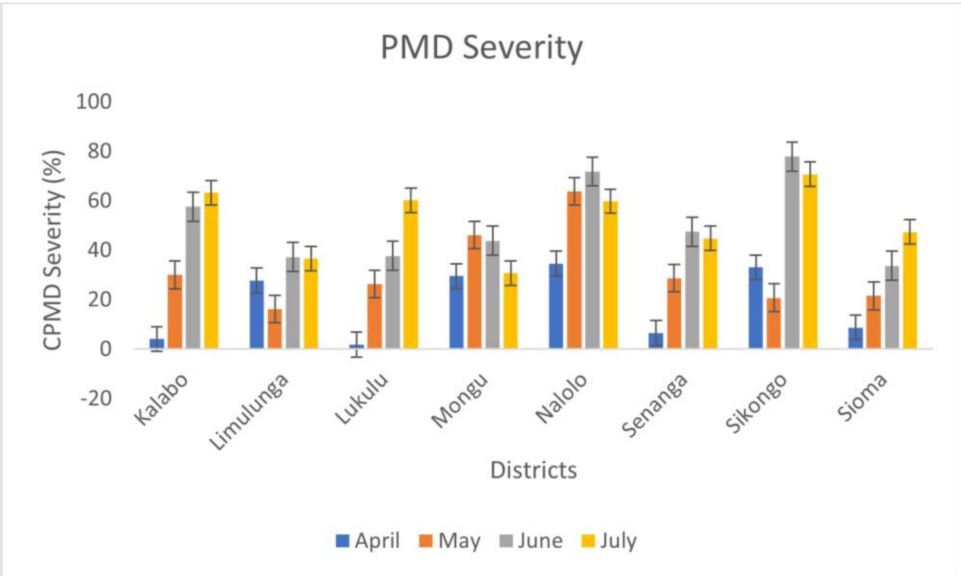
[a]Means followed by the same letter within the column are not statistically different at P=0.05

The disease incidence in the districts depended on months as there was a significant location-by-month interaction which was observed as shown in graphs 1 and 2 below;

Graph 1. PMD incidence from April to July 2020



Graph 2. PMD severity from April to July 2020



V. DISCUSSION

Prevalence of CPMD by district

This study determined the incidence and severity of cashew powdery mildew disease in the Western Province of Zambia. The results showed that Limulunga district had the highest PMD incidence (55.88%) while Sikongo district had the lowest (36.9%). These results indicate that PMD is widespread in the locations studied. These relatively high occurrences of PMD in cashew nuts could be due to the predominant use of susceptible planting materials (Wonni *et al.*, 2017; Masawe, 1996) or favourable environmental conditions for developing PMD. The temperatures during study periods ranged from 15^0C to 28^0C, a range very supportive of PMD (Sijaona *et al.*, 2001). In addition, inappropriate cultural practices such as lack of selective thinning, formative pruning, top-working, gap filling using grafted seedlings, clonal and polyclonal seedlings, intercropping, the possible emergence of a new and virulent pathotype, and a possible narrow genetic base of the cashew population in Zambia could be responsible for the observed high incidence and severity in the study sites (Milheiro & Evaristo, 1994; Prasad *et al.*, 2000). However, studies are needed on the virulence of the causal organism in Zambia to confirm this. Although the prevalence rates were high in all districts, Limulunga has much higher rates than the rest of the province. Although the results clearly show variation in the prevalence of

PMD in the study sites and that genetic-environmental interactions may have contributed to the observed differences in powdery mildew prevalence, it is improbable that the environment had a significant impact on the incidence and severity of PMD in the study sites since the environmental conditions for the study sites do not differ significantly. The sites lie in the same agroecological zone with similar rainfall, temperature, and humidity. Therefore, such observations are more likely resulting from the effect of host susceptibility and pathogen virulence differences from one district to the next PMD (Majune *et al*., 2018; Sijaona *et al.*, 2005; Sijaona *et al.*, 2006). This study clearly shows that Limulunga should receive proportionately higher mitigation efforts compared to other district districts in order to prevent losses due to PMD in the district.

Prevalence of CPMD by month

In general, the PMD incidence and severity were very low in April when the temperatures were slightly high and increased with a reduction in temperatures from May to July, which has the coldest days or lowest temperatures in the Western Province. This could be because the epidemic's development is favoured by dry and cold conditions (Glawe, 2008; Waller *et al.*, 1992; Milheiro & Evaristo, 1994). This is supported by previous studies (Majune *et al*., 2018; Agrios, 2005; Lopez, 2008; Suffert *et al*., 2011) that showed that three factors necessary for the disease to occur included host susceptibility, pathogen virulence, and a low temperature. In addition, earlier studies (Shomari & Kennedy,1998) demonstrated that *O. anarcadii* conidial germination and cashew tissue infection by a PMD pathogen occurred over a wide range of temperatures and humidity. Therefore, environmental factors that promote the fungus's growth and viability are expected to result in higher PMD disease prevalence (Shomari & Kennedy, 1999). Furthermore, differences in weather conditions are expected over time and between various cashew production areas (Nathaniels & Kennedy, 1996). Therefore, the different district patterns of epidemic development observed in the study sites agree with the findings reported in different regions of Tanzania (Nathaniels *et al.*, 1993; Nathaniels, 1990) and Mozambique (Uaciquete *et al.*, 2003; Nathaniels, 1994; Topper *et al*., 2000).

The phenological development stages of cashew nuts that are very susceptible to PMD attack are the leaf, shoot, inflorescence, flowering, and fruit development stages (Adiga *et al.*, 2019). In Zambia, these development stages occur from April to September. From December to early April, the cashew's principal growth stage is the vegetative leaf development stage, with minimal availability of susceptible tissue (Uaciquete *et al.*, 2003; Uaciquete *et al*., 2017) and unfavourable environmental conditions (Nathaniels *et al.*, 1996), hence the lower disease prevalence observed for April in all the study sites. The higher prevalence of the disease observed in Zambia from May through to July could be attributed to a more extended period of availability of susceptible tissue, a favourable environmental condition, and a virulent pathogen (Agrios, 2005), as it coincides with the most susceptible phenological developmental stages of cashew (Adiga *et al.*, 2019). Zhai *et al.* (2021) reported that the highest combined and mixed effects of temperature variables and the duration of leaf development to the maturation of rubber PMD are strongly influenced by both extrinsic and intrinsic factors, as that found in oak trees, which are highly affected by winter temperature and phenology (Marcais *et al*., 2018). The observed PMD progress in the study areas could also be related to the inoculum density in cashew trees (Martins *et al.*, 2018). Although the present study did not investigate the effect of temperature from one month to the next and leaf development phenology on cashew PMD severity, this is very likely for cashew, as observed from previous studies (Uaciquete *et al*., 2013; Nathaniels & Kennedy, 1996; Adiga *et al.*, 2019).

Cross-cutting issues

The above observations have led to the hypothesis that chemical applications for disease mitigation require more frequency in some regions than others because of climatic differences. This suggests that disease mitigation in Sikongo, Nalolo, Mongu, and Limulunga districts should begin in mid-April and in May for the rest of the districts to manage the disease effectively. This is because the disease control severity threshold should be 20% or above before reaching the economic threshold (Sijaona *et al.*, 2001). Therefore, severe losses in both cashew nut quality and quantity would be experienced if disease control is not done by this time. Field observations showed that the dwarf cashew genotypes exhibited high levels of disease tolerance compared to the common giant genotypes in the leaf-flushing phenological stages but were both susceptible at the inflorescence and flowering stages (unpublished). This observation suggests that chemical control of the disease for the dwarf genotypes could start at the inflorescence and flowering stages for the dwarf genotypes and the leaf-flushing development stage for the common giant genotypes, as this would be more economical even for resource-limited farmers. The variation in microclimate likely plays a role in the development and the evolution of the disease in the study locations as it was associated with the types of cashew genotypes, location, and the phenology of the trees (Lopez, 2008; Suffert *et al*., 2011).

VI. CONCLUSION AND RECOMMENDATIONS

This study revealed that PMD is widespread in the area surveyed and that prevalence differed by month and district. The study also revealed that incidence and severity increased from April to July and were highest in the Limulunga district. Therefore it is recommended that control measures such as the removal of water shoots should begin in February through March for all districts, while chemical control should be initiated in April in Limulunga district and delayed to May for the rest of the districts. The study has also identified other hotspots of PMD, in addition to Limulunga, that should be priority targets for disease management to maximize the use of limited resources.

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