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Varietal Resistance and the Use of Fungicide for the Integrated Management of Sorghum Anthracnose in Parts of North-Eastern Nigeria

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ABSTRACT

Sorghum [*Sorghum bicolor* (L) Moench] anthracnose caused by *Colletotrichum sublineolum* is a serious and destructive foliar disease and a major production problem of sorghum in Nigeria. Field experiments were conducted to determine the efficacy of Apron Star 42 WS seed dressing fungicide and varietal resistance for the integrated management of leaf sheath and midrib anthracnose disease of sorghum in Northeastern Nigeria. The treatments consisted of improved sorghum varieties and local sorghum varieties that were both fungicide treated and untreated. Seed dressing with fungicide significantly reduced the incidence and severity of anthracnose disease in sorghum. The local variety 'Warwarbashi' recorded the highest disease incidence (62.2%), while 'Bauchi Early Selection' and 'Ex-Mali' consistently had the lowest disease incidences. Fungicide-treated varieties significantly lowered the severity of leaf sheath anthracnose at all growth stages. The fungicide also lowered the severity of midrib anthracnose and varieties differed both in their levels of leaf sheath and midrib disease severity. 'Warwarbashi' had the highest severity of leaf sheath anthracnose (75.9%) while 'Warwarbashi' also recorded the highest midrib disease severity (65.9%) indicating that it is a susceptible variety. 'ICSV 111' and 'Bauchi Early Selection' recorded the lowest leaf sheath and midrib anthracnose severity. All varieties performed differently in their grain yield: 'Ex-Mali' recorded the highest grain yield (1234.0 kg/ha) followed by 'Paul Biya' and 'Ex-Mali', at 1151.0 and 1122.0 kg/ha, respectively, despite their high levels of anthracnose incidence and severity.

Keywords: Apron Star 42 WS, incidence, leaf sheath, midrib, severity, variety

INTRODUCTION

Sorghum [*Sorghum bicolor* (L) Moench] is an important cereal crop that is well adapted to the Sahel and Sudan savanna ecologies of north eastern Nigeria (Izge and Alimta 2008; Dugje *et al*. 2008). However, this important crop is affected by numerous biotic problems among which is anthracnose. Sorghum anthracnose caused by *Colletotrichum sublineolum* is among the most destructive foliar diseases (**Fig. 1**) and a major production constraint of sorghum in Nigeria. The pathogen has a wide host range including cultivated and wild species of cereals and grasses (Tarr 1962; Esele 1995). The disease is transmitted by seed and soil-trash and is favoured by warm humid weather, and as such it is prevalent in tropical and semi-tropical regions where sorghum is grown, especially when seeds are sown undressed without fungicide. The pathogen can infect leaves, stalks, peduncle, panicle and the grain either separately or together (Pastor-Corrales and Frederiksen 1980). It can also infect susceptible sorghum producing patchy and different lesions on the leaf lamina, leaf midrib and leaf sheath resulting in grain yield reduction of up to 50% or more (Rivera 2006).

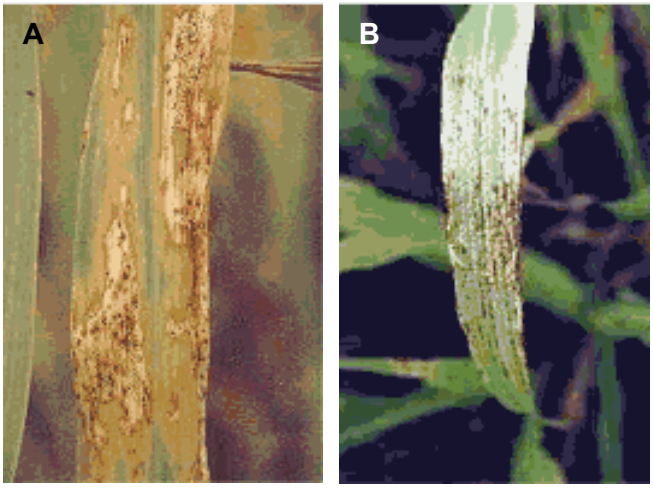

Fig. 1 (**A**) Anthracnose symptom on susceptible sorghum. (**B**) Anthracnose symptom on resistant sorghum.

In Nigeria anthracnose disease has been reported to cause severe foliar damage on sorghum and could cause yield losses of up to 47% (Tyagi 1980; Marley *et al*. 2004). Yield loss of up to 67% has also been reported in other parts of West Africa (Thomas *et al*. 1996). The disease has also contributed to losses in grain quality due to incomplete grain fill.

In a survey of the prevalence of fungal diseases of sorghum in three agro ecological zones in Nigeria, anthracnose disease was found to be the most important in more than 95% of the surveyed fields (Pande *et al*. 1993). Loss in grain yield estimated on susceptible sorghum cultivars have been reported to involve grain abortion (Thomas *et al*. 1996). The damage caused by this disease ranges from deterioration of grain to peduncle breakage, stalk rot and foliage damage (Pastor-Carroles and Federiksen 1980; Gwary *et al*. 2002). Damage by this disease may occur at different stages of plant growth (Warren and Nicholson 1975; Gwary *et al*. 2003). The leaf blight phase of the disease is the most serious. In severe cases, yield losses can be as high as 50% or more, especially under alternating wet and dry cycles and

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high temperatures (Harris *et al*. 1964; Harris and Sowell 1970; Ali *et al*. 1987; Rivera 2006).

Various methods and strategies like field sanitation and the use of disease-free seeds have been suggested for the control of this disease however, the use of resistant crop varieties has often been recommended as the best option because it is considered the most economical approach for successful management of the disease (Erpelding and Pom 2004). The International Crops Research Institute for the Semi-Arid Tropics based in India with field stations in West Africa has worked hard for the general improvement of sorghum and has released sorghum varieties like IS2834 and ICSB88019 (Hess *et al*. 2002) for semi-arid regions that are anthracnose resistant, in addition to having other enviable agronomic traits. New fungicides have also been developed that could be effective in the control of anthracnose disease in sorghum even though they are considered as uneconomical because of the low value of sorghum in other parts of the world. In addition, potential risks to the environment and human health can occur from fungicide use.

Even though the use of resistant varieties has been considered as an economical approach, there have been reported cases of erosion of resistance in crop plants over time (Erpelding 2008). In addition, because anthracnose is highly variable with the occurrence of many physiological races, changes in the virulence pattern of populations have occurred resulting in a loss of plant host resistance (Erpelding 2008). With the level of research at present, the issue of break down of resistance or pathogen developing resistance to a particular fungicide is a re-occurring phenomenon and control measures will always need to be updated with time. In addition, timely control and choice of control is very important and therefore, on top of fungicide control advocated by Gwary and Asala (2006), there is a need for farmers to have alternative control measures among other choices. The use of fungicides, especially newly developed ones, is important considering yield loss as a result of this disease. The use of varietal resistant is equally essential considering its environment friendliness and cost effectiveness. Esele (1995) has advocated the use of varietal resistance as the most effective control measure of anthracnose disease in sorghum, because the method is cheap and environmentally friendly.

With the level of agricultural awareness in Nigeria farmers are conversant with the use of fungicides and varietal resistance for the integrated control of crop diseases and these chemicals and resistant varieties are readily available. The objectives of this study were to evaluate the use of a relatively newly developed fungicide for the control of anthracnose disease in sorghum. In addition, the study also evaluated the use of varietal resistance in sorghum as an alternative or a combination measure for the control of anthracnose disease.

MATERIALS AND METHODS

Field trials were conducted at the Teaching and Research Farm of Faculty of Agriculture, University of Maiduguri Nigeria (11° 53′ N, 13° 16′ E) under rain-fed condition during 2001 and 2002 cropping seasons. The treatments consisted of three improved sorghum varieties (treated and untreated), plus three local varieties (treated and untreated) with relatively newly developed fungicide (Apron Star 42 WS) making a total of 12 treatments in all. The three improved sorghum varieties were 'ICSV111', 'ICSV400' and 'Bauchi Early Selection', while the three local varieties were 'Paul Biya', 'Ex-Mali' and 'Warwarbashi'. The improved varieties were obtained from the Lake Chad Research Institute, Maiduguri, Nigeria while the local varieties were obtained from the Borno State Agricultural Development Program (BOSADP), also in Maiduguri, Nigeria. Apron Star 42 WS, which is a relatively new fungicide, was obtained from Sygenta Nigeria Ltd. (formally known as Novartis Nigeria Ltd.). The treatments were laid out in a strip-plot design, made up of three replications. Each replication consisted of 12 plots and each plot consisted of a 5 m × 5 m area with an inter- and intra-row spacing of 90 and 60 cm, respectively. There were 4 rows of 5 m length in each plot.

The seedbeds were prepared using a hand-hoe to obtain a fine tilth after the land was ploughed and harrowed with a tractor. Compound fertilizer NPK (15: 15: 15) was applied at a rate of 259 kg/ha and later followed by side placement of urea at a rate of 100 kg/ha four weeks after planting as recommended by BOSADP (1989, 1993). The sorghum variety seeds were dressed with Metalaxyl (Apron Star 42 WS) at a rate of 2.5 g product/kg of seeds by shaking thoroughly for 5 min. The undressed seeds on the other hand were used as control treatments. Both the dressed and undressed seeds were sown in the field within a period of 24 hours. Weeding was done at two weeks after sowing using a hand-hoe and the seedlings were thinned down to two plants per stand. The study was conducted on anthracnose-infected plots where the natural inocula had been built up over time due to the cultivation of susceptible sorghum varieties in this area. The incidence of anthracnose was determined at physiological maturity using the following formula according to Gwary *et al*. (2002).

$$\text{Disease incidence (\%)} = \frac{\text{Number of diseased plants}}{\text{Total number of plants}} \times 100$$

The severity of leaf sheath anthracnose were determined on the two middle rows on five randomly selected plants tagged at 10 days interval from 65 through 95 days after sowing (DAS) using the disease rating scale of 1-10 according to Thakur (1995).

The mean percentage of the disease severity was computed using the following formula:

$$\text{Mean \% of disease severity} = \sum n \times \frac{100}{N \times 10}$$

where $\sum n$ = Summation of individual assessments/ratings, N = total number of plants assessed/rated and 10 = highest score of the severity scale.

The panicles were harvested, sundried, threshed and winnowed. The grain yield of individual plots were weighed and converted into kilogram per hectare.

All data collected were subjected to analysis of variance (ANOVA) and the mean were separated using Duncan's New Multiple Range Test (DNMRT) at the 5% level of probability.

RESULTS AND DISCUSSION

Anthracnose incidence

The absence of identified and stable means of controlling anthracnose disease of sorghum in several countries, including Nigeria, has put the burden of integrated control on seed dressing and the use of resistant varieties as the most effective measures of managing sorghum anthracnose disease.

The result of the efficacy of seed dressing fungicide and sorghum varieties on the incidence of anthracnose disease (**Table 1**) indicates that there was a significant difference in anthracnose incidence among the dressed and the undressed treatments. This implies that the varieties reacted differently to anthracnose disease. The result shows that 'Warwarbashi' had the highest disease incidence in 2001 on dressed and undressed plants with disease incidences of 47.7 and 76.7%, respectively. This was followed by 'Paul Biya', which also recorded high anthracnose incidence on sorghum varieties grown from dressed and undressed seeds. These sorghum varieties that recorded high anthracnose incidences whether dressed or not could be susceptible morphologically and may not possess a gene for resistance to this pathogen. Marley and Ajayi (2002) reported that many local landraces in West Africa lack satisfactory resistance. However, in the case of 'Paul Biya' even though it recorded the highest anthracnose incidence it produced the highest grain yield when the seeds were not dressed indicating that it is resistant to anthracnose. The lowest anthracnose disease incidence on the other hand was recorded on 'Ex-Mali' (10.3%) that was seed dressed with fungicide followed by 'Bauchi Early Selection' with incidence of 15%, whether dressed or not. 'Ex-Mali' exhibited low anthracnose incidence probably because it has not been grown and adapted to this part

Table 1 Efficacy of seed dressing fungicide and sorghum varieties on incidence of anthracnose disease (%) in 2001 and 2002 cropping seasons.

Year	Treatments	Sorghum varieties						Mean
		ICSV 111	ICSV 400	BES	Paul Biya	Ex-Mali	Warwarbashi	
2001	Seed dressed	25.0 bcd	17.3 d	15 d	25.3 bcd	10.3 d	47.7 b	23.4 b
	Control	21.7 cd	25.7 bcd	15 d	40.3 bc	22 cd	76.7 a	33.6 a
	SE±	-	-	2.61**	-	-	-	1.09*
	Variety Mean	23.3 bc	21.5 bc	15 c	32.8 b	16.2 c	62.2 a	-
	SE±	-	-	3.61**	-	-	-	-
2002	Seed dressed	17.3	17.7	14.7	23.7	8.3	44	20.9
	Control	25	32.7	18	40.7	18	69.3	33.9
	SE±	-	-	4.97	-	-	-	0.83**
	Variety Mean	21.1 bc	25.2 bc	16.3 c	32.2 b	13.2 c	56.7 a	-
	SE±	-	-	4.78**	-	-	-	-

Means with the same letter (s) in the same column are not significantly different from each other at 5 % level of probability.

of Nigeria and therefore could still have some resistance as the pathogen may not have developed some kind of virulence against it. Improved varieties recorded a relatively lower anthracnose disease incidence. However, 'Ex-Mali', which is among the local varieties, surprisingly recorded a lower incidence (16.2%), much lower than that of 'ICSV400' and 'ICSV111', with a 21.5 and 23.3% incidence, respectively in 2001.

Similarly, the result in 2002 (**Table 1**) also indicated that 'Warwarbashi' recorded the highest incidence when dressed or not dressed (44 and 69.3%, respectively). This is expected of most local and unimproved varieties as they could probably lack the gene for anthracnose resistance (Pande *et al*. 1991; Thakur and Mathur 2000). The lowest disease incidence in 2002 was recorded by 'Ex-Mali', which incidentally also had the lowest disease incidence in 2001, indicating that this variety has some resistance status considering the high grain yield produced. The variety 'Ex-Mali' is second to 'Paul Biya' in terms of grain yield.

On average, in both years 'Ex-Mali' had the lowest disease incidence followed by 'Bauchi Early Selection' and 'ICSV111'. The lowest disease incidence was recorded on crops grown from dressed seeds in 2002. The interaction between seed dressing and varieties on incidence of anthracnose was significant in 2001, but was not so in 2002.

Leaf sheath anthracnose severity

Results on leaf sheath anthracnose severity are presented in **Table 2**, which indicates that significant differences existed in leaf sheath anthracnose severity among the dressed and undressed treatments. Results show that all the sorghum varieties grown from the dressed treatment had a significantly lower anthracnose leaf sheath severity compared to the undressed treatments at 75, 85 and 95 DAS, but not at 65 DAS. Anthracnose is a late season disease and this confirms the result of TeBeest and Cartwright (2006) who reported that anthracnose disease usually begins to develop rapidly to severe levels after flowering begins, corroborating why the disease was not devastating in the few days after sowing. However, the disease became destructive as indicated by a higher level of incidence or severity in later periods after sowing. According to Thomas *et al*. (1996), anthracnose can destroy sorghum plants rapidly as they approach maturity.

'Warwarbashi' had the highest anthracnose leaf sheath severity (82.2%) at 85 DAS in 2001 when not dressed with fungicide and this was followed by 'Paul Biya' with severity of 70.4% at 85 DAS in the same year. The level of susceptibility in 'Warwarbashi' and 'Paul Biya' seem to be consistent, confirming that these varieties are prone to infection unless chemical controls are used to control anthracnose.

Table 2 Efficacy of seed dressing fungicide and sorghum varieties on the severity of leaf sheath anthracnose in 2001 and 2002 cropping seasons.

	Severity of leaf sheath anthracnose disease among the sorghum varieties (%)													
Treatments	ICSV 111		ICSV 400		BES		Paul Biya		Ex-Mali		Warwarbashi		Mean	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
65 DAS														
Seed dressed	11.1	11.1 e	20.7	18.5 e	11.1	11.1 e	27.4	34.8 cd	21.5	25.2 de	31.1	45.2 ab	20.3	24.3 b
Control	11.1	11.1 e	28.9	31.9 d	11.1	11.1 e	30.4	41.5 bc	27.4	31.9 d	37	53.3 a	24.3	30.1 a
SE±	-	-	-	-	2.27 ns	1.88*	-	-	-	-	-	-	0.83 ns	0.63*
Varietal means	11.1 e	11.1 e	24.8 c	25.2 d	11.1 e	11.1 e	28.9 b	38.2 b	24.4 c	28.5 c	34.1 a	49.3 a	-	49.3 a
SE (±)	-	-	-	-	0.79**	1.85**	-	-	-	-	-	-	-	-
75 DAS														
Seed dressed	11.1	11.1 d	28.9	11.1 d	11.1	11.1 d	36.3	40 bc	29.6	34.1 c	42.2	51.9 ab	26.5	26.5 b
Control	11.1	11.1 d	37.8	40 bc	11.1	11.1 d	43	51.1 ab	35.6	46.7 abc	51.9	59.3 a	31.7	36.5 a
SE±	-	-	1.82 ns	2.24**	-	-	-	-	-	-	-	-	0.80**	0.15**
Varietal means	11.1 e	11.1 e	33.3 e	25.6 c	11.1 e	11.1 e	39.6 b	45.66 b	32.6 c	40.4 b	47 a	55.6 a		55.6 a
SE (±)	-	-	-	-	0.77**	1.81**	-	-	-	-	-	-	-	-
85 DAS														
Seed dressed	20.7 e	23 cd	43.7 d	18.5 d	22.2 e	22.2 cd	58.5 c	42.3 bc	40 d	24.5 cd	69.6 b	50.4 b	42.5 b	30.1 b
Control	25.9 e	26.7 cd	58.5 c	40 bc	22.2 e	22.2 cd	70.4 b	60 ab	54.8 c	40.7 bc	82.2 a	73.3 a	52.3 a	43.8 a
SE±	-	-	1.85*	2.59**	-	-	-	-	-	-	-	-	1.11*	0.95**
Varietal means	23.3 e	24.8 cd	51.1 c	29.3 cd	22.2 e	22.2 d	64.4 b	51.2 b	47.4 c	32 bc	75.9 a	61.9 a	-	-
SE (±)	-	-	-	-	1.85*	3.06**	-	-	-	-	-	-	-	-
95 DAS														
Seed dressed	18.9 e	22.2	40.7 d	24.4	19.3 e	21.5	55.6 c	51.1	34.8 d	34.8	63.7 abc	66.7	38.8 b	36.8
Control	22.2 e	23.3	57 bc	46.7	21.1 e	23.3	68.9 ab	64.4	40 d	44.4	63.7 abc	77.8	47.6 a	46.7
SE±	-	-	-	3.11 ns	1.14**	-	-	-	-	-	-	-	1.14*	1.24*
Varietal means	20.6 e	22.8 e	48.9 c	35.6 c	20.2 e	22.4 e	62.2 b	57.8 b	37.4 d	39.6 c	70 a	72.2 a	-	-
SE (±)	-	-	-	-	2.08**	2.50**	-	-	-	-	-	-	-	-

Means with the same letter (s) in the same column are not significantly different from each other at 5 % level of probability.

The lowest leaf sheath severity in 2001 was recorded on 'Bauchi Early Selection' and 'ICSV111' when dressed or not at earlier growth stages (65 and 75 DAS). These varieties are improved and could have the ability to be resistant to leaf sheath anthracnose and could equally have a gene that confers resistance to this disease.

Similarly, in 2002, dressing sorghum seeds with fungicide significantly reduced the severity of leaf sheath anthracnose than when fungicide was not applied (**Table 2**). The sorghum varieties when not dressed with fungicide before planting were also significantly different among themselves in anthracnose leaf sheath severity. 'Warwarbashi' had the highest anthracnose leaf sheath severity in 2001 at 85 DAS and this was the same in 2002 at the same growth stage. Severity in leaf sheath anthracnose may intensify with an increase in time of the growth period, corroborating the work of many other authors like Ngugi *et al*. (2000) and Prom *et al*. (2007), who studied the epidemiology of anthracnose pathogen in sorghum. For example, 'Warwarbashi' dressed with fungicide before planting had a leaf sheath severity of 45.2% at 65 DAS and that rose to 66.7% at 95 DAS in 2002. Similarly, the same variety, when not dressed with fungicide, had a leaf sheath severity of 53.3% at 65 DAS and this rose to 77.8% at 95 DAS also in the same year. The trend was similar with other varieties in both cropping seasons.

The lowest anthracnose leaf sheath severity was recorded on 'ICSV111' and 'Bauchi Early Selection' at 65 and 75 DAS in 2002. The effect of the interaction between seed dressing and variety was not significant from 65 to 75 DAS, but was significantly different from 85 to 95 DAS in 2001. The effect of the interaction between seed dressing and variety was relatively variable even though significantly different in 2002.

Leaf midrib anthracnose severity

The result of leaf midrib anthracnose severity (**Table 3**) shows that all varieties grown from dressed seeds recorded significantly lower midrib disease severity than those not dressed in 2002 from 65 DAS through 95 DAS. In 2001, varieties grown from dressed seeds recorded significantly lower midrib disease severity than those that were not dressed at 85 and 95 DAS but not at 65 and 75 DAS. This result is similar to results reported on leaf sheath anthracnose severity. 'Warwarbashi' recorded the highest midrib anthracnose severity in 2001 (57% at 85 DAS and 67.4% at 95 DAS) when the seeds were not dressed with fungicide. The anthracnose symptoms in susceptible and resistant sorghum varieties differ in their patterns of infection. Similarly, 'Warwarbashi' also recorded the highest midrib anthracnose severity of 64.4% at 85 DAS and 74.8% at 95 DAS in 2002 when seeds were not treated with fungicide. Higher midrib severities were also recorded in 'Warwarbashi' even when the seeds were treated with fungicide.

Lower midrib anthracnose severity on the other hand was recorded in 'ICSV111' and 'Bauchi Early Selection' in 2001 and 2002 at all the growth stages whether the seeds were dressed or not with fungicide. The interaction between varieties and seed dressing fungicide with respect to midrib anthracnose severity was significantly different at 85 DAS in 2001 and 2002. The foliar characteristic symptoms of anthracnose in sorghum have been reported by Tar (1962), Edmunds *et al*. (1970) and Edmunds and Zomno (1975).

Thus, all six sorghum cultivars showed varied anthracnose symptoms: 'Warwarbashi' and 'Paul Biya' were severely infected; 'Ex-Mali' and 'ICSV400' were moderately infected while 'ICSV111' and 'Bauchi Early Selection' were less infected by the disease. The variability in anthracnose disease symptoms may be due to variation in pathogen virulence level, host resistance or physiological status of the host plant following the infection. This report therefore, agreed with Harlan and de Wet (1972) who stated that genetic source of resistance to anthracnose exists in varied races of sorghum.

Grain yield

The result on the effect of seed dressing fungicide and variety response on grain yield of sorghum under anthracnose infection is presented in **Table 4**. Seed treatment with fungicide and varietal response affected sorghum grain yield significantly in 2001 and 2002. 'Ex-Mali' recorded the highest grain yield, 1270 and 1198 kg/ha when dressed or not dressed with fungicide, respectively. This variety was among those having lower values of midrib and leaf sheath anthracnose severity. Harris *et al*. (1964) reported a highly significant and negative correlation between grain yield and anthracnose leaf and head ratings in commercial and experimental hybrids.

Table 3 Effect of seed dressing fungicide and sorghum varieties on the severity (%) of midrib anthracnose in 2001 and 2002 cropping seasons.

Treatments	ICSV 111		ICSV 400		BES		Paul Biya		Ex-Mali		Warwarbashi		Mean	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
65 DAS														
Seed dressed	11.1	11.9 e	21.5	11.1 e	11.1	11.1 e	23	31.1 bcd	19.3	24.4 cd	26.7	34.1 bc	18.8 b	20.6 a
Control	11.1	11.1 e	28.2	21.5 de	11.1	11.1 e	28.9	39.3 ab	20	23 cd	32.6	48.2 a	22 a	25.7 a
SE±	-	-	-	-	2.33 ns	1.50**	-	-	-	-	-	-	0.38*	1.11
Varietal means	11.1 c	11.5 e	24.8 a	16.3 e	11.1 c	11.1 e	25.9 a	35.2 b	19.6 a	23.7 c	29.6 a	41.1 a	-	-
SE (±)	-	-	-	-	1.55**	1.70**	-	-	-	-	-	-	-	-
75 DAS														
Seed dressed	11.1	12.6	28.2	19.6	11.1	11.1	30.4	34.8	24.4	35.6	39.3	40.7	24.1 b	25.7 a
Control	11.1	11.1	28.2	26.6	11.1	11.1	39.3	43	29.6	37	46.7	54.8	28.9 a	31.1 a
SE±	-	-	-	-	1.85 ns	3.02 ns	-	-	-	-	-	-	0.40*	1.64
Varietal means	11.1 d	11.9 e	31.9 b	24.6 c	11.1 d	11.1 e	38.4 b	38.9 ab	27 c	36.3 b	43 a	47.8 a	-	-
SE (±)	-	-	-	-	1.11**	2.93**	-	-	-	-	-	-	-	-
85 DAS														
Seed dressed	11.1 e	11.1 d	34.8 cd	11.1 d	11.1 e	11.5 d	35.6 cd	31.1 c	30.4 d	31.1 c	52.6 a b	43 bc	29.3 b	23.2 b
Control	11.1 e	11.1 d	43.7 bc	31.9 bc	11.1 e	11.1 d	52.6 ab	51.9 ab	40 c	37.8 bc	57 a	64.4 a	35.9 a	34.7 a
SE±	-	-	-	-	2.28*	3.11**	-	-	-	-	-	-	0.66*	0.78
Varietal means	11.1 e	11.1 d	39.3 bc	21.5 c	11.1 e	11.3 d	44.1 b	41.5 b	35.2 c	34.4 b	54.8 a	53.7 a	-	-
SE (±)	-	-	-	-	1.58**	2.45**	-	-	-	-	-	-	-	-
95 DAS														
Seed dressed	11.1	11.1	43.7	11.1	11.1	11.1	47.4	36.3	28.9	30.4	64.4	51.9	34.4 b	25.3 b
Control	11.1	11.1	49.6	27.4	11.1	11.1	60.4	57	45.9	40	67.4	74.8	40.9 a	36.9 a
SE±	-	-		-	3.38 ns	ns	-	3.98	-	-	-	-	0.87*	0.62
Varietal means	11.1 e	11.1 e	46.7 c	19.3 d	11.1 e	11.1 e	53.9 b	46.7 b	37.4 d	35.2 c	65.9 a	63.3 a	-	-
SE (±)	-	-	-	-	1.72**	2.31**	-	-	-	-	-	-	-	-

Means with the same letter (s) in the same column are not significantly different from each other at 5 % level of probability.

Table 4 Effect of seed dressing fungicide and varietal resistance on grain yield (Kg/ha) of sorghum under anthracnose in 2001 and 2002 cropping seasons.

	2001			2002		
Varieties	**Seed Dressed**	**Control**	**Mean**	**Seed Dressed**	**Control**	**Mean**
ICSV111	616.9	815.1	716 bc	1222	432.8	827.2 ab
ICSV400	502.1	261.4	381.7 d	441.3	401.4	421.3
BES	652.5	689	670.7 bcd	633.4	460	546.7 ab
Paul Biya	881.5	906.8	894.2 b	1151	1383	1267 a
Ex-Mali	1270	1198	1234.09 a	1122	735	928.5 a
WBS	467.3	507.4	487.3 cd	973.2	850.4	911.8 ab
Mean	731.7	729.6		998.8	710.4	
Seed dressed SE± = 49.3				Seed dressed SE± = 65.2		
Varieties SE± = 97.72				Varieties SE± = 2.18		
Interactions SE± = 120				Interactions SE± = 263.4		

Means with the same letter (s) in the same column are not significantly different from each other at 5 % level of probability.

The lowest grain yield was recorded in 'ICSV111' (261.4 kg/ha) in 2001 when seeds were not treated with fungicide before planting. The result in 2002 indicated that 'Paul Biya' recorded the highest grain yield of 1383 kg/ha when seeds were not dressed and this out-yielded that of 2001 under dressed or undressed conditions. Even though 'Paul Biya' is a local variety it was able to yield more even when the seeds were not treated with fungicide before planting it could probably posses a gene that could confer resistance to anthracnose. Prom *et al*. (2007) have mentioned a lot of local accessions of sorghum in China that has gene for resistance to sorghum anthracnose. The improved variety 'ICSV111' on the other hand recorded the second highest grain yield of 1222 kg/ha when the seeds were treated with fungicide in 2002.

CONCLUSION

The results of this work have shown that Apron Star 42 WS fungicide was effective in reducing the incidence and severity of leaf sheath and midrib anthracnose in sorghum. The results give first-hand information on the general performance and the levels of disease resistance in the sorghum varieties evaluated. The use of a systemic fungicide as a seed dressing chemical therefore, was effective against anthracnose. The sorghum varieties responded differently to anthracnose infection. The use of fungicide and varietal resistance will surely provide disease control techniques that give maximum flexibility and choices to farmers.

'Paul Biya' recorded among the highest anthracnose incidence and severity produced higher grain yields even when it was not treated with fungicide. This variety could therefore have genes that can confer resistance to anthracnose disease. Since host resistance is an important component for integrated disease management, the availability of a stable source of resistance with high yield and good grain quality appears to be very important to maintain sustainable sorghum productivity, as well as to reduce the risk of lower sorghum production because of severe anthracnose epidemics.

This study affirms that anthracnose disease is a progressive disease, becoming devastating with an increase in the age of the plant. The study also concludes that the local variety 'Paul Biya' and 'Ex-Mali' may posses a gene that can confer resistance to anthracnose infection. The improved varieties 'ICSV111' and 'Bauchi Early Selection', which performed well in terms of grain yield, may also posses a resistant gene and can safely be recommended to farmers experiencing this kind of disease. The important thing is that farmers will have choices between the use of chemical fungicide, varietal resistance or a combination of these measures. However, there will be a need for broader research that will examine the genetics of resistance in sorghum varieties to anthracnose disease, since little information is known about that at the moment. In addition new sources of anthracnose disease resistance need to be more readily introgressed into advanced breeding lines for sorghum improvement.

REFERENCES

Ali MEK, Warren HL, Latin RX (1987) Relationship between anthracnose leaf blight and losses in grain yield of sorghum. *Plant Diseases* **77**, 825-827

BOSADP (1989) *Package of Cropping Recommendations in Borno State*, 24 pp

BOSADP (1993) *Package of Crop Recommendations in Borno State*, 37 pp

Dugje IY, Odo PE, Izge AU (2008) Screening of 'masakwa' sorghum cultivars for yield and yield traits on vertisols in the Sahel savanna zone of Nigeria. *Green Farming* **1 (12)**, 6-10

Edmunds LK, Futrell MC, Frederiksen RA (1970) *Sorghum diseases*. In: Wall JS, Rose WM (Eds) *Sorghum Production and Utilization*, AVI Publishing Co., Inc., Westport, CT, USA, pp 200-234

Edmunds LK, Zomno N (1975) Sorghum diseases in the United States and their control. *Handbook* 468, Washington D.C., USA

Erpelding JE, Prom LK (2004) Evaluation of Malian sorghum germplasm for resistance against anthracnose. *Plant Pathology Journal* **3**, 65-71

Erpelding JE (2008) Sorghum germplasm resistance to anthracnose. *The Americas Journal of Plant Science and Biotechnology* **2(1)**, 42-46

Esele JP (1995) Foliar and head diseases of sorghum. *African Crop Science Journal* **3 (2)**, 185-189

Gwary DM, Rabo TD, Anaso AB (2002) Assessment of leaf anthracnose caused by *Colletotrichum graminicola* on sorghum genotypes in the Sudan Savanna of Nigeria. *Agricultura Tropica et Subtropica* **35**, 53-8

Gwary DM, Rabo TD, Anaso AB (2003) The development of anthracnose symptoms on sorghum genotypes in the Nigerian Savanna. *Journal of Plant Diseases and Protection* **111**, 96-102

Gwary DM, Asala SW (2006) Cost-benefit of fungicidal control of anthracnose on sorghum in Northern Nigeria. *International Journal of Agricultural Biology* **8 (3)**, 306-308

Harris HB, Johnson BJ, Dobson JW Jr., Luttrell ES (1964) Evaluation of anthracnose on grain sorghum. *Crop Science* **4**, 460-462

Harris HB, Sowell G Jr. (1970) Incidence of *Colletotrichum graminicola* on *Sorghum bicolor* introductions. *Plant Disease Reporter* **54**, 60-62

Harlan JR, de Wet JM (1972) A simplified classification of cultivated sorghum. *Crop Science* **12**, 172

Hess DE, Bandyopadhyay R, Sissoko I (2002) Pattern analysis of sorghum genotype x environment interaction for leaf panicle and grain anthracnose in Mali. *Plant Diseases* **86**, 1374-1382

Izge AU, Alimta DP (2008) Comparative performance of Masakwa sorghum and other sorghum cultivars under rainfall conditions. *The African Journal Plant Science and Biotechnology* **2**, 30-33

Marley PS, Diourte M, Neya A, Ratunde FW (2004) Sorghum anthracnose and sustainable management strategies in West and Central Africa. *Journal of Sustainable Agriculture* **25**, 43-56

Ngugi HK, Julian AM, King SB, Peacocke BJ (2000) Epidemiology of sorghum anthracnose (*Colletotrichum sublineolum*) and leaf blight (*Exserohilum turcicum*) in Kenya. *Plant Pathology* **49**, 129-140

Pande S, Mughogho LK, Bandyopadhyay R, Karunakar RI (1991) Variation in pathogenicity and cultural characteristics of sorghum isolates of *Colletotrichum graminicola* in India. *Plant Diseases* **75**, 778-783

Pande S, Hariskrishan R, Mughogho LK, Karunakar RL, Alegbejo MD, Ajayi O (1993) Prevalence of sorghum disease in Nigeria. *International Journal of Pest management* **39 (3)**, 297-383

Pastor-Corrales MA (1980) Variation in pathogenicity of *Colletotrichum graminicola* (Cesati) Wilson and in symptom expression of anthracnose of [*Sorghum bicolor* (L) Moench]. PhD thesis, Texas A & M University, College Station, Texas, USA, 122 pp

Prom LK, Erpelding JE, Montes-Garcia N (2007) Chinese sorghum germplasm evaluated for resistance to downy mildew and anthracnose. *Communication in Biochemistry and Crop Science* **2 (1)**, 26-31

Rivera Y (2006) Variation for anthracnose (*Colletotrichum sublineolum*) resistance with sorghum [*Sorghum bicolor* (L) Moench] germplasm collection from the Kayes region of Mali, West Africa MSc thesis, University of Puerto Rico, Mayaguez Campus 61 pp

Tarr SAI (1962) Diseases of sorghum, Sudan grass and broom corn. Kew, Sur-

vey U.K., *Common Wealth Mycological Institute*, 380 pp

TeBeest DO, Cartwright RD (2006) Screening sorghum varieties for resistance to anthracnose and other foliar diseases. *Annual Report*, Department of Plant Pathology, University of Arkansas, Fayetteville, Arkansas 7 pp

Thakur RP (1995) Status of international sorghum anthracnose and pearl millet downy mildew virulence nurseries, In: Leslie JF, Frederiksen RA (Eds) *Disease Analysis through Genetics and Biotechnology-Inter disciplinary Bridges to Improve Sorghum and Millet Crops*, Iowa State University Press, Ames, pp 75-92

Thakur RP, Mathur K (2000) Anthracnose. In: Frederiksen RA, Odvody GN (Eds) *Compendium of Sorghum Diseases*, The American Psychopathological Society, St. Paul, MN, USA, pp 10-12

Thomas MD, Sissoko I, Sacko M (1996) Development of leaf anthracnose and its effect on yield and grain weight of sorghum in West Africa. *Plant Disease* **80**, 151-153

Tyagi PD (1980) Sorghum disease in Nigeria. In: *Sorghum Diseases, a World Review*, ICRISAT, Patencheru, pp 45-52

Warren HL, Nicholson RL (1975) Kernel infection seedling blight and wilt of maize caused by *Colletotrichum* on corn. *Phytopathology* **64**, 293-296