Yield Losses in Sorghum Due to Covered Kernel Smut in Northeast Ethiopia

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Abstract

A study to determine yield losses in four cultivars of sorghum (*Sorghum bicolor*) due to covered kernel smut caused by *Sporisorium sorghi* was made at Sirinka and Kobo, both located in Northeast Ethiopia, during 2001 and 2002. Seeds of cultivars Jigurty, Gambella 1107, 76T$_1$#23 and Meko were artificially inoculated with teliospores of covered kernel smut. The control treatment was protected from the disease using fungicide. Different levels of covered kernel smut infection were produced among the cultivars in the inoculated plots, causing significant grain yield reductions. At Kobo, higher grain yield reduction (40.2%) occurred in 2001 when disease incidence was 32.6% and severity 4.7 than in 2002 (12.9%) when disease incidence was 35.0% and severity 3.2. Similarly, at Sirinka, higher yield reduction occurred in 2001 (9.9%) at 4.0% disease incidence and 2.8 severity than in 2002 (7.8%) at mean disease incidence of 20.5% and severity of 2,5. There were highly significant positive ($p < 0.05$) correlations between covered kernel smut severity and grain yield losses. The findings indicated that grain yield was highly influenced by disease severity. The levels of yield loss were found significant enough to justify control of the disease.

Key words: Sorghum, epidemics, smut, yield loss

Introduction

Sorghum (*Sorghum bicolor*) is a major crop in the semi-arid areas of Northeast Ethiopia (Berhane and Yilma 1979). The crop is a staple cereal used for food and local beverages. In addition, the stalk of sorghum is used as animal feed, fuel and construction material. However, the national average grain yield of sorghum is low (12 q/ha), as compared to the world average of 30.6 q/ha (CSA 2000, Davies 1980).

The production of sorghum is affected by various constraints including diseases. Many diseases are reported to infect sorghum in Ethiopia. These include grain diseases such as smuts, grain mold and ergot and leaf diseases such as anthracnose, downy mildew and leaf blight (Teklemariam 1985 and Temam 1990). According to Mengistu (1982), smuts are the most widely spread grain diseases of sorghum in Ethiopia. The major ones are loose kernel smut [*Sporisorium cruentum* (Kühn) Vanky], covered kernel smut [*S. sorghi* Link in Willd.], head smut [*S. reilianum* (Kühn) Langdon & Fullerton] and long smut [*S. ehrenberghii* Vanky].

Covered kernel smut has been reported to be widely distributed in most sorghum growing areas of Northeast Ethiopia (SARC 1996). Covered kernel smut is a seed-borne disease, and sorghum seeds contaminated with teliospores of the fungus are the main source of inoculum. In infected sorghum plants, the grains are individually replaced by smut, either in part or whole of the panicle (Frederiksen 2000).

In Ethiopia, the extent of combined loss of sorghum grain due to smuts may reach up to 20% (Mengistu 1982, Teklemariam 1985, Temam 1990). In addition, the estimated losses in major sorghum producing areas of

East Ethiopia due to the three smuts are 3 to 28%. The extent of damage in grain varies among sorghum genotypes; besides, cultivars of sorghum vary in susceptibility to covered kernel smut (Tar 1962, Frowd 1980). In Pakistan, 25 varieties from different sources screened against covered kernel smut were found to vary greatly in their resistance to covered kernel smut. None of the varieties was immune, and all showed different levels of infection (Mirza. et al. 1982). The variability of the disease in the level of infection among the varieties might be due to the existence of physiological race of the pathogen.

About five physiological races of *S. sorghi* were identified and well characterized in USA on the bases of color, length and manner of rupture of sori (Frowd 1980). According to the results of a previous study in Northeast Ethiopia, early-maturing sorghum cultivars were more susceptible to the disease than late-maturing cultivars (Eshetu 2003). Therefore, among the six common sorghum cultivars grown throughout northeast Ethiopia, there appears to be variation in the pathogen population.

Despite the fact that covered kernel smut is widely prevalent in Northeast Ethiopia, the extent of yield losses due to the disease in the area were not assessed. Moreover, the extent of losses in the different cultivars grown in the area were not determined. The present study was, therefore, undertaken to determine the yield losses caused by covered kernel smut in some important sorghum cultivars grown in Northeast Ethiopia.

Materials and Methods

Two field experiments were conducted at Sirinka and Kobo research sites of Sirinka Agricultural Research Center in 2001 and 2002 crop seasons. Sirinka is located at an altitude of 1880 m and receives an annual mean rainfall of 900 mm, while Kobo is located at an altitude of 1470 m and receives a mean annual rainfall of 800 mm. In both Sirinka and Kobo areas, uneven distribution of rainfall results in severe moisture stress (SARC 1996).

Four cultivars of sorghum, namely, Jigurty (local), Gambella 1107, 76T$_1$#23 and Meko (all improved), were used under inoculated and protected conditions. The treatments were arranged in randomized complete block design with four replications in a factorial arrangement. Each entry in a replication was planted in a plot that consisted of 5 rows with 5 m length each. A spacing of 20 cm between plants and 75 cm between rows were used. The recommended agronomic practices were followed. Fertilizer was applied using DAP (21 N: 23 P) at a rate of 100 kg/ha at planting and urea (45% N) at a rate of 100 kg/ha in split application at planting and 60 days after sowing (Teshome et al. 1995).

Seeds of the four cultivars were surface-disinfected with 70% ethanol, washed with distilled water to remove all traces of disinfectant and left on the laboratory bench to dry. The dried seeds were inoculated with teliospores of covered kernel smut at the rate of 2.5 g/kg of seeds (House 1985). Seeds for the control plots were treated with seed dressing fungicide. The commercial fungicide apron plus 50 DS (methylacyl + carboxin + furathiocarb) was used at the rate of 2.0 g/kg of seeds.

Disease severity was measured at milk and dough growth stages of the crop. The proportion of damage on each head was recorded using a 1–5 scoring scale, where 1 stands for 0% panicle damage, 2 for 1–10%, 3 for 11.25%, 4 for 26–50% and 5 for 50% or above. Disease incidence of infected plants was counted and expressed as percentage of the total counts. Thousand seed weight and seed yield per plot were recorded after harvest. Relative yield loss due to covered kernel smut was estimated as the proportion of the difference between mean yields of protected and inoculated plots. Percentage yield loss was computed using the formula (Miller 1965):

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

where, YL is yield loss; YP, yield of protected plot and YI, yield of inoculated plot.

Statistical analysis was made using MSTAT-C (MSU 1988). Mean separation was done using LSD Test. Regression coefficient was calculated to determine the relationship of yield and selected parameters (Gomez and Gomez 1984).

Results

Covered kernel smut developed in the inoculated treatments at both Kobo and Sirinka. There were significant differences between inoculated and protected treatments in all cultivars. In the 2001 crop season at Kobo, the mean disease incidence in the inoculated treatments was 32.6% and the mean severity score was 4.7 (Table 1). At Sirinka, the mean disease incidence was 4.0% and mean severity score was 2.8 (Table 2). Gambella-1107 showed the highest disease incidence (8.4%) at Sirinka, while Jigurty showed the lowest (0.6%). However, at Kobo the highest disease incidence (49.9%) was recorded on 76T_1#23 and the lowest (7.0%) on Jigurty. In 2002, the mean disease incidence at Kobo was 35.0% and the severity score was 3.2 (Table 3). The mean disease incideace at Sirinka for the same year was 20.5% and the severity score was 2.5 (Table 4). Similar trends of smut development were observed in all the cultivars and both seasons, the disease being more severe at Kobo than Sirinka. In general, the lowest disease infection was observed on local sorghum cultivar (Jigurty) compared to the other cultivars across the two locations.

Table 1. Effect of covered kernel smut on grain yield of sorghum cultivars at Kobo, 2001

Variety	Incidence %		Severity*		Grain yield (t/ha)		
	Protected	Inoculated	Protected	Inoculated	Protected	Inoculated	Yield loss (%)
Jigurty	0.0	7.0c**	1.0	4.4	5.2ab	3.7a	28.8
Gambella-1107	0.0	31.5b	1.0	5.0	4.5b	2.1b	53.3
Meko	0.0	42.1a	1.0	4.6	5.5a	3.4a	38.2
76 T_1#23	0.0	49.9a	1.0	4.8	4.9ab	2.9ab	40.8
Mean	0.0	32.6	1.0	4.7	5.0	3.0	40.2
LSD at 0.05	0.73		2.03		931.4		
CV%	16.2		12.7		14.0		

*Disease severity recorded on 1-5 scale, where 1 = 0%, 2 =1-10%, 3 =11.25%, 4 = 26-50% and 5 ≥50% panicle damage.

**Values with the same letter in a column are not significantly different using DMRT at 5% level

Table 2. Effect of covered kernel smut on the grain yield of sorghum cultivars at Sirinka, 2001

Variety	Incidence %		Severity*		Grain yield (t/ha)		
	Protected	Inoculated	Protected	Inoculated	Protected	Inoculated	Yield loss (%)
Jigurty	0.0	0.6b**	1.0	1.5	3.0	2.9	3.3
Gambella-1107	0.0	8.4a	1.0	3.6	4.4	3.8	13.6
Meko	0.0	3.2b	1.0	3.1	4.3	3.9	9.3
76 T_1#23	0.0	3.8ab	1.0	3.1	4.4	3.8	13.6
Mean	0.0	4.0	1.0	2.8	4.0	3.6	9.9
LSD at 0.05	0.98		1.53		NS		
CV%	50.5		46.9		16.2		

*Disease severity recorded on 1-5 scale, where 1 = 0%, 2 =1-10%, 3 =11– 25%, 4 = 26-50% and 5 ≥ 50% panicle damage

**Values with the same letter in a column are not significantly different using DMRT at 5% level

Table 3. Effect of covered kernel smut on the grain yield of sorghum cultivars at Kobo, 2002

Variety	Incidence %		Severity*		Grain yield (t/ha.)		
	Protected	Inoculated	Protected	Inoculated	Protected	Inoculated	Yield loss %
Jigurty	0	12.7	1.0	2.6	4.0	3.8	5.0
Gambella-1107	0	32.9	1.0	4.2	3.4	3.2	5.8
Meko	0	45.6	1.0	2.9	3.2	2.9	9.3
76 T_1#23	0	48.9	1.0	3.0	4.1	2.8	31.7
Mean	0	35.0	1.0	3.2	3.7	3.2	12.9
LSD at 0.05	1.42		1.67		NS		
CV%	30.9		18.1		24.0		

*Disease severity recorded on 1–5 scale, where 1 = 0%, 2 = 1–10%, 3 = 11–25%, 4 = 26–50% and 5 ≥50% panicle damage

Table 4. Effect of covered kernel smut on the grain yield of sorghum cultivars at Sirinka, 2002

Variety	Incidence %		Severity*		Grain yield (t/ha)		
	Protected	Inoculated	Protected	Inoculated	Protected	Inoculated	Yield loss (%)
Jigurty	0	8.4	1.0	1.5	4.6	4.5	2.1
Gambella-1107	0	18.2	1.0	3.4	3.8	3.6	5.2
Meko	0	30.2	1.0	2.1	2.7	2.5	7.4
76 T_1#23	0	25.4	1.0	3.1	3.6	3.0	16.6
Mean	0	20.5	1.0	2.5	3.7	3.4	7.8
LSD at 0.05	1.58		2.28		NS		
CV%	49.8		27.1		15.9		

*Disease severity recorded on 1–5 scale, where 1 = 0%, 2 = 1–10%, 3 =11–25%, 4 = 26–50% and 5 ≥ 50% panicle damage

In 2001, the yield difference between protected and inoculated treatments was highly significant ($p < 0.05$) at Kobo and the relative grain yield loss ranged from 28.8 to 53.3% (Table 1). The highest sorghum yield loss occurred on improved variety Gambella-1107, while the lowest was on the local cultivar Jigurty. At Sirinka the yield differences between protected and inoculated plots were not statistically significant. But the highest yield loss (13.6%) was recorded on Gambella-1107, and 76T_1#23 and the lowest (3.3%) on Jigurty (Table 2).

In 2002 crop season, though the yield differences among cultivars were not statistically significant, the yield loss caused by covered kernel smut in different cultivars ranged from 5.0 to 31.7% at Kobo (Table 3) and from 2.1 to 16.6% at Sirinka (Table 4). Smut development was relatively low in 2002 at both locations, and that could be the reason for not having statistically significant yield losses among cultivars.

There was significant and positive relationship between percentage disease incidence and severity at both locations (figures 1 and 2). But highly significant and positive correlation ($r = 0.76$) was observed at Sirinka (Figure 1). The grain yield of sorghum, however, negatively correlated with the incidence of covered kernel smut. At kobo, there was highly significant ($p < 0.05$) and negative correlation ($r = 0.82$) between grain yield and disease severity. Grain yield also negatively correlated with severity ($r = 0.14$) at Sirinka (Figure 2). The results indicated that there was strong negative relationship between the intensity of the disease and sorghum grain yield.

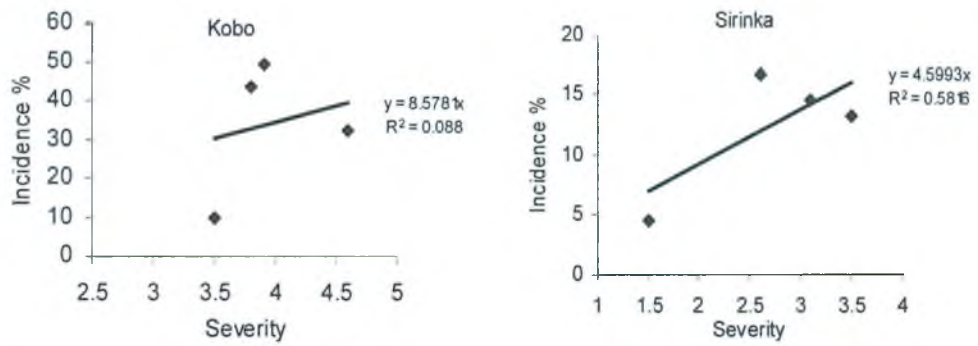

Fig.1 Estimated linear relationship between mean disease incidence and severity, 2001 and 2002

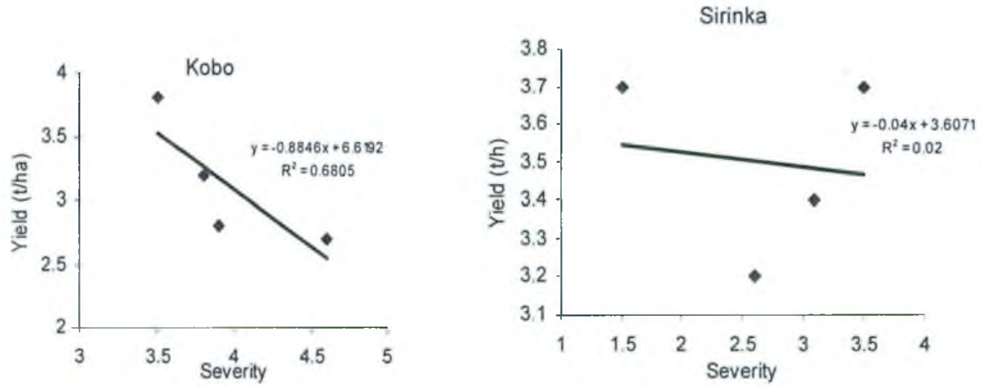

Fig.2 Estimated linear relationship between mean disease severity and grain yield of sorghum, 2001 and 2002

Discussion

The study revealed that covered kernel smut reduced sorghum grain yield substantially. The yield loss was highest on $76T_1$#23 and lowest on Jigurty cultivar. The cultivars responded to the disease differently, resulting in different disease incidence and severity levels of covered kernel smut. In addition, the result established variation in relationship between yield losses and disease infection levels in the field. The result of covered kernel smut infection in major sorghum growing areas of Northeast Ethiopia showed that there was variation in pathogen population among sorghum cultivars (Eshetu 2003). The study also showed that the local sorghum cultivar (Jigurty) had lower smut infestation as compared to the improved sorghum varieties.

According to Frowd (1980), temperature at sowing time is important for initial infection and higher infection rate was observed when mean temperature was 23.9 °C. In the present study during both cropping seasons, the mean monthly air temperature at Kobo (23.4 °C) and at Sirinka (21.9 °C) were conducive to the germination and infection of teliospores (figures 3 and 4). At Kobo, the weather and soil types were more favorable for disease development and, therefore, resulted in higher disease and significant grain yield loss. However, at Sirinka higher amount of rainfall during sowing in July increased waterlogging in the Vertisol and the high soil moisture might have reduced the germination of spores and host infection (Figure 4). This is in agreement with the report of Frederiksen (2000) in which it was stated that free water significantly retarded spore germination, promycilia growth and subsequent host infection. Adlakha and Munjal (1963) also stressed the importance of temperature as a determinant factor at initial infection of covered kernel smut during sowing time.

Grain yield was highly influenced by the severity of covered kernel smut. Yield loss among cultivars was widely varied and the higher sorghum grain yield reduction was recorded on improved sorghum varieties than local cultivars. The current study showed a mean seed yield loss of 17.7% in different sorghum cultivars in two growing seasons at two locations in Northeast Ethiopia. This is estimated at 1.00 to 3.24 q/ha mean grain yield reduction in the two years. Some researchers reported different results; in some parts of Africa up to 50% yield loss was recorded (Frowd 1980). In East Ethiopia, combined losses due to smuts were estimated to be up to 28% in which losses caused by covered kernel smut alone accounted for about 17% (Ashagari 1973). Another study at Bako showed that sorghum grain yield loss due to covered kernel smut ranged from 31 to 42% compared to untreated susceptible treatments.

In conclusion, the results of the present study showed that covered kernel smut has a potential to cause enormous losses in grain yield of sorghum in Northeast Ethiopia. This suggests a need to develop control measures that may reduce such considerable yield losses in sorghum and contribute to stabilization of sorghum production in similar agro-ecologies.

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