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Research Article
Survey of the Prevalence and Incidence of Foliar and Panicle Diseases of Sorghum Across Production Fields in Niger

[1]Louis Kajac Prom, [2]Haougui Adamou, [3]Adamou Issa, [3]Abdoulaye Abdoulaye Abdoulkadri, [2]Karimou Issa, [2]Ali Outani Bibata and [4]Clint Magill

[1]USDA-ARS, Crop Germplasm Research Unit, 2881 F and B Road, 77845 College Station, Texas, United States
[2]Institut National de la Recherche Agronomique du Niger, BP 429, Niamey, Niger
[3]Université BoubakarBâ de Tillabéri, BP 175, Tillabéri, Niger
[4]Department of Plant Pathology and Microbiology, Texas A&M University, 77843 College Station, Texas, United States

Abstract

Background and Objective: In Niger, sorghum ranks second as the most important cereal after pearl millet and is used primarily as a staple food and fodder. In 2019, an extensive survey of the occurrence and distribution of foliar and panicle diseases affecting sorghum in farmers' fields from major production regions of Niger was conducted. **Materials and Methods:** A total of 121 fields in the regions of Tillabéri, Tahoua, Dosso and Maradi along paved and unpaved roads, including National and Secondary (RN1, RN2, RN3) were surveyed. In each field, 60 plants at late flowering to hard dough stages of development were assessed using a W-shaped pattern. **Results:** The study documented 21 different sorghum diseases, including anthracnose, long smut, oval leaf spot, leaf blight, head smut and zonate leaf spot. The most prevalent diseases were anthracnose, leaf blight, oval leaf spot, rough leaf spot and long smut. The highest mean incidence of anthracnose, leaf blight and rough leaf spot was recorded from Maradi, whereas, the regions of Dosso and Tahoua exhibited the highest mean oval leaf spot incidence. The highest incidence of long smut and zonate leaf spot was recorded in fields in Dosso region. Locations with highest incidence of these diseases can be considered 'hot spots' for resistance evaluations. **Conclusion:** This study is significant because for the 1st time it provides researchers, funding and governmental agencies in Niger a guide on the occurrence, distribution, prevalence and 'hot spots' for sorghum diseases.

Key words: Sorghum, disease incidence, fungal diseases, dwarf mosaic virus, anthracnose

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Corresponding Author: Louis Kajac Prom, USDA-ARS, Crop Germplasm Research Unit, 2881 F and B Road, 77845 College Station, Texas, United States

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sorghum is one of the most indispensable crops and millions of people, especially in the drier tropics rely on it[1]. In addition to its uses such as baked foodstuff, alcoholic beverages, fiber, starch, paper and syrup, recently, sorghum is being used as a source of biofuel[2-4].Compared to other cereals, sorghum is drought tolerant and can survive under harsh environmental conditions and is often grown under marginal lands in several countries[2,5-7]. In Niger, sorghum hectarage and production continue to increase and in 2017, 3,820,696 ha was harvested, resulting in production of 1,945,136 metric tonnes[8]. When compared to North America, Mexico, India, China and even some other African Countries, sorghum yield in Niger is still low, ranging from 420 kg g^{-1} a little over[9-11] 900 kg ha^{-1}. The lower sorghum yield ha^{-1} in Niger and other African Countries can be attributed to several factors such as weather patterns, type of sorghum cultivars/landraces used, lower farm inputs, pests and diseases[9,12]. In Niger, sorghum, which ranks second as the most important cereal after pearl millet, is used primarily as a staple food for the population and secondarily for animal feed, especially their haulms[10,13,14]. Despite all the limitations in sorghum cultivation and profitability, farmers in Niger and other African Countries are encouraged by the increasing regional demands and prices in the commodity and its potential as a source of biofuel[3,9]. Sorghum will continue to grow in importance as the world's population increases and the estimated 3 billion tons increase of cereal for food and non-food purposes expected[9,15] to be needed by 2050. However, increases in sorghum production and climate change will likely increase diseases incited by fungal, bacterial and viral microorganisms. Some of these fungal diseases can cause yield losses of up to 100% when susceptible sorghum lines are planted and in addition, some of these pathogens are capable of producing mycotoxins, limiting the use of the crop for human and animals[16,17]. This study was conducted to investigate the occurrence and distribution of foliar and panicle diseases affecting sorghum in farmers' fields from major production regions of Niger.

MATERIALS AND METHODS

Tillabéri, Tahoua, Dosso and Maradi in Niger, representing 4 of the top 5 major sorghum production regions were surveyed for foliar and panicle diseases during the 2019 growing season (Fig. 1). These regions have a Sahelian,

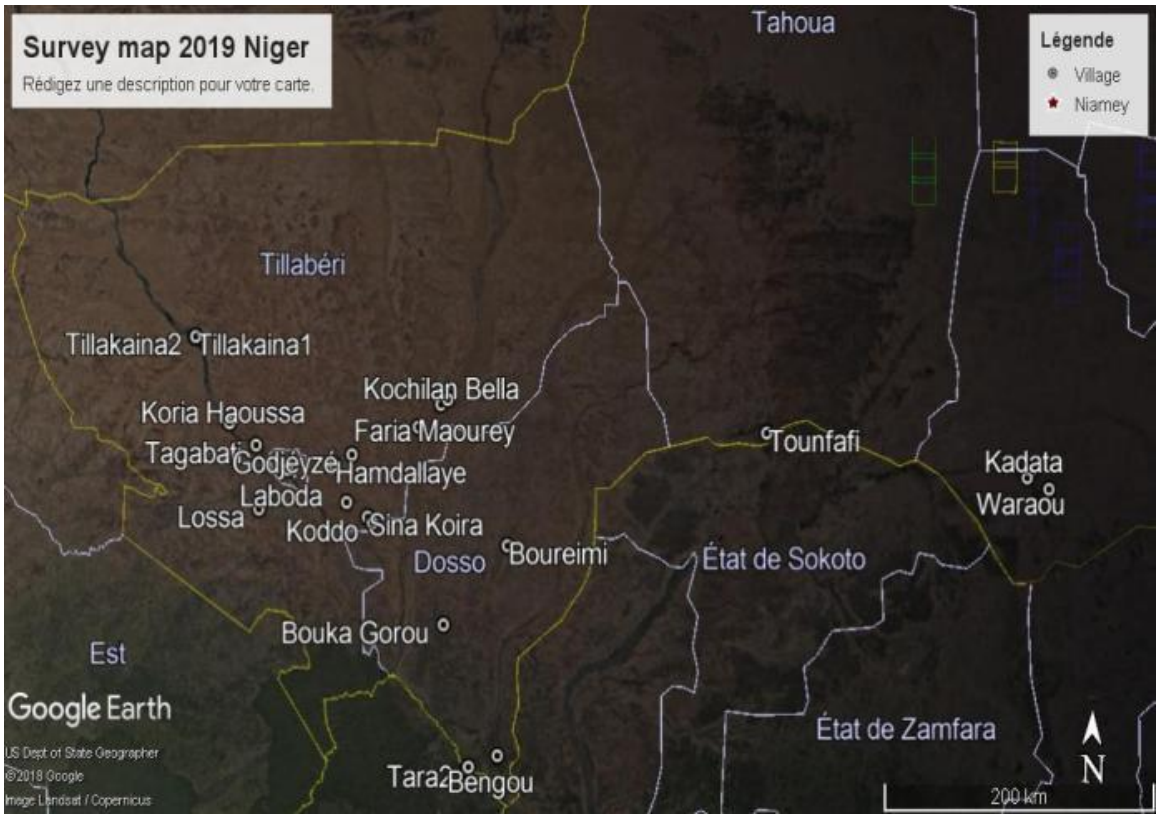

Fig. 1: Regions and locations of the sorghum fields surveyed
Source: Adamou[21]

Table 1: Weather parameters and soil types of the surveyed regions of Niger

	Regions			
Data	Tillabéri	Tahoua	Dosso	Maradi
Annual rainfall	450 mm from April to October (66% in July and August)	Average of 435 mm in this region, but up to 509 mm in Konni, from April to October (58% in July and August)	Average of 700 mm in this region, but up 814 mm in Gaya from March to October (86% between June to September)	550 mm from April to October (66% in July and August)
Climate	Sahelian	Konni is in the Sahelian climate while the northern part of Tahoua belongs to the Sahelo-saharian climate	Northern Dosso has Sahelian climate while the Southern part (Gaya) belongs to the Sahelo-sudanian climate	Sahelian
Mean temperatures during the rainy season	Temperatures (Max: 28°C, Mini 23°C)	Temperatures (Max: 33°C, Mini: 24°C)	Temperatures (Max: 33°C, Mini: 24°C)	Temperatures (Max: 28°C, Mini: 23°C)
Soil type	Ferruginous tropical	Ferruginous tropical	Ferruginous tropical in the most part of this region, but Hydromorphous at Bengou and Less evoluted at Tara locality	Ferruginous tropical

Sources: Direction of Statistics[11], Moussa[18]

Northern Tahoua having a Sahelo-Saharian and Gaya, part of Dosso region having a Sahelo-Sudanian types of climate[11] (Table 1). The annual rainfall ranges from 435 mm (Tahoua) to 700 mm (Dosso) and the soil type is mainly Ferruginous tropical, with Bengou and to a lesser degree Tara also having a hydromorphous type soil[18] (Table 1). During the rainy season, the maximum and minimum temperatures for the surveyed regions are noted in Table 1.These regions covered an area of 262,402 km^2 and lie between 11 and 19 degrees North of the equator[19, 20].Table 2 shows the ranks in term of annual sorghum production among the 8 regions of Niger. A total of 121 farmers' fields along paved and unpaved roads, including National and Secondary (RN1, RN2, RN3) were surveyed and plants at late flowering to hard dough stages of development were assessed for diseases arbitrarily using a W-shaped pattern to cover the whole field. Table 3 shows the coordinates of the fields that were surveyed[21]. Along the roads, stops were made at intervals of 30 km. At each stop, 2-5 fields (60 plants/field) were surveyed for disease prevalence and incidence:

$$\text{Prevalence rate} = \frac{\text{Number of fields with the disease}}{\text{Total number of fields surveyed}} \times 100$$

$$\text{Incidence} = \frac{\text{Number of plants with the disease in a field}}{\text{Number of plants assessed in a field}} \times 100$$

RESULTS

The majority of the farmers' fields assessed in this study were planted with different landraces, with a few exceptions that were planted with National Institute of Agricultural Research of Niger improved varieties. The fields surveyed ranged in size from 0.2-1.0 ha and were mostly reasonably maintained. The production systems employed by farmers in the surveyed regions were pure sorghum stands and intercropping with early and late varieties, millet-sorghum-cowpea, millet-cowpea-peanut, millet-sorghum-cowpea-hibiscus (Table 2).

Disease prevalence and incidence: In each field, 60 plants were assessed. The following sorghum diseases were identified as presented in Table 4. Figure 2a shows anthracnose infected sorghum plants in the field, 2b anthracnose infected mid rib showing the fruiting bodies or acervuli, 2c long smut infected panicle, 2d leaf Blight, 2e zonate leaf spot, 2f rough Leaf spot, 2g head smut on sorghum and 2h oval leaf spot. Anthracnose was found in 120 fields, representing 99% prevalence of the disease in the surveyed areas. In this study, anthracnose was followed by leaf blight with a prevalence of 89%, oval leaf spot (76%), rough leaf spot (67%) and long smut (63%) (Table 4). Out of the total number of fields surveyed in this study, maize dwarf mosaic virus, downy mildew, bacterial leaf spot and loose smut were found in either one or 2 fields. The highest mean incidence of anthracnose (64%), leaf blight (62%) and rough leaf spot (35%) was recorded from Maradi, whereas, the regions of Dosso and Tahoua exhibited the highest mean oval leaf spot incidence of 73% as presented in Table 5. Among the regions, overall mean long smut incidence was highest in Tahoua (28%), followed by 24% in Dosso and 20% in Tillabéri.

A total of 20 fields out of the 121 surveyed had anthracnose incidence of over 95%, 4 fields were from the region of Tillabéri, 7 from Dosso, 6 from Tahoua and 3 from Maradi (Table 6). Out of the 20 fields, 6 fields exhibited 100% incidence of anthracnose. These 6 fields and their locations

Table 2: Mean sorghum yield, rank in production, hectarage, yearly production and farming practices in the 4 major growing regions of Niger

	Regions			
Data	Tillabéri	Tahoua	Dosso	Maradi
Average sorghum yield	420 kg ha^{-1}	621 kg ha^{-1}	685 kg ha^{-1}	571 kg ha^{-1}
Rank in sorghum production within the 8 regions of the Niger	4th	3th	5th	1st
Quantity and hectarage	230,105 Mt 547,885 ha	450,258 Mt 724,808 ha	213,468 Mt 311,631 ha	620,371 Mt 1,085,575 ha
Coordinates	See coordinates in Table 3			
Sorghum production systems	Monoculture, Association (Millet-sorghum-cowpea)	Sorghum intercrop (Early and late maturing varieties) Association (millet-sorghum-cowpea)	Association (Sorghum-millet-cowpea-peanut)	Association (Millet-sorghum-cowpea-hibiscus)

Sources: Hamidou *et al.*[10], Direction of Statistics[11]

Table 3: Coordinates of surveyed fields in the different towns and villages in Niger

Village	Latitude	Longitude
Tagabati	N13°38'49.3''	E1°52'55.0''
Koria Haoussa	N13°45'47.8''	E1°41'53.6''
Lossa	N13°17'37.8''	E1°54'48.7''
Tillakaina 1	N14°13'55.2''	E1°26'45.6''
Tillakaina 2	N14°14'02.0''	E1°27'01.2''
Hamdallaye	N13°33'27.8''	E2°24'33.7''
Godjéyzé	N13°37'05.4''	E2°31'33.2''
Kochilan Bella	N13°56'35.3''	E3°09'11.3''
Faria Maourey	N13°54'52.5''	E3°06'28.1''
Ballayara	N13°47'03.8''	E2°57'41.5''
Tchoudaoua	N13°21'13.5''	E2°29'57.1''
Sina Koira	N13°16'38.6''	E2°38'29.1''
Koado	N13°14'45.0''	E2°40'29.2''
Boukagorou	N12°42'00.1''	E3°09'46.6''
Tara 1	N11°54'56.2''	E3°21'04.2''
Tara 2	N11°54'16.0''	E3°20'25.9''
Bengou	N11°59'04.4''	E3°32'25.0''
Boureimi	N13°09'01.8''	E3°34'21.9''
Laboda	N13°31'12.9''	E2°05'59.5''
Tounfafi	N13°48'52.7''	E5°16'14.7''
Kadata	N13°37'49.2''	E7°03'01.6''
Waraou	N13°35'55.6''	E7°01'49.5''
Dan Gamji	N13°32'14.4''	E7°10'53.2''

Source: Adamou[21]

Table 4: Prevalence of sorghum diseases across the 121 fields in Niger, West Africa, 2019[1]

Disease	Fields with disease (%)
Anthracnose (*Colletotrichum sublineola*)	99
Bacterial leaf stripe (*Burholderia andropogonis*)	11
Long smut (*Sporisorium ehrenbergii*)	63
Oval leaf spot (*Ramulispora sorghicola*)	76
Leaf blight (*Exserohilum turcicum*)	89
Bacterial leaf blight (*Acidovorax avenae*)	10
Target leaf spot (*Bipolaris sorghicola*)	22
Bacterial leaf streak (*Xanthomonas campestris* pv. *holcicola*)	31
Sooty stripe (*Ramulispora sorghi*)	17
Covered smut (*Sporisorium sorghi*)	33
Maize mosaic virus	6
Rough leaf spot (*Ascochyta sorghi*)	67
Downy mildew *(Peronosclerospora sorghi*)	2
Head smut (*Sporisorium reilianum*)	26
Maize dwarf mosaic virus	2
Crazy top (*Sclerophthora macrospora*)	14
Gray leaf spot (*Cercospora sorghi*)	4
Bacterial leaf spot (*Pseudomonas syringae* pv. *syringae*)	1
Grain mold (Various fungal genera)*	21
Loose smut (*Sporisorium cruentum*)	1
Zonate leaf spot (*Gloeocercospora sorghi*)	23

[1]Sorghum fields from 4 major sorghum growing regions of Tillabéri, Dosso, Tahoua and Maradi were surveyed, *Lower prevalence of grain mold may be attributed to the fact that some of the surveyed plants were ta the late flowering early soft dough stage of development

Fig. 2(a-h): (a) Anthracnose infected sorghum plants, (b) Anthracnose infected mid rib showing the fruiting bodies (acervuli), (c) Long smut infected panicle, (d) Leaf blight, (e) Zonate leaf spot, (f) Rough Leaf spot, (g) Head smut on sorghum and (h) Oval leaf spot

Table 5: Mean incidence (%) across fields infected with respective sorghum diseases in the four regions[1]

Disease	Tillabéri	Dosso	Tahoua	Maradi
Anthracnose	48	61	48	64
Bacterial leaf stripe	6	2	0	4
Long smut	20	24	28	9
Oval leaf spot	9	73	73	39
Leaf blight	20	23	33	62
Bacterial leaf blight	4	6	0	0
Target leaf spot	3	11	53	3
Bacterial leaf streak	8	6	8	48
Sooty stripe	13	0	0	0
Covered smut	14	9	5	8
Maize mosaic virus	5	0	2	0
Rough leaf spot	21	25	13	35
Downy mildew	4	0	0	0
Head smut	10	8	8	6
Maize dwarf mosaic virus	2	0	0	0
Crazy top	2	3	3	3
Gray leaf spot	3	5	0	5
Bacterial leaf spot	2	0	0	0
Grain mold	5	20	22	19
Loose smut	2	0	0	0
Zonate leaf spot	0	29	23	0

[1]Number of surveyed fields in each region: Tillabéri: 50 fields, Dossa: 30 fields, Tahoua: 20 fields, Maradi: 21 fields, In each field, 60 plants were evaluated using a W-shaped pattern

can be considered 'hot spots' for anthracnose evaluation to identify resistance sources. Ten fields from the regions of Dosso, 7 from Tahoua and one field from Maradi exhibited over 95% incidence of oval leaf spot, with 5 fields recording

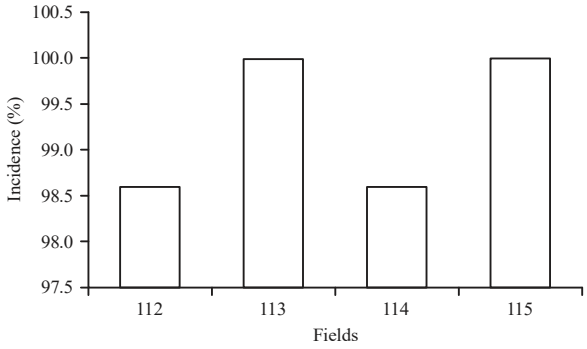

Fig. 3: Incidence (%) of leaf blight in fields (112th-115th) surveyed at Galadentchi, Maradi, Niger in 2019

100% incidence (Table 7). The highest incidence of long smut (87%) and zonate leaf spot (80%) was recorded in Kodo and Tara, in the region of Dosso, respectively. Over 95% incidence of target leaf spot was recorded in Dogaraoua, Tahaoua, sooty stripe in Koiria Haoussa, Tillabéri and rough leaf spot in Boureini, Dosso. Four sorghum fields assessed around the town of Galadentchi, Maradi, recorded the highest infection of leaf blight with 2 fields with 100% incidence (Fig. 3). In this survey, low prevalence of downy mildew was noted in Niger. Globally, grain mold is most important sorghum disease and during the survey, the highest mean incidence, 22%, was recorded in Tahoua, 20% in Dosso and 19% in

Table 6: Region and location of fields with over 95% incidence of anthracnose[1]

Regions	Field number	Locations
Tillabéri	6	Koria Haoussa
	22	Godjeyze
	34*	Faria Maourey
	42	Tchoudaoua
Dosso	57	Tara
	59	Tara
	65	Bengou
	66*	Bengou
	71*	Gouywa
	73	Gouywa
	74	Gouywa
Tahoua	75	Laboda
	76*	Laboda
	80	Konni
	81	Konni
	85	Dogueraoua
	86*	Dogueraoua
Maradi	96	Kadata
	100	Waraou
	101*	Waraou

[1]In each field, 60 plants were evaluated using a W-shaped pattern, *Fields with 100% incidence

Table 7: Region and location of oval leaf spot infected fields with over 95% incidence[1]

Regions	Field number	Locations
Dosso	57	Tara
	58*	Tara
	60*	Tara
	64	Tara
	65	Bengou
	68	Koira Tequi Bangou
	70	Koira Tequi Bangou
	71	Gouywa
	72	Gouywa
	118	Boureini
Tahoua	81	Konni
	82*	Konni
	85	Dogueraoua
	86	Dogueraoua
	92	Tounfafi
	93*	Tounfafi
	94*	Tounfafi
Maradi	101	Kalgo Waraou

[1]In each field, 60 plants were evaluated using a W-shaped pattern, *Fields with 100% incidence

Maradi (Table 5). Compared to the other diseases with high incidence, grain mold infection was not very high in most fields and this may be partially attributed to the fact that plants were mainly assessed at the late flowering to hard dough stage of development. During this survey, farmers' participation was important; as a result, varietal information (Table 8), farmers' names and contact information and on field disease identification and control methods were discussed. These interactions will continue and should ease the transfer of new technology to the sorghum farmers in Niger.

Table 8: Landraces and INRAN improved varieties identified during the survey[1]

Region	Field number	Landraces or variety
Tillabéri	3	Hameyze Wassa
Mota (Maradi)+BDF	4	Locale Koria (Hamokoiraye)
	6	Hamotchiraye/Hamokoiraye
	9	Mota Maradi
	11	Mota Maradi
	19	Locale
	21	Locale
	22	Mota Ja
	30	Locale
	41	Mota
Dosso	51A	Sokomba Koiraye
	52	Sokomba
	57	Moloko
	59	Hamoberi
	116	Mota
	117	Mota
Tahoua	80	Matché da Kumiya
	81	El Tchadoua Cedaoua
	85	Matché da Kumiya
	86	Makafo da Wayo
	90	Matché da Kumiya
	91	El Tchadoua
Maradi	95	Makafo da Wayyo
	96	Mota Ja
	100	Makafo da Wayyo
	105	Makafo da Wayyo
	106	Makafo da Wayyo

[1]These names of the landraces and varieties that were planted in some of the surveyed fields in 2019

DISCUSSION

In Niger, sorghum plays an integral part in the daily survival of the population and their livestock. However, the crop is hampered by biotic stresses and with the expected increase in world's population to around 9.1 billion[15], will require increases in sorghum production and with climate change will likely increase diseases incited by fungal, bacterial and viral microorganisms. Due to the paucity of information on the occurrence and distribution of sorghum foliar and panicle diseases, especially those that are of economic importance in Niger, the study was undertaken.

In this survey, the prevalence of anthracnose was 99% in the surveyed areas. Teferi and Wubshet[22] reported 93.7% prevalence of anthracnose in surveyed fields in South Tigray, Ethiopia, while Tsedaley *et al.*[23] noted the presence of anthracnose in all fields surveyed in Southwestern and Western Ethiopia. Also, Chala *et al.*[6] recorded 84% prevalence of anthracnose in several parts of Ethiopia. In this study, after anthracnose, leaf blight followed by oval leaf spot, rough leaf spot and long smut were the most frequently documented sorghum diseases. Teferi and Wubshet[22] also noted 84.8% leaf blight and 88.6% long smut prevalence in South Tigray,

Ethiopia. Sorghum farmers' fields surveyed across four major growing climatic zones in Nigeria, revealed that anthracnose, oval leaf spot, sooty stripe and gray leaf spot were the predominant diseases[24]. In the Sahelian zone, Pande *et al.*[24] noted that fields had long smut incidence of <10 to over 20%. Survey of sorghum diseases conducted by Njoroge *et al.*[25] in Tanzania and Uganda, found that leaf blight and rust were more prevalent in Tanzania while anthracnose and zonate were more prevalent in Uganda. Anthracnose, leaf blight, gray leaf spot and zonate leaf spot were found to be the most prevalent diseases in farmers' fields in Western Kenya[26].Similar to this current work in Niger, oval leaf spot also was found to be one of the predominant diseases of sorghum in four major growing climatic zones in Nigeria[24]. Out of the total number of fields surveyed in this study, maize dwarf mosaic virus, downy mildew, bacterial leaf spot and loose smut were found in low frequency. Pande *et al.*[24] also noted the presence of maize mosaic virus, maize stripe virus and potyvirus in some climatic zones in Nigeria. In this survey, low prevalence of downy mildew was noted in Niger, this agrees with reports by Kutama *et al.*[27], who found low distribution of the disease in sorghum in the Sudano Sahelian savanna zones of Nigeria.

CONCLUSION

In conclusion, disease management, especially providing farmers with genetic resistance source to diseases of economic importance will be critical in ensuring food security. Thus, this work is significant because for the first time it provides sorghum researchers, such as Plant Pathologists, students, funding and governmental agencies in Niger a guide on the occurrence, distribution, prevalence and 'hot spots' (Fields and locations with over 95% incidence of a particular disease) where certain sorghum diseases can be evaluated to identify resistant sources. Once resistant sources are identified, they can be deployed in regions where the disease occurs or impacts yields.

SIGNIFICANCE STATEMENT

This study reveals that sorghum anthracnose, leaf blight, oval leaf spot, rough leaf spot and long smut were the most widely distributed diseases in major production regions of Niger. Hot spots" for resistance evaluation of diseases such as anthracnose, leaf blight, oval leaf spot, long smut and zonate leaf spot were identified. There is little or no documentation about the prevalence and incidence of sorghum diseases in farmers' fields in Niger, as a result, this is the first extensive survey of sorghum diseases in major production regions of the Country. This document will serve as a guide for present and future sorghum workers, especially sorghum pathologists and funding agencies interested in sorghum disease management.

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