Plant Health Survey

Survey of Fungal Foliar and Panicle Diseases of Sorghum in Important Agroecological Zones of Tanzania and Uganda

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Abstract

A survey was conducted in 2014 to determine the prevalence of fungal diseases on sorghum across different agroecological zones in Tanzania and Uganda. In Tanzania, 37 sorghum fields were sampled in Dodoma and Singida Provinces, representing the central drier areas, and in Simiyu, Shinyanga, Mwanza, and Mara Provinces, representing the lake-zone region. In Uganda, 134 fields were sampled across four agroecological zones of Teso, Western, Northern, and West Nile. Farmers were purposively selected, and at least 30 plants per field along two diagonal transects were visually assessed for disease. Ten and 14 diseases were identified in Tanzania and Uganda, respectively. Among the major diseases identified, those more prevalent in Tanzania than in Uganda were leaf blight caused by *Setosphaeria turcica* ($P = 0.0031$) and rust caused by *Puccinia purpurea* ($P < 0.0001$). Major diseases more prevalent in Uganda than in Tanzania were anthracnose caused by *Colletotrichum sublineola* ($P = 0.0207$) and zonate leaf spot caused by *Gloeocercospora sorghi* ($P = 0.0312$). We report for the first time the occurrence of ladder leaf spot caused by *Cercospora fusimaculans* in Uganda and confirm its occurrence in Tanzania. This is the first comprehensive sorghum disease survey report in over 15 years in both countries.

Sorghum (*Sorghum bicolor* L.) is an important crop utilized for food and brewing alcohol in Tanzania and Uganda. In Tanzania, the crop is mainly grown in Dodoma, Singida, Shinyanga, Mwanza, and Mara Provinces, which fall in the central, western, and lake-zone regions of the country (Monyo et al. 2004; Rowhani et al. 2011). Improved varieties such as Lulu, Pato, Macia, Serena, and Tegemeo are liked by farmers, who cite early maturity and drought tolerance as important traits (Monyo et al. 2004); however, landraces are still planted (Table 1). Interestingly, over the past few years, the net change of area under production and the annual production have both increased (by 4.6 and 1.6%, respectively); however, yield gains over the same period have reduced by 2.9% (FAO 2015), probably owing to increased biotic and abiotic stresses. Between 2010 and 2013, the total production of sorghum in Tanzania ranged from 798,000 metric tons to a high of 838,000 metric tons in 2012 (FAO 2015).

In Uganda, sorghum, the third most important cereal food crop, is grown across five agroecological zones: Teso, Western, Northern, West Nile, and the South West highlands (Ebiyau et al. 2005). Both local (i.e., Akindi and Dura) and improved varieties (i.e., Seso1 and Gadam) are also grown in Uganda (Table 1). Recent crop production statistics indicate that production of sorghum in Uganda peaked in 2011 at 437,000 metric tons but dropped to 300,000 metric tons in 2013. Productivity also dropped from 1.2 metric tons/ha in 2011 to 854 kg/ha in 2013. Importantly, unlike in Tanzania,

TABLE 1
Varieties and landraces of sorghum identified in the field during the survey in Tanzania and Uganda

Country, agroecological zone	Varieties or landraces
Uganda	
Teso	Landrace: Abir, Ededei, Elemurieng, Emumwai, Epuripur, Eterema, Otura, red local
	Improved: Gadam, Seso1, Seso2, Seso3, Serena, Socadido, Sekedo
Northern	Landrace: Abiri, Amira (red), Awera (white), Ayi yak (loose), Eideidei, Emumwai, Lawena, Lawerk
	Improved: IESU 8191, Seso1, Seso3, Serena, twin seed
Western	Landrace: red local, white local
	Improved: Seso1, Seso3
West Nile	Landrace: Akindi, Dura
	Improved: God'o, Goma, Goma Red
Tanzania	
Central	Landrace: Isusu, Kakela, Langa Langa Nyeupe, Ntora, Manyi ya Ng'ombe, Nkolongo, Langa Langa Ibiwa, Gangisi
	Improved: Hakika, Sila, Pato, Tegemeo, KARI Mtama1, Wahi
Lake zone	Landrace: Bukenya, Ukula, Mwanagudungu, Nyakochol, Ochuti, Ochuti Fupi
	Improved: Macia, hybrid, Weijita, KARI Mtama1, Hakika, ATX623 × Macia

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there has been a decline in area harvested, production, and yield, by 0.18, 10, and 10%, respectively (FAO 2015).

There is no updated and comprehensive information on the occurrence of diseases affecting sorghum in Tanzania and Uganda. The last published comprehensive report listing sorghum diseases in Tanzania (de Milliano 1992) and Uganda (Guiragossian 1986; Hulluka and Esele 1992) showed that 17 and 15 diseases, respectively, had been reported and confirmed. However, recent reports on the occurrence of individual diseases have been published (Bigirwa et al. 1998; Okori et al. 2004; Ramathani et al. 2011). Of these recent reports, most have focused on leaf blight (caused by *Setosphaeria turcica*) (Okori et al. 2004) and downy mildew (caused by *Peronosclerospora sorghi*) (Bigirwa et al. 1998), possibly because these diseases are increasing in importance. A survey was therefore carried out to identify and update information on diseases of sorghum across the major production areas in Tanzania and Uganda. This information is important in guiding future research on sorghum.

Observational Methods and Sampling Protocols

In Tanzania, the survey was conducted in June 2014 on farmers' fields in Dodoma and Singida Provinces in the central region and in Simiyu, Shinyanga, Mwanza, and Mara Provinces in the lake-zone region (Fig. 1A). For Uganda, the survey was conducted at two different times of the year, to make sure that assessments were done at the grain filling stage of crop development in the different agroecological zones. Sorghum fields were therefore first assessed in July to August 2014 in the Teso agroecological zone (Katakwi, Kumi, Palisa, and Soroti districts) and also in the Northern agroecological zone (Apac, Gulu, Lira, and Pader districts). In December 2014, the crop was assessed in the West Nile agroecological zone (Arua, Maracha, Nebbi, and Zombo districts) and in Hoima district in the Western agroecological zone (Fig. 1B). Climatic data for the areas surveyed is presented in Table 2.

To identify farmers' fields, we utilized extension agents and research scientists from the national agriculture research institutes, both knowledgeable about the farmers and the area. Upon identification, we drove and stopped approximately 5 km from one sampling point to the next, where a field was identified. At each field of at least an acre, 30 plants were visually assessed for disease along two diagonal transects. During the survey, diseases were identified based on symptoms and signs, visible by the naked eye or through magnification with a hand-held lens, as described in the *Compendium of Sorghum Diseases* (Frederiksen and Odvody 2000). To confirm the identification of diseases made in the field, diseased leaf samples, infected solely with the disease of interest, were also collected into labeled paper bags and taken to the laboratory. Thin sections of tissue from the lesions were cut aseptically using a scalpel and mounted on slides. To observe microscopic characteristics, slides were observed at ×200, ×400, and ×1,000, using a Jenco bright-field compound microscope (Jenco International, Portland, OR). Other pieces of information recorded during the survey were varieties planted, geolocational information on altitude, latitude, and longitude, and the farmers' names.

Disease incidence for each field was calculated as follows: (total number of plants affected in the field/total number of plants surveyed in the field) × 100. Prevalence for each geographical area was then calculated. We adopted the definition of prevalence from Cooke (2006), as incidence within a geographical area; thus, if 20 fields in an area were inspected for anthracnose, and 10 were found to be infected, then the prevalence for that area was 50%. Country means for disease prevalence were also calculated similarly. Data were then aggregated at three levels (i.e., country, agroecological zone/production zone, and district/province).

Because data were not normally distributed, nonparametric analysis was conducted using Genstat (version 16; VSN

TABLE 2
Climatic data for the agroecological zones surveyed in Tanzania and Uganda[a]

Country, agroecological zone	Annual mean: Rainfall range (mm)	Annual mean: Temperature (°C)
Tanzania		
Central dry zone	153–365	30
Lake zone	382–400	28
Uganda		
Teso	1,286–1,441	30
Western	1,241–1,360	26
Northern	1,286–1,814	30
West Nile	1,599–1,720	28

[a] 30-year average climatic data (1984 to 2014).

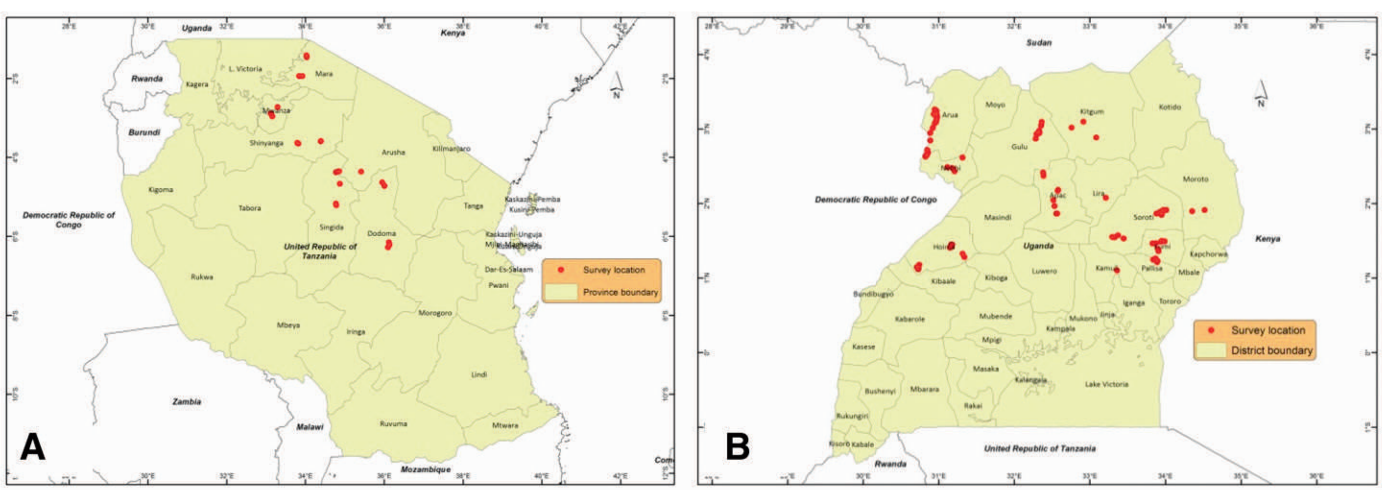

FIGURE 1
Maps of Tanzania (**A**) and Uganda (**B**) showing areas sampled during the survey.

TABLE 3
Nonparametric test of significance of the prevalence of sorghum fungal diseases between Tanzania (N = 37) and Uganda (N = 134)[a]

Disease	Prevalence		Wilcoxon rank sums		Kruskal–Wallis test	
	Tanzania	Uganda	Tanzania	Uganda	$\chi2$	Pr > $\chi2$
Anthracnose (*Colletotrichum sublineola*)	56	43	69	91	5.3	0.0207
Covered smut (*Sporisorium sorghi*)	10	4	108	79	13.8	0.0002
Downy mildew (*Peronosclerospora sorghi*)	0	4	58	94	21.1	<0.0001
Ergot (*Claviceps africana*)	0.4	2	79	88	3.5	0.0605
Fusarium head mold (*Fusarium* spp.)	5	3	85	86	0.3	0.5993
Gray leaf spot (*Cercospora sorghi*)	0.1	12	70	90	9.7	0.0018
Ladder leaf spot (*Cercospora fusimaculans*)	8	19	62	92	11.9	0.0005
Leaf blight (*Setosphaeria turcica*)	76	55	107	80	8.7	0.0031
Oval leaf spot (*Ramulispora sorghicola*)	0	5	56	94	24.4	<0.0001
Rough leaf spot (*Ascochyta sorghi*)	0	4	77	88	5.5	0.0190
Rust (*Puccinia purpurea*)	43	6	115	77	17.4	<0.0001
Sooty stripe (*Ramulispora sorghi*)	1	2	85	86	0.8	0.3599
Tar leaf spot (*Phyllachora sacchari*)	0	2	67	91	12.1	0.0005
Zonate leaf spot (*Gloeocercospora sorghi*)	11	10	72	90	4.6	0.0312

[a] Data were not normally distributed; nonparametric analysis was conducted using Genstat (version 16; VSN International). Kruskal–Wallis tests were used to compare Wilcoxon rank sums of disease prevalence between Tanzania and Uganda, as well as among agroecological zones in each country. Prevalence is incidence within a geographical area; thus, if 20 fields in an area were inspected for anthracnose, and 10 were found to be infected, then the prevalence for that area was 50%.

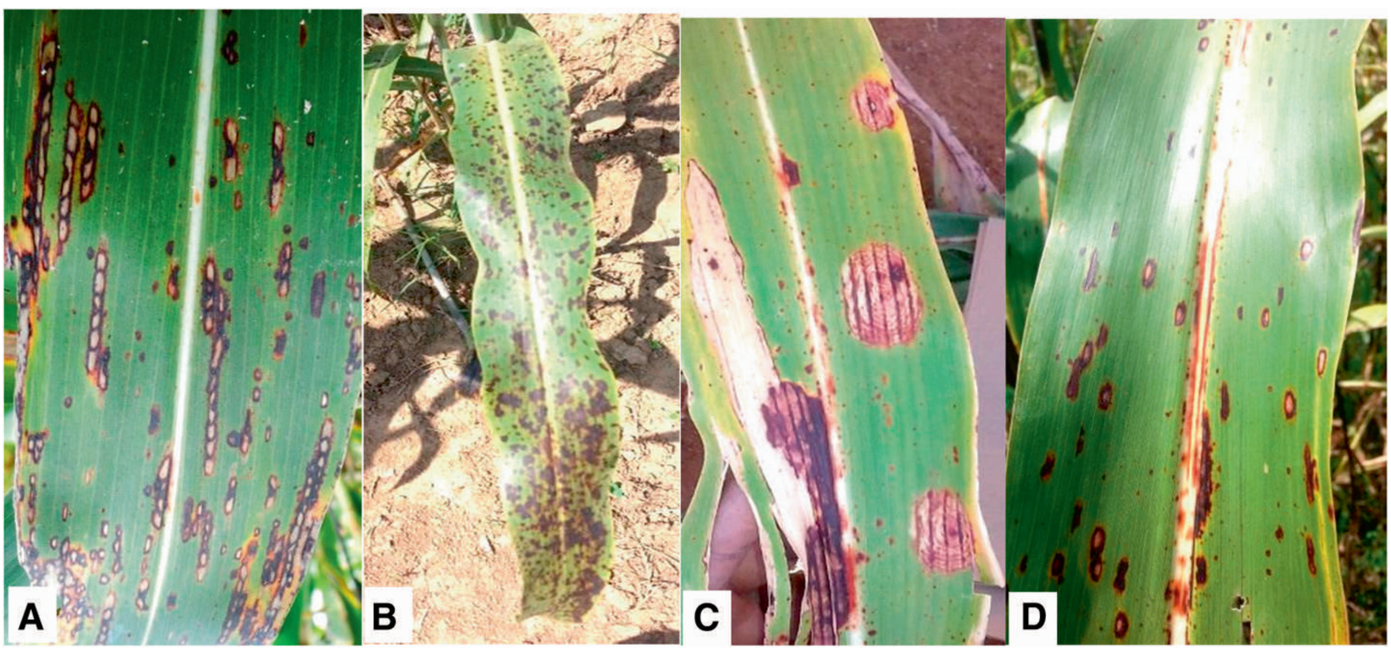

FIGURE 2

A, Ladder-like pattern of lesions of ladder leaf spot. Lesions with dark borders and pale centers. **B,** Black, slightly raised lesions (stromata) of tar leaf spot. **C,** Circular purple lesion bands alternating with brown bands, forming concentric lesion pattern of zonate leaf spot. **D,** Small circular lesions of oval leaf spot. Lesions with tan centers and few sclerotia, mostly on the underside of the leaf.

International, Hemel Hempstead, U.K.). Kruskal–Wallis tests were used to compare Wilcoxon rank sums of disease prevalence between Tanzania and Uganda, and also among agroecological zones in each country.

Diseases in Tanzania

Ten diseases were identified: three affecting the panicle and seven foliar diseases (Table 3, Figures 2, 3, 4, and 5). Among these diseases, only anthracnose, covered smut, leaf blight, rust, and zonate leaf spot had a prevalence of more than 10% (Table 3). The three most prevalent diseases were leaf blight at 76%, anthracnose at 56%, and rust at 43% (Table 3). Interestingly, when we compared prevalence between the drier central region to the lake zone, only ladder leaf spot differed significantly (P = 0.0370), with a prevalence of 2% compared with 9%, respectively. Importantly, our report, for the first time, confirms the presence of ladder leaf spot in

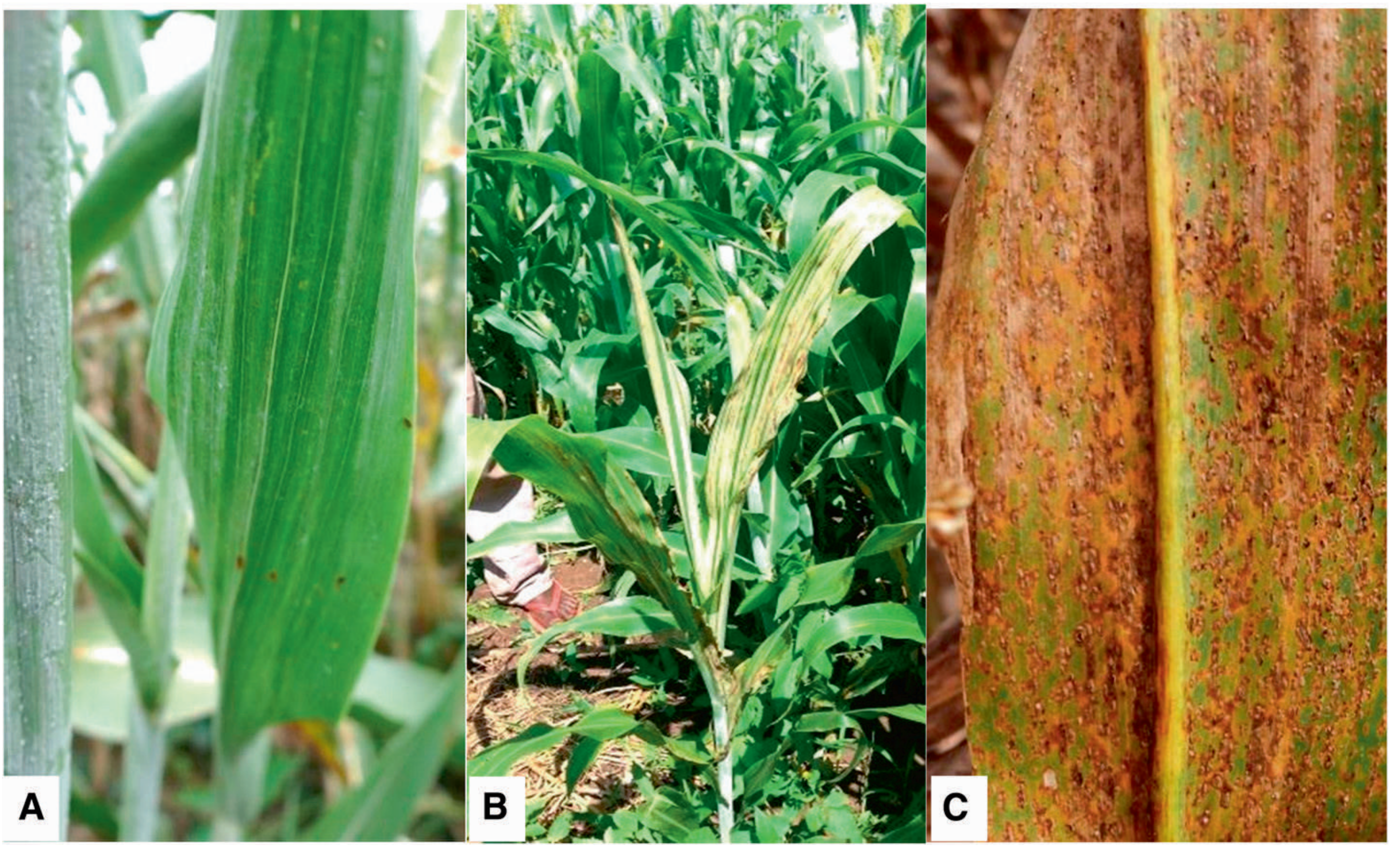

FIGURE 3

A, Under humid conditions, downy mildew–infected plants produce a visible white growth of conidiophores and conidia. **B,** Later stage of a plant infected with downy mildew. Leaves from the whorl have parallel stripes of green and white tissue. **C,** Leaf rust. Sporulation on the underside of rust-infected leaf, with urediniospores emerging from raptured uredinia.

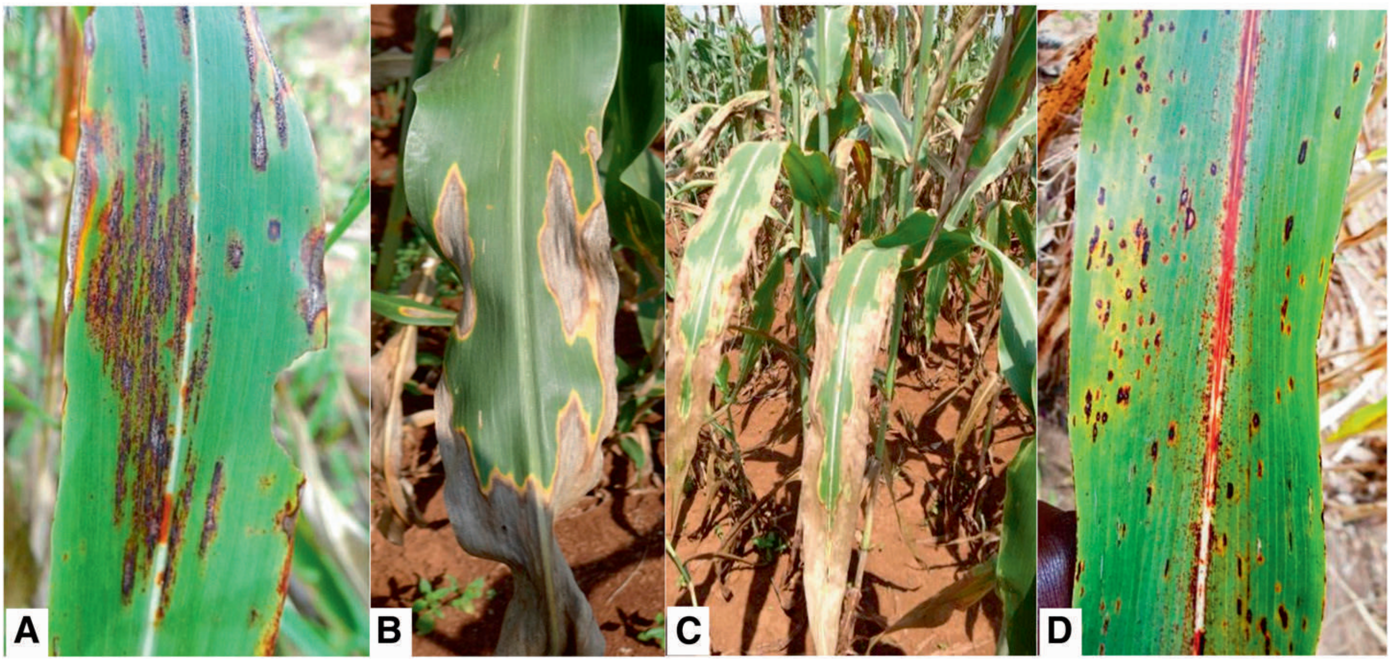

FIGURE 4

A, Rough leaf spot. Small black masses (pycnidia) in the lesions, which feel like sandpaper to the touch. **B,** Sooty blotch. Elongated lesions with tan centers and a yellow halo border. Sooty appearance is from abundant conidia. **C,** Leaf blight. Severe leaf necrosis. **D,** Anthracnose. Midrib infection, reddish in color. Black setae observable with the aid of a hand lens in the older lesions.

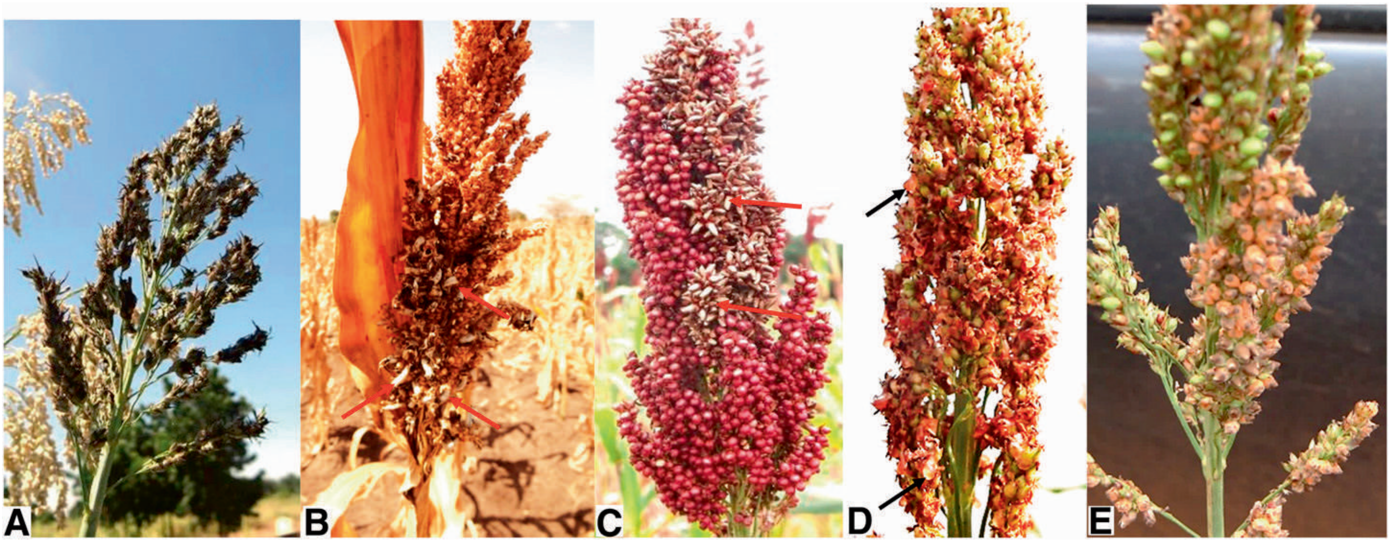

FIGURE 5

Smuts. **A,** Loose smut with nearly all the spikelets in the panicle smutted. **B,** Cylindrical white sori (red arrows) of long smut. **C,** Covered kernel smut (red arrows) at the top and middle sections of the panicle. **D,** Exudates of honeydew (red arrows) from ergot-infected florets. **E,** *Fusarium* head mold.

Tanzania. Previous reports (de Milliano 1992; Hulluka and Esele 1992) reported that ladder leaf spot had been reported in Tanzania but also that it had not been confirmed.

Diseases in Uganda

We identified 14 diseases in Uganda, 11 affecting the foliage and three on the panicle (Table 3, Figures 2, 3, 4, and 5). Diseases with more than 10% prevalence were anthracnose, ladder leaf spot, leaf blight, and zonate leaf spot (Table 3). The most three most prevalent diseases in the country were leaf blight at 55%, anthracnose at 43%, and ladder leaf spot at 19%. Of significance is that we confirm on the presence of ladder leaf spot, which had not been reported before (Hulluka and Esele 1992). In addition, our findings are in contrast to those previously reported by Hulluka and Esele (1992), who ranked grain mold (caused by many fungi), charcoal rot (caused by *Macrophomina phaseolina*), anthracnose, and ergot as high priority. A much earlier report by Guiragossian (1986) ranked, in order of importance, grain molds, smuts, anthracnose, leaf blight, and striga (*Striga hermonthica* or *S. asiatica*). We also report on the occurrence of smut and grain mold, although as minor diseases, each with a prevalence of less than 10%. Because the survey was conducted during grain fill, we might have underestimated the seriousness of grain mold, which is usually more prevalent later. Downy mildew is not a fungal disease but was included in the survey because of its potential to significantly reduce yield and also because there are reports of its significance in Uganda (Bigirwa et al. 1998; Frederiksen and Odvody 2000). Unlike in Tanzania, disease prevalence was significantly different in Uganda among the agroecological zones (Table 3). In general, disease prevalence in West Nile was higher, and can be used to screen for resistance to diseases occurring in Uganda.

Disease Management and Conclusions

We observed that the fields surveyed had both local landraces and improved varieties (Table 1), in mixed or pure stands. However, not all farmers could identify these varieties, and we named them "local" if a landrace or "improved" if an improved variety. Data from the survey showed that some landraces had more disease occurring on them than improved varieties and vice versa (Table 4). There is therefore great potential to improve on yields and reduce disease susceptibility by continued breeding for disease resistance. However, there is a need also to develop varieties with more desirable traits in addition to better disease resistance and yield potential. This is because farmers also select and adopt varieties based on grain color, drought tolerance, resistance or tolerance to feeding birds, brewing qualities, taste, storage quality, and so on.

Other disease management options such as crop rotation should also be encouraged, especially to break up the disease cycle of the pathogen by growing nonhost plants (Isakeit et al. 2000). This is because farmers in these marginal lands replant sorghum, often on the same land yearly, leading to the build-up of inoculum. In addition, to mitigate against the risk of crop failure owing to erratic rainfall, some farmers stagger the time of sowing sorghum. We noted that this practice could also increase the spread of disease from the earlier planted crop to the establishing crop (Fig. 6).

Our report is the first comprehensive survey on sorghum diseases in Tanzania and Uganda in over 15 years. We confirm on the presence of ladder leaf spot for the first time in Uganda, and also in Tanzania. Continued crop improvement work is needed to develop improved varieties that are more resistant to major diseases such as rust, anthracnose, ladder leaf spot, and leaf blight. However, there are no current reports on the loss of yield to the diseases we have reported on in both countries. It is hard to assign yield loss to the diseases we identified in the survey, because loss to disease would be confounded with poor agronomic practices, coinfection with multiple diseases (Ngugi et al. 2001), insect pest damage, the occurrence of drought, and so on. Therefore, more work is needed to determine loss to disease from controlled experiments, which can be used as a basis for quantifying loss. In addition, there is no current information on the diversity of pathogens causing disease on sorghum.

Acknowledgments

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TABLE 4
Diseases identified on varieties and landraces of sorghum during the survey in Tanzania and Uganda

Country, varieties or landraces	Diseases
Uganda, landrace	
Abir	Downy mildew, gray leaf spot, head smut, kernel smut, leaf blight, rust
Adedei	Anthracnose, ergot, kernel smut, ladder leaf spot, rough leaf spot, rust, zonate leaf spot
Awera	Anthracnose, gray leaf spot, head smut, kernel smut, ladder leaf spot, leaf blight, oval leaf spot, rust, zonate leaf spot
Ayi yak	Gray leaf spot, ladder leaf spot, leaf blight, oval leaf spot, rust, zonate leaf spot
Ayakayaka	Gray leaf spot, leaf blight, kernel smut, zonate leaf spot
Ededei	Anthracnose, ergot, gray leaf spot, head smut, kernel smut, ladder leaf spot, leaf blight, oval leaf spot, rough leaf spot, rust, zonate leaf spot
Emumwai	Anthracnose, gray leaf spot, head smut, kernel smut, ladder leaf spot, leaf blight, oval leaf spot, rough leaf spot, rust
Epuripur	Downy mildew, sooty stripe
Otura	Gray leaf spot, kernel smut, leaf blight, oval leaf spot, rough leaf spot
Red local	Anthracnose, downy mildew, ladder leaf spot, leaf blight, rough leaf spot
Uganda, improved	
IESU 8191	Anthracnose, ladder leaf spot, leaf blight
Gadam	Anthracnose, ladder leaf spot, leaf blight, kernel smut, rust, tar leaf spot, zonate leaf spot
Seso1	Downy mildew, leaf blight, sooty stripe
Seso2	Anthracnose, gray leaf spot, ladder leaf spot, leaf blight
Seso3	Gray leaf spot, ladder leaf spot, leaf blight, oval leaf spot, zonate leaf spot
Socadido	Anthracnose, downy mildew, ergot, ladder leaf spot, leaf blight, kernel smut, rough leaf spot
Twin seed	Anthracnose, gray leaf spot, leaf blight, zonate leaf spot
Tanzania, landrace	
Bukenya	Anthracnose, ladder leaf spot, leaf blight, kernel smut, rust
Gangisi	Anthracnose, ladder leaf spot, leaf blight, long smut, kernel smut, rust
Isusu	Anthracnose, leaf blight
Kakela	Anthracnose, kernel smut, long smut, zonate leaf spot
Langa Langa	Anthracnose, ladder leaf spot, leaf blight, long smut, rust, zonate leaf spot
Nkolongo	Anthracnose, leaf blight
Nyakochol	Anthracnose, ergot, ladder leaf spot, leaf blight, rust, zonate leaf spot
Ntora	Anthracnose, gray leaf spot, kernel smut, ladder leaf spot, leaf blight, long smut, rust, zonate leaf spot
Mwanagudungu	Anthracnose, kernel smut, leaf blight, rust
Ochuti	Anthracnose, ladder leaf spot, leaf blight, rust, zonate leaf spot
Tanzania, improved	
ATX623 × Macia	Anthracnose, leaf blight, rough leaf spot, rust
Hakika	Leaf blight, long smut, kernel smut, rust
KARI mtama1	Downy mildew, leaf blight, rust
Pato	Anthracnose, ladder leaf spot, leaf blight, rust
Sila	Leaf blight, kernel smut, long smut
Seso1	Downy mildew, leaf blight, rust
Tegemeo	Leaf blight, kernel smut, rust
Wahi	Leaf blight, kernel smut, rust
Macia	Leaf blight, rust, zonate leaf spot
Weijita	Anthracnose, ergot, ladder leaf spot, leaf blight, kernel smut, zonate leaf spot

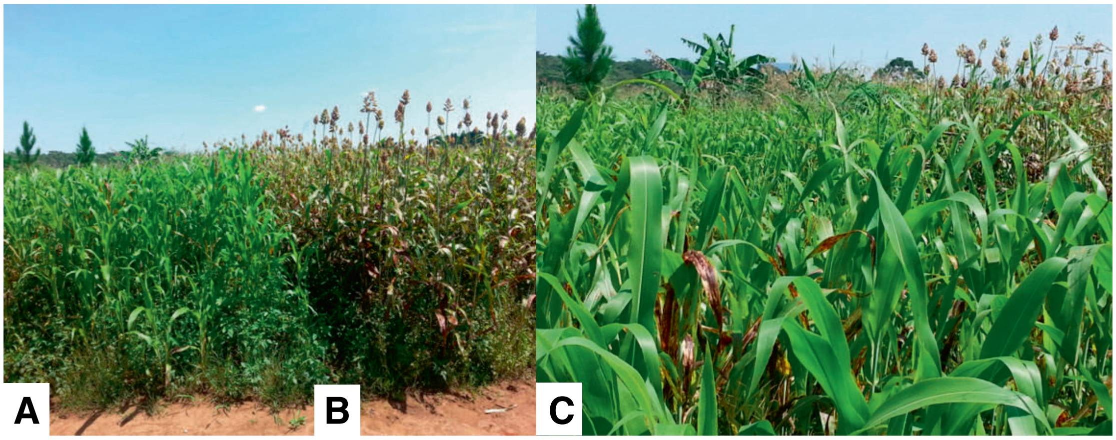

FIGURE 6
Cultural practice of planting at different times in adjacent fields (**A**) provides inoculum to the younger crop (**B**).

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