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Prevalence of sorghum anthracnose in different agro-ecologies of Uganda

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Abstract

Nine major sorghum growing agro-ecologies of Uganda were surveyed to establish the sorghum anthracnose incidence and severity. Hierarchical sampling was used. Severity of anthracnose in the field was rated on a scale of 1-5 where 1= low severity and 5 = high severity. Analysis of Variance (ANOVA) results showed that there was variation in incidence and severity sorghum anthracnose disease. Both incidence and severity varied significantly (P<0.05) between agroecologies reflecting the effect of different cropping pattern on sorghum anthracnose epiphytotics. Districts within agroecologies showed a significant variation in both incidence (P<0.05) and severity (P<0.05) of sorghum anthracnose. This might be attributed to the different crop management practices carried out by the farmers within an agroecology. Similar observations were made for fields within the districts with significant differences occurring at P<0.05 for both incidence and severity. Variation in the prevalence, incidence and severity of the anthracnose epidemic in the sorghum growing agroecologies of Uganda suggest that sorghum anthracnose is a major threat to production in virtually all agro-ecologies in Uganda. Moreover the high severities suggest cultivation of very susceptible varieties. The cultivation of resistant varieties will support management of the disease.

Key words: Sorghum Anthracnose, Colletotrichum sublineolum, incidence, severity

Introduction

Sorghum anthracnose caused by *Colletotrichum sublineolum* is considered to be one of the most devastating diseases affecting cultivated sorghum (Sherriff *et al.,* 1995; Thakur and Mathur, 2000). Severe losses in many parts of the world have been attributed to high levels of incidence and severity of this disease due to conducive environments for proliferation of the pathogen. Estimates of yield losses from this disease in Uganda do not exist, but losses in excess of 50% have been reported on susceptible sorghum cultivars for anthracnose (Thomas *et al*., 1996)

In addition, alternative hosts and volunteer crops provide sources of primary inoculum, and seed transmission has been reported for *C. sublineolum* (Cardwell *et al.,* 1989). In the host crop, secondary spread of *C. sublineolum* is mainly through rain-splashed spores. Nicholson and Moraes (1980) speculated that the conidial mucilage may act as a protectant, allowing windborne dispersal of dry conidial masses.

While many countries have recognised sorghum anthracnose as a disease of concern, in Uganda, no quantifiable information is readily available about the problem. This study was, therefore, initiated to establish the magnitude of sorghum anthracnose in major sorghum growing districts of Uganda.

Materials and methods

Study area

Diseased sorghum leaves were collected from sorghum fields in nineteen districts of Uganda where sorghum and/or maize are commonly cultivated. These districts were selected to represent different agro-ecological zones, differentiated from each other by farming systems, edaphic factors; climatic factors, altitude and major vegetation cover (Wortmann and Eledu, 1999). Also, it is important to note that farming systems tend to overlap between districts and agro-ecological zones.

The districts of Lira, Kaberamaido, Soroti, Dokolo and Apac are found in the Northern moist Farmlands (Wortmann and Eledu, 1999). This agro-ecological zone is characterised by mean annual temperatures of about 20^{0}C and an annual precipitation of about 1200 mm received during one long rain season (Wortmann and Eledu, 1999; Ruecker *et al.,* 2003). The zone is on average 1073 meters above sea level. Two very similar farming systems exist in this agro-ecological zone; the annual cropping and cattle Northern system, practiced in Lira and the annual cropping and cattle Teso system, practiced in Soroti (Ruecker *et al.,* 2003). Both farming systems are characterised by unimodal rainfall seasonality, with annual precipitation potentials of 900 - 1200 mm of rainfall and temperatures ranging between 28 - 31^{0}C (Ruecker *et al.,* 2003).

Vegetation in both systems is characteristic of moist *Combetrum/ Butyrospermum* and grass savannas; short grassland ideal for grazing. The major cereals include millet (*Eleusine coracana*), maize, and sorghum. Mixed agriculture (crops and livestock) is practiced and the use of crop residues is very common in these systems. Soils are of poor to low productivity.

The district of Amuria is found in the North-Eastern Central Grass-Bush Farmland (Wortmann and Eledu, 1999). This agro-ecological zone is characterised by the mean annual rainfall varies from 1000 - 1500 milimeters and records a mean annual maximum temperature of 31.3°C and a mean minimum of 18°C. The agro-ecological zone lies approximately between 1,036 - 1,127 meters above sea level. The soils are mainly of ferralitic type (sandy sediments and sandy loam). They are well drained and friable. Bottomland contains widespread deposits of alluvium. The vegetation in this district largely comprises of savannah grasslands dotted with shrubs and trees. It can generally be described as a wood land/shrub land – grassland vegetation dominated by *Acacia, Conbretum, Piliostigma, Butyrosperum paradoxum and Hyperenia* species. Most areas are underlain by rocks of basement complex of precambrian age, which include: granites, mignalites, gneiss, schists and quartzites.

The districts of Kumi and Pallisa are found in the Southern and Eastern Lake Kyoga Basin (Wortmann and Eledu, 1999). This agro-ecological zone receives an annual precipitation of 1200 mm, with mean temperatures of 28 - 31^{0}C and is 1143 meters above sea level. The farming system prevalent in Kumi district is the annual cropping and cattle Teso system whereas, the farming system in Pallisa is the Banana-millet-cotton system. Vegetation in this system is moist *Combetrum/Terminalia/ Butyrospermum* savannah with moderate biomass production. The major cereals include millet, sorghum and maize. In the drier areas, livestock keeping is the main activity.

Iganga, Mbale, Masaka, and Tororo districts represented the Lake Victoria Crescent and Mbale Farmlands (Wortmann and Eledu, 1999). This agro-ecological zone is about 1106 meters above sea level with mean annual precipitation between 1200 - 1400 mm of rainfall received during two rain seasons (Ruecker *et al.,* 2003). The banana-millet-cotton system is the farming system prevalent in Tororo. Conversely, the farming system practiced in Iganga district is the intensive Banana-Coffee lake shore system. The Lake Victoria Crescent and Mbale Farmlands are characterised by soils of medium to high productivity. Vegetation is mainly forest-savannah mosaic with pastures suitable for intensive livestock production.

Maize and banana are the major crops in this agro-ecological zone; sorghum, millet, and sweet potatoes are secondary food security crops. Livestock are generally not integrated into the system but dairy cattle are gaining in prominence.

The districts of Bushenyi, Kabale and Rukungiri are found in the Bushenyi - North Rukungiri Farmland, and Kabale-Rukungiri highlands (Wortmann and Eledu, 1999). This agro-ecological zone receives annual rainfall exceeds 1875 mm, with mean temperatures of < 20^{0}C and is 2123 meters above sea level. It is hilly, with steep slopes in some areas and the dominant soils are highly-weathered ferralitic and sandy loams with some sandy clay loams but nutrient supply is generally good and productivity is medium to high. In this agro-ecological zone, there is greater reliance on annual food crops (millet, sorghum and maize) since rainfall is less stable than under the Banana-Coffee System. In the drier areas, livestock is a main activity. The farming system prevalent in this region is Western Banana- Coffee- Cattle System. The major cereals include millet, sorghum and maize.

The districts of Nebbi and Arua are found in the West Nile farm lands (Wortmann and Eledu, 1999). This agro-ecological zone receives rainfall of about 1250 mm annually and occurs in 140 to 170 days of the year, with mean temperatures of 28 - 31^{0}C and is 1143 meters above sea level. The farming system is the West Nile Cereal- Cassava-Tobacco system and the rainfall is adequate for most crops but the intensity of the dry season requires that drought tolerant annuals are cultivated (finger millet, sesame, cassava and sorghum). Tobacco and cotton are major cash crops. Intercropping is common with a wide variety of crops. The system is in the sub-humid zone and livestock activities are limited by the presence of tsetse fly (*Glossina* sp).

Hoima and Masindi district are found in the Western Mid-altitude farmlands and Semiliki flats. This agro-ecological zone receives about 875-1000 mm of rainfall falling in 80 to 100 days, with mean temperatures of 28-31^{0}C and is 1143 meters above sea level. Temperatures are high and vegetation varies from medium altitude moist forests, forest-savanna mosaic, savanna and swamps to post-cultivation communities. The forest-savanna mosaic is the most widespread and consists of a mixture of forest remnants, incoming savanna trees and a grass layer dominated by *Pennisetum purpureum* (elephant grass).

Sampling strategy

Hierarchical sampling was used to collect anthracnose diseased sorghum leaf samples from sixteen districts within seven agro-ecologies. This was done to permit the capture of diversity at leaf, plant, fields within location and fields between locations. In the sampling structure, at least two districts were selected per agro-ecology and within each district; 15-20 farms were visited. Leaf samples were picked at 20 m intervals across each field, 80-100 diseased leaf sample were collected per district depending on field sizes and disease incidence. Global Positioning Systems (GPS) readings were taken at each sampling point using a GPS receiver model 315 (Magellan Navigation, Inc. Tulsa, Oklahoma, U.S.A). The coordinates were used to generate maps using the Geographic Information Systems (GIS) software Arc View 3.2a and spatial analyst 1.1 (Environmental Systems Research Institute, Inc. Seattle, WA, U.S.A). All disease samples were taken from the most susceptible red local variety because they were the most common variety grown and exhibited the highest incidence and severity and also because farmer's lack of knowledge of the other varieties they cultivated.

Disease assessment

Anthracnose disease incidence data in each field was assessed by counting the total number of plants along a transect and expressing the proportion of diseased plants as percentage of the total. Severity of anthracnose in the field was rated on a scale of 1-5 where 1= low severity and 5 = high severity (Ward *et al.,* 1997; Ward *et al.,* 1999). These data were used to generate a disease maps using the GIS software Arc View 3.2a with spatial analyst by interpolating the surface from GPS points and the associated field severity data using the inverse distance weighted interpolation method. Prior to interpolation, a power parameter of 5 was set to control for influence of surrounding points at each location (Environmental Systems Research Institute, Inc. Seattle, WA, and U.S.A).

Data analyses

Statistical analyses were performed using Genstat 5 version 3.2, 1995 (Lawes Agricultural Trust: Rothamsted Experimental Station, UK). Field incidence and severity data were subjected to one-way analysis of variance (ANOVA) (Steel *et al.,* 1997). Field severity was also subjected to nested analysis of variance using MINITAB release 15 version 15.0.0.1, 2007 (Minitab Inc, Pennsylvania, USA).

Results

Incidence and severity

There was variation in incidence and severity of sorghum anthracnose disease. Both incidence and severity (248.24 and 7.1874 respectively, Table 1) varied significantly ($P<0.05$) between agroecologies, reflecting the effect of different cropping patterns on sorghum anthracnose epiphytotics. Districts within agroecologies showed a significant variation (P<0.05) in both incidence and severity (173.31and 6.9178 respectively, of sorghum anthracnose. Similar observations were made for fields within the districts with significant differences at P<0.05 occurring for both incidence and severity (181.18 and 4.1330, respectively, Table 1).

The highest sorghum incidences were registered in Northern moist farmland, Western mid-altitude Farmlands and the Semiliki flats, Bushenyi- Northern Rukungiri Farmland and Kabale-Rukungiri highlands all at 100% (Table 2). The associated severities were 3.7, 3.2, 4.0, 3.4, 3.1, 3.4, and 3.2 respectively. In these agroecological zones, the farming system which exists there comprised of sorghum-maize intercrops. On the other hand, the Southern and Eastern Lake Kyoga basin registered low incidence (94.76%) compared all the agroecologies and a mean severity score (2.9). In this agroecology, the cropping pattern comprised blocks of sorghum and maize

Table 1. Mean squares of sorghum anthracnose incidence and severity at the different hierarchical levels

Source of variation	Mean square		
	d.f	incidence	severity
Agro ecological zone	7	248.24*	7.1874*
Districts	19	173.31*	6.9178*
Fields	43	181.18*	4.1330*

* indicate mean squares significant at the P≤ 0.05 level

Table 2. Sorghum anthracnose mean incidence and severity in the different agroecologies of Uganda

Study site	Incidence (%)	Severity
Agroecological zone		
Lake Victoria crescent and Mbale farmland	97.5	3.0
Southern and Eastern Lake Kyoga basin	94.8	3.0
Northern moist farmland	100.0	3.7
West Nile farm land	97.9	2.9
Western Mid-altitude farmlands and the Semiliki flats	100.0	3.2
Bushenyi - Northern Rukungiri farmland (Southwestern Highland)	100.0	4.0
Kabale- Rukungiri highlands	100.0	3.2
Mean	98.5	3.2
SED	2.3	0.3
CV%	6.7	29.3

CV = coefficient of variation, SED= Standard Error of Difference of mean fields grown side by side and rarely intercropped. Thirteen districts had the highest incidence of 100% and mean severity of 3; while the six scored below. Out of the entire nineteen districts Mbale district scored the lowest incidence of 89% and severity of 2.2 (Table 3).

Colletotrichum sublineolum and anthracnose epiphytotics

Significant differences (P < 0.05) were observed in anthracnose severity in agro-ecological zones (9.93), districts within agro-ecological zones (8.81) and fields within districts (3.23) (Table 4). The analysis confirmed what was observed on incidence and severity of disease in all the sorghum growing districts. In fact, all the three levels of hierarchy tested i.e. agroecology, district and field had significantly different levels of epidemics (Table 3, 4).

Table 3. Sorghum anthracnose mean incidence and severity at the different district

Study site	Incidence (%)	Severity
District		
Iganga	95.5	2.5
Tororo	100.0	3.3
Bushenyi	100.0	4.0
Rukungiri	100.0	2.9
Kabale	100.0	3.5
Masaka	100.0	3.8
Mbale	89.0	2.2
Pallisa	95.2	3.1
Arua	99.0	3.2
Lira	100.0	3.4
Hoima	100.0	2.8
Apac	100.0	4.3
Soroti	100.0	3.4
Masindi	100.0	3.5
Nebbi	96.7	2.6
Kumi	94.4	2.8
Amuria	100.0	3.4
Dokolo	100.0	3.1
Kaberamaido	100.0	3.4
Mean	98.5	3.1
SED	2.5	0.3
CV %	6.5	27.2

CV = coefficient of variation, SED= Standard Error of Difference of mean

Spatial distribution of sorghum anthracnose

The disease severity/incidence data and GPS recordings were used to construct a disease map. The disease map illustrates severity and incidence levels over the agroecologies and was used to study epidemics pattern levels at time of the study (Fig. 2). The data show that highest disease severities were recorded in the wet humid regions such as Lira and Apac districts. The cooler agroecologies had relatively lower severity (Fig. 2). In terms of incidence virtually all districts recorded very high levels of disease (Fig. 3). The majority of districts recorded 100% incidences in fields. There was no field where anthracnose was not recorded (Fig. 3).

Discussion

Severity and incidence patterns

Anthracnose was predominant and widely distributed in all the Ugandan agroecologies. The disease incidence was on average of 98.5% and the severity of 3.3 in the farmers' field in all the agro-ecologies. The local sorghum landrace cultivars and the improved sorghum all exhibited anthracnose symptoms. These results demonstrate that sorghum anthracnose has a wider distribution in the country than was earlier thought and confirms that indeed the disease is a major threat to sorghum production in the country.

Table 4. Nested analysis of variance for severity, base on 3 levels of hierarchy used in study

Source	df	Sequential sum of squares	Adjusted mean squares	F-Value
Agroecology	8	57.8348	6.4537	9.93*
District (agroecology)	10	56.5558	5.7275	8.81*
Fields (agroecology district)	24	50.4425	2.1018	3.23*
Error	419	272.3032	0.6499	
Total	146	437.1364		

District (Agroecology) = District nested within agro-ecological zone
Field (Agroecology District) = District nested within both agro-ecological zone and District
** = significant at (P ≤ 0.05)

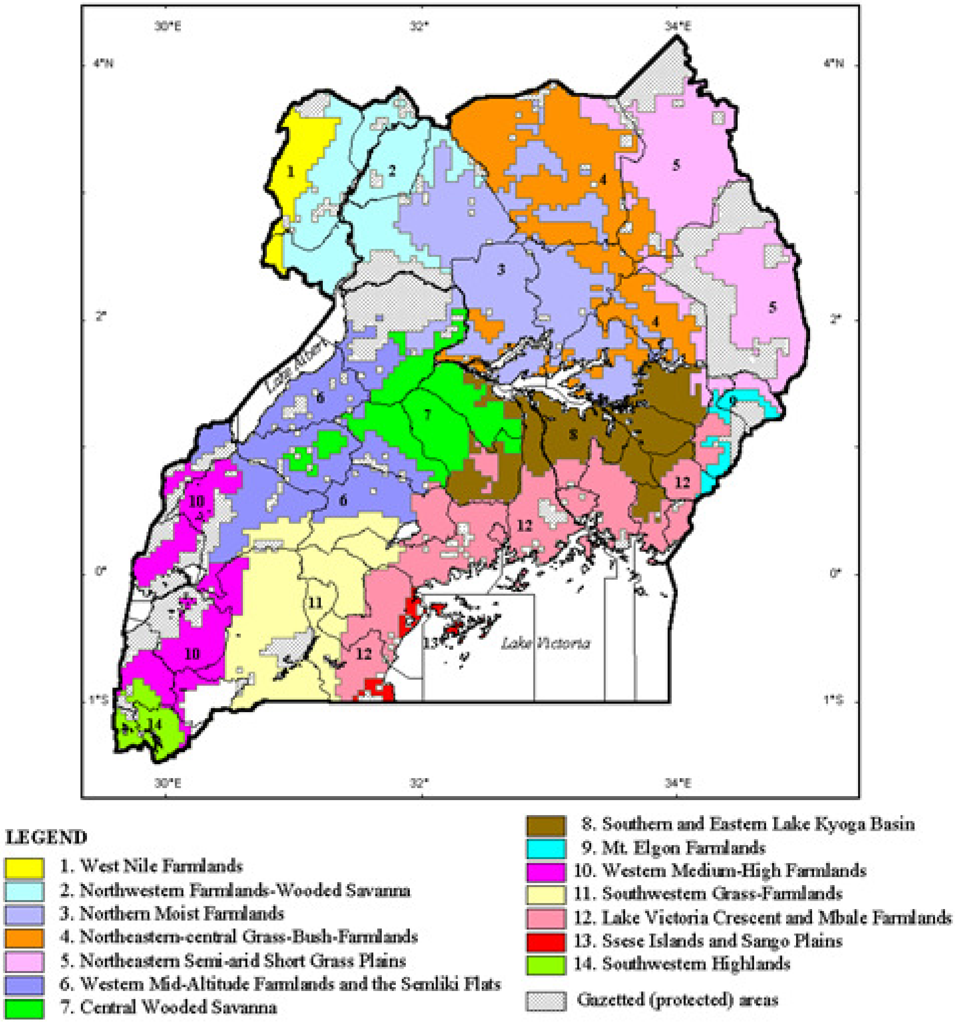

Figure 1. Map of Uganda showing an aggregation of the agro-ecological zones. Study areas are marked and enclosed in boxes.

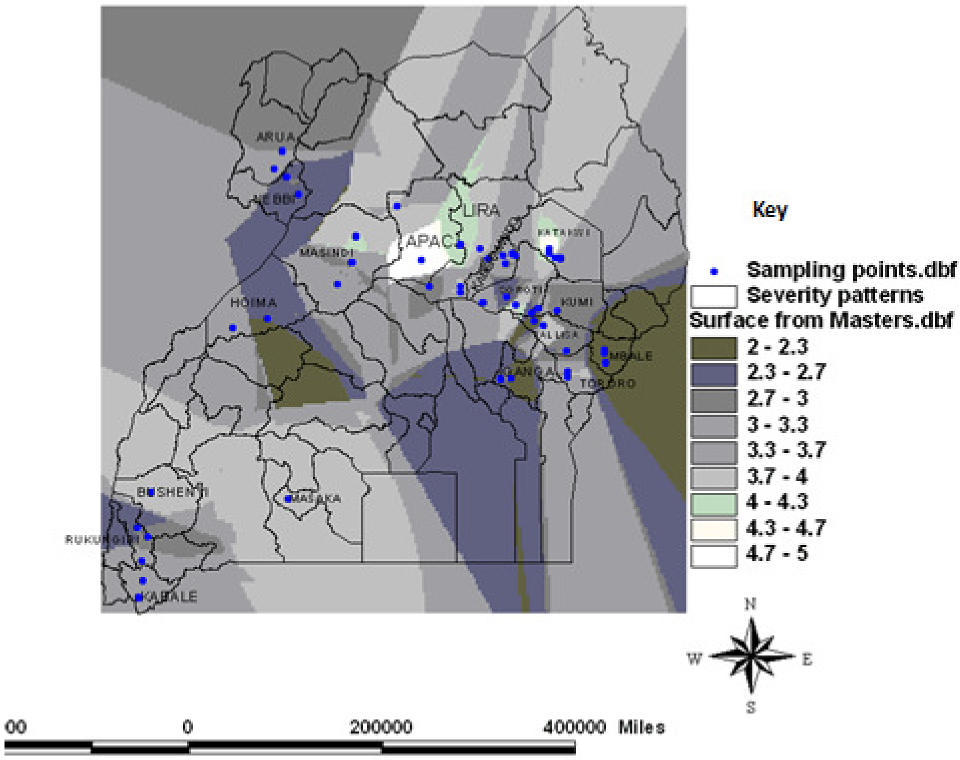

Figure 2. Disease map showing sorghum anthracnose severity patterns in various agroecologies of Uganda. The variations in colour/shades over the map are used to typify disease severity patterns in the study areas. Districts that are labeled are the ones where the study was conducted.

Part of the reason for the high incidence can be attributed to high inoculum level associated with Uganda's farming systems (Okori, 2004). Farmers generally, do not practice closed seasons (do not plant the crop in one season of the year) and grow the crop year to year. This leads to quick inoculum build-up. From the literature, *C. sublineolum* can survive from season to season as mycelia, sclerotia or chlamydospores on infected crop debris or in the soil (Casela *et al.*, 1993). Moreover, alternative hosts and volunteer crops may also provide sources of primary inoculum, and seed transmission has been reported for *C. sublineolum* (Cardwell *et al.,* 1989).

Anthracnose, a polycyclic and epidemic disease, is favoured by high rainfall and humidity, moderate temperatures and the presence of large amounts of inoculum (Frederiksen, 1986). Previous studies on epidemiology of anthracnose have indicated that the disease is mostly severe with mature plants (Mishra *et al.,* 1992). These facts suggest that the high incidence detected throughout this study could in fact be compounded by effects of inoculum build –up and susceptible cultivars. This would be expected of a pathosystem involving an aggressive pathogen and a susceptible host (Agrois, 1997; Okori, 2004).

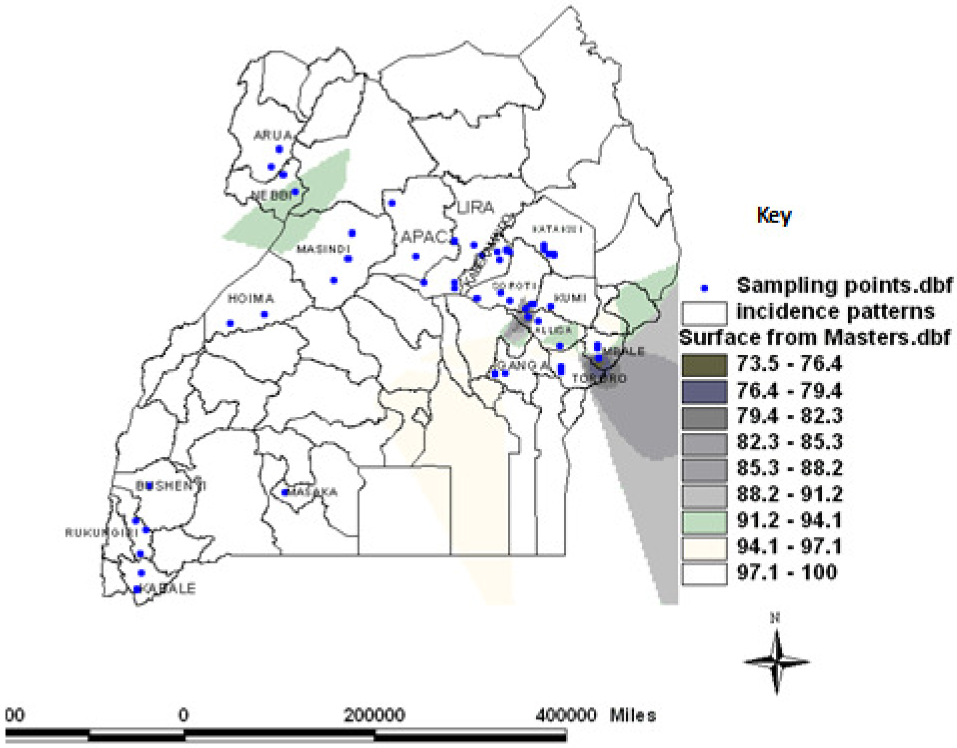

Figure 3. Disease map showing sorghum anthracnose incidence patterns. The variations in colour/shades over the map are used to typify disease severity patterns in the study areas. Districts that are labeled are the ones where the study was conducted.

Anthracnose was generally observed in all areas studied. Earlier reviews on sorghum anthracnose suggest that the disease occurs in all sorghum growing areas of the world with completely different climatic conditions (Ali and Warren, 1987). In the Uganda anthracnose-sorghum pathosystem, the interactive role of the environment, plant mineral nutrition and variety effects on epidemics under different conditions have been reported (Frederiksen *et al.,* 1995). The pathogen causes severe damage during rainy season in a wide climatic range from the hot (35 ^{o}C) and dry savannas Niger and Mali to the cool (12 ^{o}C) and wet (2200 mm average rainfall) highlands of Rwanda (Frederiksen *et al.,* 1995). Casela *et al.* (1993) reported that *Colletotrichum* produce small sclerotia embedded in stalks of mature infected sorghum plants. These sclerotia appear to be an important means by which the organism survives in many sorghum growing regions. Such a phenomenon may account for high disease incidence and severity observed during this study.

In this study, agroecologies experiencing warm and humid conditions had high disease incidence and severity perhaps due to favourable weather conditions in general. However, there was a generally high incidence and severity perhaps due to susceptible varieties cultivated by the farming communities. On average, disease severity was 3, suggesting susceptibility of sorghum varieties to *C. sublineolum.* The majority of farmers/farms visited during the study, cultivated sorghum for subsistence purposes. There was limited evidence of adoption of elite resistant varieties in the majority of farms visited. Even districts close to the sorghum research programme of NASARI registered high incidences. For example, Apac, Soroti, Amuria, all had high severity close to 4 indicative of limited adoption. The low severities in Western Nile farmlands and Western mid altitude compared to the rest of the country could be attributed unfavorable climatic condition of low humidity due to the high temperature ranging from 28 - 31 ^{o} C (Wortmann and Eledu, 1999).

Nested ANOVA revealed significant differences in anthracnose severity at the agroecological zone level, district within the agroecology and fields within districts. These findings allude to the relative importance of within field condition variations that might impact on anthracnose epiphytotics relative to the broader differences between agroecological zones (Wang and Schmidt, 2002). Other studies have suggested local adaptation as a possible explanation to the predicted severities obtained at different locations attributable mainly to host availability. Local adaptation has been confirmed among isolates and/or races of the bean pathogen *Colletotricum lindemuthianum* (Gandon *et al.,* 1996; Kaltz and Shykoff, 1998; Capelle and Neema, 2005).

Conclusion

The high severity and incidence of anthracnose suggest that sorghum anthracnose is a major threat to production in virtually all agroecologies of Uganda. Morever, the high severities suggest cultivation of very susceptible varieties. No evidence was found for massive adoption of elite varieties perhaps accounting for the high disease incidence recorded. This combination of susceptible genotypes and good weather (warm-humid) supports high disease severity and incidence. It is therefore obvious that deployment of disease resistant varieties will go a long way in management of sorghum anthracnose.

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