Status of Sorghum Smuts and Their Control in Eastern Ethiopia

Temam Hussien
Department of Plant Sciences, Alemaya University, P.O. Box 165, Dire Dawa, Ethiopia

Abstract

A survey was made in East Ethiopia during October to November over 2001–2003 to investigate the status of sorghum smuts, their importance, local control practices and reasons for their continued occurrence. A total of 240 farms and 120 farmers randomly from four sorghum growing districts in the region were used. According to farmers, smuts were endemic and they knew them since childhood. In farmers' view, the main sorghum smuts requiring control were covered kernel smut (*S. sorghi* Link.) and long smut (*S. ehrenbergii* Vanky). The incidence of covered kernel smut and long smut ranged 5–20% and 7–14%, respectively; and In some isolated farms, it reached 80%. Loose kernel smut (*S. cruentum* (Kuhn.) Potter.) and head smut (*S. reilianum* (Kuhn) Langdon & Fullerton) were rarely encountered, and their incidence never exceeded 4%. Smuts caused a 13% estimated combined yield loss in sorghum. Farmers never applied chemical seed dressings against smuts because fungicides were not available and/or affordable to farmers. Farmers mainly used local sorghum cultivars selected and retained for yield potential, with little emphasis on smut resistance. Improved varieties were not available, and when available, the supply was inadequate. Many farmers (48%) did not exercise any control measure; whereas, some used different local control methods. Many reasons contributed to the continued occurrence of smuts in the region.

Key words: Sorghum smuts, control practices, eastern Ethiopia

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench.] is an important and indispensable crop in Ethiopia. In eastern Ethiopia, sorghum is the major staple food crop, and it is largely produced by smallholder farmers. There is high genetic variability in highland and lowland sorghum types (Brhane 1973). Diseases constitute an important production constraint under traditional and improved cropping systems and cause tremendous crop loss depending mainly on the environment (Mengistu 1982). Among panicle diseases, smuts such as covered kernel smut (*S. sorghi*), loose kernel smut (*S. cruentum*), head smut (*S. relianum*) and long smut (*S. ehrenbergii*) are the most wide-spread diseases (Mengistu 1982, Temam 1990). In the Horn of Africa, smuts are economically important that cause 5–80% yield losses, and collectively they are the most damaging of all sorghum diseases (Esele 2002). Covered and loose smuts are also reported to be the most important sorghum diseases in East Africa (Esele 2002).

In eastern Ethiopia, sorghum smuts have been a problem for a long time. All of the above-mentioned four smuts occur in all sorghum-growing areas in the region; but disease intensity varies from place to place (AU 2003). Covered kernel smut and loose smut, both seed-borne, are most common. According to AU (2003), long smut also became very important during 2001–2003 particularly in Fedis and Dire Dawa areas. Little is known of the exact yield losses in sorghum due to these diseases. However, the incidence and severity of smuts every year could justify that they are economically important and may result in significant yield losses depending mainly on the environment. For instance, unlike those afflicted by covered kernel smut and long smut, plants

infected with loose and head smuts are nearly always barren, resulting in a directly proportional yield loss to the number of plants infected.

In many parts of the world, seed-treatment fungicides are routinely used for disease control in sorghum. The fungicides are effective in reducing or eliminating seed-borne pathogens. For example, covered and loose kernel smuts, which were once among the most serious diseases of sorghum, are no longer problems because of the use of seed treatment fungicides (Frowd 1980). Covered kernel smut is very destructive in developing countries where seed dressing is not practised. In West Africa, losses of 5 to 10% due to the disease are reported (Frowd 1980). According to Merkuz (2001), the mean yield loss under farmers condition in northwest Ethiopia ranged from 38 to 44%. Similarly, Eshetu (2002) reported yield losses ranging from 1 to 54% in artificially inoculated fields that consisted of different varieties in northeast Ethiopia.

Research on sorghum smuts in Ethiopia has largely been limited to diagnosing diseases, recording outbreaks, and advising farmers on a cultural control method, i.e., the use of fermented cattle or goat urine for the control of covered kernel smut (EARO 1996). Of course, seed treatment with the fungicide Thriam is recommended for the control of covered kernel smut; but very few farmers treat seeds before planting (EARO 1997). According to EARO (1996), the most promising control method for covered kernel smut is the use of goat urine and the fungicide Apron Plus.

The occurrence, distribution, and incidence of sorghum smuts and the traditional control practices used by farmers in eastern Ethiopia were not adequately studied and documented In spite of the availability of some control methods, smuts continued to jeopardize sorghum production. Moreover, the reasons for the continued occurrence of the diseases in subsistence farms were not studies.

According to a survey in Uganda, very few farmers had any technical knowledge of smuts or their control, and the traditional practices employed by farmers were largely responsible for the continued occurrence of sorghum smuts in the Horn of Africa (Esele 2002). Some of the traditional practices were: most farmers keep and use their own seed for planting during the next season, very few farmers treat seeds before planting, some farmers ratoon their sorghum which serves as a means of loose smut propagation and most farmers use late-maturing varieties that are susceptible to head smut. However, whether the survey findings on the situation and continued occurrence of smuts in the Horn (Esele 2002) held true for eastern Ethiopia and whether farmers used any local control measure was not investigated. The present survey was, therefore, undertaken to determine the distribution, incidence and severity of sorghum smuts; assess the reasons for their continued occurrence and collect and document available indigenous smut control practices in East Ethiopia.

Materials and Methods

Description of the study areas

Five major sorghum-growing districts were selected for the study as representatives of three major agro-ecological zones in East Ethiopia: highland (> 1900 m), mid-altitude (1500–1900 m) and lowland (< 1500 m). The districts were: Alemaya (highland); Babile, Fedis, and Jijiga (mid-altitude); and Dire Dawa Administrative council (lowland). Table 1 presents some descriptions of the study areas.

Eastern Ethiopia has a bimodal rainfall pattern with short and long rainy seasons. The short rainy season occurs from April to June and the long season from July to October. The region receives about 25% of its annual rainfall during the short rainy season and 45% during the long season.

Table 1. Elevation, latitude, longitude, soil properties, rainfall, and temperature of the study areas

District	Altitude (m)	Latitude	Longitude	Soil type	pH	Total annual rainfall (mm)	Mean annual temperature (°C)
Alemaya	1820–2040	9°26'N	42°03'E	clay loam	8.5	790	17
Babile	1650–1710	9°08'N	42°21'E	sandy loam	7.0	500	22
Dire Dawa	1110–1770	9°31'N	41°51'E	sandy loam	8.0	500	28
Fedis	1650–1700	9°12'N	42°04'E	sandy loam	7.0	600	22
Jijiga	1600–1700	8°44'N	40°22'E	sandy loam	8.0	510	23

Field survey

Field surveys were conducted for three years during October–November in 2001–2003 when most of the sorghum was at milk and dough stages. Five peasant associations (PAs) from each of the 5 districts and 10 farms from each PA were randomly selected for the filed surveys. A total of 240 farms consisting of 40 from Alemaya and 50 from the other 4 districts were used.

Fields were sampled on both sides of the road and smut incidence and severity were recorded by inspecting 100 plants per sample field. Sample plants were systematically selected by moving diagonally in an 'X' pattern from one end of each field to the other. Plants were selected randomly from five spots in each of the two diagonals of the field and the panicles were recorded as either diseased or healthy. Disease severity was determined as percentage of infection on each panicle. To obtain the variation between the surveyed districts, data on disease incidence and severity were statistically analyzed (t-test) using the MSTAT-C computer software package.

Field surveys were supplemented by conducting interviews with subsistence farmers' during October–November. A total of 120 sample farmers were selected from the five major sorghum growing districts. The interviews were administered using a pre-coded questionnaire.

Distribution of sorghum genotypes and their reactions to smuts

During the survey, the types of sorghum cultivars or varieties grown by farmers were documented. The reactions of the cultivars to smuts under farmers' field condition were determined using the method suggested by Abbas (1991). To classify the reactions of the test genotypes, the mean disease incidence was used, where < 1% incidence = highly resistant, 1–2% = resistant, 2.1–5% = moderately resistant, 5.1–10% = moderately susceptible, and > 10% = susceptible (Abbas 1991).

Yield loss assessment

Losses in sorghum yield due to covered kernel and long smuts were estimated using healthy and diseased heads in randomly selected fields from each sample PA. Differences in yield between the healthy and diseased heads were calculated to assess the effect of the pathogen on sorghum yield under actual farm condition. In each selected field, 10 healthy and 10 diseased heads were randomly selected and tagged. Disease severity on each selected diseased head was scored and the average of the ten plants was computed. The selected healthy and diseased heads were harvested separately and threshed. Yield loss was determined using the formula (Miller 1965):

$$YL(\%) = \frac{YH - YI}{YP} x100$$

where, YL = yield loss, YH = yield of healthy heads, and YI = yield of infected heads

Data were transformed with square root transformation, and statistical analysis was performed using the MSTAT-C software.

Unlike those afflicted by covered kernel and long smuts, plants infected with loose and head smuts are nearly always barren. Therefore, the yield caused by loose and head smuts loss is directly proportional to the incidence or number of plants infected.

Results

Occurrence and distribution of sorghum smuts

All the four sorghum smuts were observed attacking sorghum in farmers' fields in all the surveyed areas (Table 2). In Alemaya district, loose kernel smut was predominant with a mean incidence of 2.18%, followed by covered kernel smut (1.33%) and head smut (1.18%). The incidence of long smut was less than 1%. The mean disease severity of both covered and long smuts was about 50%. There was no statistically significant difference (p = 0.05) in disease incidence between the different smut diseases in Alemaya.

In Babile district, covered kernel smut was predominant with 20% mean incidence and 50% severity. This was followed by long smut with 70% mean incidence and 50% severity. The incidence of both head and loose kernel smuts was about 1%. There was statistically significant difference ($p \leq 5\%$) in the incidence of these diseases in the district. In Dire Dawa Administrative Council, long smut was predominant with 13% disease incidence and 5% severity. Covered kernel smut showed about 5% mean disease incidence and 4% disease severity levels. Loose kernel and head smuts were very rarely observed (< 1% incidence).

In Fedis, long and covered kernel smuts were predominant with mean disease incidence of 10 and 7%, respectively. Loose kernel and head smuts were very rarely observed (< 1% incidence). The severity of all the four smuts was more than 50%. In Jijiga area, covered kernel and long smuts were dominant with mean disease incidence of 16 and 11%, respectively, and severity of more than 50%. There were lesser incidences of head and loose kernel smuts, 3 and 1%, respectively.

Reaction of sorghum genotypes

In the surveyed areas, both local cultivars and improved varieties of sorghum were cultivated by farmers. Five local cultivars were grown in Alemaya: Muyra Dima (42%), Fendisha Adi (21%), Worabi Dima (14%), Worabi Adi (14%), and Fendisha Dima (7%).

Table 2. Incidence of smuts in five sorghum-growing districts in eastern Ethiopia

District	No. of farms surveyed	Incidence (%)			
		Covered kernel smut	Long smut	Head smut	Loose kernel smut
Alemaya	40	3	2	2	4
Babile	50	20	7	1	0.24
Dire Dawa	50	5	14	0.1	0.05
Fedis	50	7	10	0.5	0.04
Jijiga	50	16	11	3	1
Mean*		10.11[a]	08.75[b]	1.40[c]	01.10[c]

*Values with the same letter are not significantly different ($p \leq 0.05$)

Table 3. Occurrence of smuts on different sorghum genotypes in eastern Ethiopia

District	Sorghum genotypes	Local or improved	Composition (%)	Smut incidence (%)*			
				CKS	LS	LKS	HS
Alemaya	Fendisha Dima	Local	0 7.00	00.00	00.00	00.0	00.0
	Fendisha Adi	Local	21.00	0.00	00.00	04.0	03.0
	Muyra Dima	Local	42.00	04.67	01.83	01.0	00.0
	Muyra-1	Improved	01.50	00.00	00.00	00.0	00.0
	Muyra-2	Improved	00.50	00.00	00.00	00.0	00.0
	Worabi Dima	Local	14.00	0.00	07.00	0.00	00.0
	Worabi Adi	Local	14.00	00.00	00.00	00.0	00.0
Babile	Beduqani	Local	06.00	04.50	21.00	00.0	00.0
	Bullo	Local	28.00	07.88	08.00	00.0	0.22
	Chamie	Local	39.00	11.00	07.00	01.0	0.11
	Mishsinga Adi	Local	03.00	24.00	01.00	00.0	00.0
	Mishinga Dima	Local	07.00	02.50	19.50	00.0	00.0
	Muyra Dima	Local	10.00	03.70	50.00	00.0	00.0
	Wodaageray	Local	07.00	01.50	64.50	00.0	00.0
	Worabi	Local	03.00	02.00	036.00	00.0	00.0
Dire Dawa	Alisho Adi	Local	17.00	00.00	00.00	00.0	00.0
	Amagikita Dima	Local	08.00	05.00	09.00	00.0	00.0
	Amagikita Adi	Local	08.00	00.00	00.00	00.0	00.0
	Jeldi	Local	50.00	05.17	13.17	00.0	00.0
	Worabi	Local	08.30	00.00	09.00	00.0	00.0
	Others (mixed)	Local	09.00	02.00	06.00	00.0	00.0
Fedis	Cherchero	Local	25.00	00.00	02.50	00.00	00.0
	Gubiye	Imp.	20.00	03.20	01.80	00.00	00.0
	Hafera	Local	13.00	18.70	04.00	00.00	00.0
	Lugo	Local	04.00	30.00	01.00	00.00	00.0
	Oldhale	Local	13.00	02.30	01.30	00.00	00.0
	Shuna	Local	25.00	02.00	14.50	00.00	00.0
Jijiga	Abdiro	Local	05.00	15.00	02.00	00.00	00.0
	Adengab	Local	30.00	18.20	09.00	00.00	00.0
	Aqlibadan	Local	02.00	16.00	00.00	00.00	00.0
	Harur	Local	02.00	28.00	00.00	00.00	00.0
	Ilmijama	Local	27.00	25.60	01.10	00.00	00.0
	Kelmali	Local	02.00	03.00	00.00	00.00	00.0
	Kemisne Guru	Local	02.00	18.00	00.00	00.00	00.0
	Kusso	Local	05.00	16.00	09.00	00.00	00.0
	Mukurie	Local	07.00	17.70	06.00	00.00	00.0
	Qoldere	Local	02.00	08.00	00.00	00.00	00.0
	Sudan	Local	02.00	16.00	18.00	00.00	00.0
	Washenad	Local	02.00	36.00	02.00	00.00	00.0
	Wagare	Local	05.00	42.50	00.50	00.00	00.0
	Yeriyeri	Local	07.00	07.70	00.30	00.00	00.0

*CKS, covered kernel smut; LS, long smut; LKS, loose kernel smut; HS, head smut

There was no smut incidence on Fendisha Dima, Muyra-1, Muyra-2, and Worabi Adi. However, very low infections were encountered On Muyra Dima, Fendisha Adi, Worabi Dima and Worabi Adi, (Table 3). More than 86% of the cultivars were resistant to moderately resistant to all the four smut diseases Moreover, about 36% of the surveyed farmers' fields were free from smut infection.

In Dire Dawa, the local cultivars grown were: Alisho White, Amagikita Red, Amagikita White, Jeldi, and Worabi. However, Jeldi (50%) and Alisho White (17%) were predominant. Amagikita Red, Amagikita White and Worabi were more or less of equal importance (about 8% each). About 8% of the farms were covered with a mixture of cultivars. None of the surveyed fields were free from smut infection. About 67% of the

cultivars were resistant to covered kernel smut and 33% to long smut. One cultivar, Amagikita Adi, was free from smuts. It Ado was a short cultivar, and it was liked by farmers.

Cultivars locally known as Beduqani, Bullo Chamie, Mishinga Adi, mishinga Dima, Muyra Dima, Wodageri, and Worabi were grown in Babile (Table 3). Chamie and Buillo were the dominant cultivars with frequencies of 39% and 28%, respectively. The other cultivars had low frequencies ranging from 3 to 10%.

Covered kernel and long smuts were the dominant smut diseases in Babile, and none of the eight cultivars grown in the area were free from these two smuts. The highest incidence of covered kernel smut (24%) was recorded on the cultivar Mishings Adi and the lowest (1.5%) on Wodageray. The mean incidence of covered kernel smut on the dominant cultivars Chame and Bullo were 11% and 7.9%, respectively (Table 3). Whereas, the highest incidence of long smut (64%) was recorded on the cultivar Wodageray. This was followed by incidences on Muyra Dima (50%), Worabi (36%), Beduqani (21%), and Mishinga Dima (20%). The lowest incidence (1%) was recorded on Mishinga Adi. The incidence of long smut on Bullo was 8.% and Chame 7.%.

In general in Babile Woreda, 25% of the genotypes were resistant to covered kernel smut, while only 12.5% were resistant to long smut. On the other hand, about 25% of the genotypes were susceptible to covered kernel smut and 62.5% to long smut. The reaction of the rest of the genotypes ranged from moderately resistant to moderately susceptible. According to the survey results, none of the cultivars grown in Babile area were resistant to both of the diseases at the same time. Moreover, those cultivars that were resistant or moderately resistant to covered kernel smut were susceptible to long smut and vice versa, indicating that under favorable environmental conditions these local cultivars could be susceptible to either covered kernel or long smuts.

In Fedis district, five local cultivars and an improved variety (Gubiye or P9403) were encountered (Table 3). Cherchero, Gubiye and Shuna were the dominant cultivars with a frequency of 25% each. The frequency of Hafera and Oldhale was 13% each, while the cultivar Lugo comprised only 4%. Lugo and Hafera were susceptible to covered kernel smut with 30 and 18.7% incidence, respectively; but they cultivars were resistant to long smut. Cherchero was resistant to covered kernel smut, and moderately resistant to long smut. Shuna was resistant to covered kernel smut, but susceptible to long smut. In general, cultivars Oldhale, Cherchero and Gubiye showed resistant to moderately-resistant reactions to both covered kernel and long smuts (Table 3).

In Jijiga area, 14 local cultivars were recorded in farmers' fields. Among these, the cultivars Adengab and Ilmijama were predominant with frequencies of 30% and 27%, respectively. The other 12 cultivars were of low frequencies ranging from 2 to 7% (Table 3). Covered kernel and long smuts were the dominant smut diseases encountered on the cultivars. All the cultivars were infected; but there were differences in the degree of infection. The incidence of covered kernel smut on the cultivars ranged 3–42.5%. The highest incidence (42.5%) was on the cultivar Wagare, followed by Washenad (36%), Harur (28%), Ilmchame (25.6%), and Adengab (18.2). Whereas, the lowest incidence was recorded from Kelmali (3%).

In general, in Jijiga area about 79% of the cultivars were susceptible to covered kernel smut, and only 7% were moderately resistant. On the contrary, 71% of the cultivars were resistant and 29% susceptible to long smut. Only one cultivar, Kelmali, showed resistance to both of these smuts. In addition, the results showed that almost all cultivars that were resistant to long smut were susceptible to covered kernel smut.

Table 4. Percentage of farmers practicing different local smut control measures in some sorghum growing areas in eastern Ethiopia

Indigenous control measure	Percentage of farmers practicing different local control measures for smuts				
	Babile	Dire Dawa	Fedis	Jijiga	Mean %
Rouging out infected heads and feeding to domestic animals	23.26	20.00	22.00	21.00	21.57
Harvesting, piling and threshing healthy and diseased heads separately in separate threshing grounds.	18.60	20.00	15.00	14.00	16.90
Harvesting, healthy and vigorous heads and staring them separately un-threshed	5.00	2.00	2.25	3.25	3.13
Harvesting healthy and vigorous heads and hanging them on smoke till planting	10.00	5.00	4.00	4.22	5.81
Washing seeds with fine sand before planting	5.00	2.00	3.00	2.22	3.06
Washing seeds with *Atela*, a by-product of the local beer *tella*	2.00	0	0	0	0.5
Washing seeds with goat or cow urine	1.00	0	0	0	0.25
No control measure	35.14	51.00	53.75	55.31	48.30

Indigenous smut control practices

The results of the study showed that the majority of the farmers in eastern Ethiopia (48.3%) did not exercise any control measure against smuts. Some farmers, however, used different local control methods (Table 4). About 22% of the farmers rouged out infected heads and fed it to domestic animals. They then harvested healthy and vigoros heads and stored them separately till planting in the next season.

About 17% of the farmers harvested, piled, and threshed healthy and diseased heads separately on different threshing grounds. The practice was sought to avoid contamination of healthy seeds by spores from infected panicles during threshing and transportation. Generally the farmers threshed infected sorghum heads after normal heads were threshed and the seed yields were transported to the store. According to the farmers, seeds obtained from infected heads were never used for planting. A few farmers harvested healthy and vigoros heads and stored them separately (3%) or hanged them near the kitchen fire place till planting (6%). In Babile area, some farmers (2%) washed seeds with Atela, a by-product of local beer called *tella*. Moreover, some farmers (1%) in the area washed their seeds with goat or cow urine, while some others (3%) rubbed seeds with fine sand before planting.

Management practices favoring smut intensity

The farmers in the survey districts never applied chemical seed dressings against smuts because seed dressing fungicides were not available and/or affordable to farmers. Farmers mainly used local sorghum cultivars

Table 5. Farm management practices that favor occurrence of smut in eastern Ethiopia

Farm practices	Alemaya	Babile	Dire Dawa	Fedis	Jijiga	Mean*
Use of own seed/susceptible Varieties	70.00	61.00	55.00	62.00	55.00	60.60[a]
Harvesting and piling healthy and diseased heads together	0.00	4.80	6.20	5.60	2.20	03.76[d]
Threshing healthy and diseased heads in the same ground	1.00	2.00	3.60	3.40	3.10	02.62[e]
Rouging infected heads very Late	3.20	6.70	13.30	6.20	8.60	07.60[c]
Using market seed	3.70	5.20	3.25	5.40	7.28	04.97[d]
Practicing crop rotation	20.00	54.00	44.00	22.00	36.00	35.20[b]

*Means with the same letter are not significant (P≤0.05)

Table 6. Sorghum yield loss due to smuts under farmers' field condition in eastern Ethiopia

District	Mean sorghum yield loss (%)			
	Covered kernel smut	Long smut	Head smut	Loose kernel smut
Alemaya	00.10	00.00	02.00	04.00
Babile	10.00	05.00	01.00	00.24
Dire Dawa	05.00	08.00	00.11	00.05
Fedis	06.00	06.00	00.48	00.04
Jijiga	09.00	06.00	03.40	00.97
Mean*	6.02[a]	05.00[a]	01.40[b]	01.10[b]

*Means with he same letter are not significantly different (P ≤ 0.05)

selected and retained for yield potential, but with little or no emphasis on smut resistance (Table 5). Improved varieties were unavailable and when available, the supply was not enough. When there was shortage of seeds, farmers used market seeds that might not be appropriate for planting. Crop rotation in sorghum fields was not widely practised due to land shortage (Table 5). Severe infections with covered kernel and long smuts were encountered in fields of farmers that did not rogue out infected heads early or those that used market seed for planting and those that used same threshing grounds for healthy and diseased heads. These might had contributed to the severe infestation of sorghum with these smuts in eastern Ethiopia.

Yield losses due to smuts in eastern Ethiopia

In the surveyed areas, all the four smuts were found to cause yield losses of different degrees (Table 6). Covered kernel and long smuts caused losses of 6 and 5%, respectively; while the losses due to head and loose kernel smuts were about 1% each. The highest losses due to covered kernel smut were recorded in Babile (10%) and Jijiga (9%), followed by Fedis (6%) and Dire Dawa Administrative Council (5%). Long smut caused 8%, 6%, 6% and 5% losses in Dire Dawa Administrative Council, Fedis, Jijiga, and Babile, respectively. In Alemaya, the combined loss due to smuts was insignificant.

In general, the estimated combined loss due to smuts in eastern Ethiopia was about 13%. According to the survey findings, covered kernel and long smuts were economically important in the region and, therefore, needed to be controlled.

Discussion

All the four smuts were observed infecting sorghum in farmers' fields with light to severe infections. Covered kernel smut was the most predominant, and its incidence ranged from about 3% to 20% infected panicles. The highest mean incidence of covered kernel smut was encountered in Babile (20%) followed by Jijiga (16%). In Alemaya, Dire Dawa and Fedis, the incidence of the disease was 3, 5 and 7%, respectively. Most of the panicles (16%) were severely infected, and almost 50% of the grains were replaced by covered kernel smut sori. Mary of the fields had 5 to 20 diseased panicles. However, in a few scattered fields, the disease incidence was more than 30% and in one field, 80% infected panicles were recorded.

Incidence of long smut ranged from 2 to 14%. The highest mean incidence of long smut was found in Dire Dawa Administrative Council (14%). This was followed by Jijiga (10%), Fedis (10%), and Babile (7%). The incidence in Alemaya area was less than 2%. The occurrence of loose kernel and head smuts was sporadic, and their incidence ranged from less than 1 to 4%.

Covered kernel and loose kernel smuts are seed-borne diseases. Seed-borne inoculum could, therefore, facilitate the rapid spread of the diseases to areas where they did not occur previously. Covered kernel smut and long smut were gaining increasing importance in eastern Ethiopia in spite of the different control methods used by farmers. The traditional practices employed by farmers seemed to be largely responsible for the continued occurrence of sorghum smuts in the study area. The farmers continuously used their own seeds which were saved from the preceding season. Most farmers used local varieties that were susceptible to smuts. Sometimes healthy panicles are harvested and processed along with smutted panicles, resulting in an increasing possibility of seed contamination by covered kernel and long smut pathogens. Quite often, farmers removed diseased plants very late when neighboring plants had filled grains or were ready for harvest. In such cases, wind-borne spores could have already contaminated the mature crop and increased the chances of seed infection for the next season.

In the survey areas, both local cultivars and improved varieties were cultivated by farmers. In some locations farmers widely grew white-seeded sorghum cultivars. Infected seeds on intact heads might appear to be healthy because the seed color of these cultivars had a close similarity to the peridium (white-colored resistant membrane covering the sorus) of covered kernel smut. The makes similarity could, therefore, it difficult especially for farmers to differentiate the healthy grain of the white-seeded cultivars from the diseased one without careful examination. As a result, farmers would unknowingly harvest and thresh infected panicles together with healthy ones. Hence, the similarity in color might partly be responsible for the spread of the disease.

Covered kernel and long smuts caused losses of 6 and 5%, respectively, while the losses due to head and loose kernel smuts were about 1% each. In general, the estimated combined loss due to smuts in eastern Ethiopia was about 13%. The continued incidence and severity of smuts in the area indicated that they were economically important and could result in significant yield losses. For instance, unlike those afflicted by covered kernel and long smuts, plants infected with loose and head smuts were nearly always barren. Therefore, the loss in

yield was directly proportional to the number of plants infected.

Control particularly of covered kernel and loose kernel smuts can easily be achieved by a cost effective treatment. In Ethiopia, a range of effective seed-dressing chemicals such as Thiram, Maneb, Captan, Thiram + lindance and Macozeb have been recommended for the control of covered kernel smut (EARO 1997 EARO 1996). However, farmers do not treat seeds before planting because the pesticides are expensive and only available in the city markets, and they may be accessible only to progressive farmers.

The most promising control method for covered kernel smut is the use of fermented goat urine and the insecticide Apron Plus (EARO 1996). In Nigeria, systemic seed-dressing chemicals (Apron Plus 50 DS and Vitavax 75% WP) have been found effective and economical for the control of covered kernel smut. Carboxin is known to be effective against smuts of small grains, and it is a registered compound in several African countries (Mtisi 1996).

The results of the present study showed the importance of covered kernel and long smuts in sorghum in eastern Ethiopia and presence of different local smut control methods. Farm management practices that favor smut perpetuation in eastern Ethiopia were also identified. Thus, for subsistence farmers in eastern Ethiopia integrated management of covered kernel and long smuts may be a useful approach. That may involve integration of certified disease-free seeds or resistant varieties and good farming hygiene such as rouging out diseased panicles before gall rupture, threshing infected panicles separately after normal heads are threshed and carried to the store and sound crop rotation practice. Effective seed dressing fungicides that can provide complete protection should be made available to subsistence farmers. In addition, further studies on the performance of the locally adapted cultivars should be carried out in order to use them in sorghum improvement programs.

Acknowledgements

I thank Ethiopian Institute of Agricultural Research for providing financial support to conduct the study. The technical assistance of Mr Amare Kebede, Ms Haimanot Bizuneh and Ms Kokebe Gizaw is highly appreciated.

References

Abbas A. 1991. *Screening for resistance to smuts of some new sorghum varieties and efficacy of seed dressing fungicides against covered kernel smut (Sphacelotheca sorghi).* M.Sc. thesis in Plant Protection, Damascus University, Damascus, Syria.

AU (Alemaya University). 2003. *Sorghum Improvement Project Progress Report for 2002.* Alemaya University Research Center, Alemaya, Ethiopia.

Berhane Gebre Kidan. 1973. The importance of the Ethiopian sorghum germplasm in the world sorghum collection. Economic Botany 27: 442-445.

EARO (Ethiopian Agricultural Research Organization). 1996. *Sorghum Improvement Program, Progress Report for the Period 1995/96.* Addis Ababa, Ethiopia.

EARO (Ethiopian Agricultural Research Organization). 1997. *Bako Research Center, Crop Protection Division Progress Report for 1997.* Bako Agricultural Research Center, Bako, Ethiopia.

Esele JP. 2002. Sorghum and pearl millet disease in the Horn of Africa. In: *Sorghum and millets diseases,* Leslie JF. (ed.). pp. 383–387. Iowa State Press, Ames, Iowa. 504 pp.

Eshetu Belete. 2002. *Incidence and distribution of sorghum covered kernel smut [Splacelotheca sorghi (Link) (Clint.], varietal differences and its impact on yield in North East Ethiopia.* M.Sc. Thesis. Alemaya University.

Frowd JA. 1980. A World Review of Sorghum Smuts. In: *Sorghum diseases: a world review.* Williams RJ., Frederiksen RA., Mughogho LK. *Proceedings of the International Workshop on Sorghum Diseases,* 11–15 December 1978, ICRISAT, Hyderabad,

India ICRISAT, Hyderabed, India. Pp. 331-348.

Mengistuu Hulluka. 1982. Disease of sorghum at some locations in Ethiopia. *Ethiopian Journal of Agricultural Sciences* **4**:45–54.

Merkuz Abera. 2001. *Distribution and severity of sorghum covered kernel smut, varietal differences, and its impact on yield in Northwest Ethiopia.* M.Sc. Thesis, Alemaya University.

Miller DJ. 1965. *Introduction to plant diseases.* McGraw-Hill,* New York. 265 pp.

Mtisi E. 1996. Evaluation of systemic seed dressing fugicides for the control of covered kernel smut on sorghum in Zimbabwe. In: *Drought-tolerant crops for Southern Africa*, Leuschner K., Manthes CS. (eds). *Proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop*, 25–29 July 1994, Gaborone, Botswana, ICRISAT, Hyderabad, India. pp. 185–188.

Temam Hussien. 1990. A review of sorghum disease research in Ethiopia. In: *Cereals of the semi-arid tropics.* Wolf J. N. (Ed.) pp. 253–257. *Proceedings of a Regional Seminar on Cereals of the Semi-Arid Tropics*, September 12–16, 1989, International Foundation for Science (IFS), Garoua, Cameroon. 318 pp.