Journal of Agriculture and Sustainability
ISSN 2201-4357
Volume 5, Number 1, 2014, 14-25

# Eco-Friendly Management Strategies for Gray Leaf Spot Disease of Sorghum Using Cultivar Selection and Seed Dressing Fungicides in Maiduguri, Nigeria

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**Abstract.** Gray leaf spot is one of the most important foliage diseases of sorghum. A study on the fungicidal seed treatment and screening sorghum cultivars on gray leaf spot disease was investigated in a split plot arrangement using four seed dressing fungicides (Metalaxyl, Captan, Thiobendazole and Benomyl), untreated control and five sorghum cultivars (ICSV111, ICSV400, ICSH89002NG, ICSH89009NG and Q-L INDIA). The combined results of the two year revealed that synergistic interaction of cultivars (ICSV111, ICSV400, ICSH89002NG and ICSH89009NG) with Apron plus 50Ds significantly reduced severity at 60 DAS from 40 to 25% compared with untreated check. Similarly, Cultivars ((ICSV111 and ICSV400) with Apron plus 50Ds brought about significant reduction in logistic infection from 0.023 to 0.0006 units per day over untreated check. This further culminated into better seedling establishment and grain yield were increased.

**Key words:** Seed dressing fungicides, sorghum, Gray leaf spot, incidence, severity, logistic infection rate.

## INTRODUCTION

Guinea corn [*Sorghum bicolor* (L) Moench] is an important cereal crop in many areas of the world where semi-arid conditions prevailed, including Africa, Asia and the Americans. It is also an ancient crop having been cultivated for at least 500 years. The crop was probably originally domesticated in North Eastern Africa (Mann *et al.*, 1993). The sorghum plant was reported to have good tolerance for drought and produces a yield where other crops such as maize may succumb due to lack of moisture (Anon. 1996). It is primarily grown as a grain crop for human consumption. It is also used for making beer. For instance the grain of sorghum cultivar ICSV 400 bred by International Crops Research Institute for Semi-Arid Tropics (ICRISAT) and Institute for Agricultural Research (IAR) was discovered by Guinness breweries Limited to contain an enzyme Beta-amylase, a vital ingredient for malting (Anon. 1993). It is also used for medicinal purposes, livestock feed and the stalls are used for building, fencing and fodder (Obilana *et al.*, 1984).

Foliar diseases of sorghum are among the most common and recognizable diseases of sorghum [*Sorghum bicolor* (L) Moench]. Frederiksen (1982) classified the major diseases of sorghum on the basis of prevalence and severity in temperate (outside 34° Latitude), subtropical (between 23°15´ and 34° Latitude) and tropical (within 23°15´Latitude) regions. According to their classification, the foliar pathogens *Exserohilum turcicum*, *Colletotrichum graminicola*, *Cercospora sorghi*, *Puccinia purpurea*, *Gloecercospora sorghi*, *Ramulispora sorghi*, and *Asochyta sorghina* are all commonly or generally found on sorghum grown in the sub-tropics and on sorghum grown in the tropical lowland during summer. According to Odvody (1981) the pathogens *Cercospora sorghi*, *Exserohilum turcicum*, and *Puccinia purpurea*, easily wind disseminated, are apparently the most consistent in their occurrence and incidence across all these diverse sorghum-growing environments. Among the foliar diseases of sorghum, Gray leaf spot induced by *Cercospora sorghi* Ellis and Everhart was seen to be one of the most common diseases with yield losses of up to 67% in Africa (Marley *et al.*, 2001), and epidemics have occurred sporadically and in some cases have been wide spread.

The control of fungal diseases can be achieved by the use of resistant varieties, good cultural practices and the use of fungicide. The use of resistant materials was considered by our resource poor farmers as the most cost effective way of reducing losses due to diseases (Mundit and Browing, 1985). This has led to release of varieties like IS 3443, IS 347 and VG 146 as resistant to gray leaf spot disease by ICRISAT in India (Anahosur, 1992). In Nigeria no much is being done in screening sorghum for durable resistance to gray leaf spot disease. Seed treatment is another cost effective means of controlling fungal diseases. Seed treatments use only small amount of pesticides. They are cheap and convenient for the farmers to use. ICRISAT (1982) reported that seed treatment with fungicides improves the stand, and the seedlings raised from treated seeds were healthier than those from untreated seeds. In Nigeria no concerted effort has been made to control gray leaf spot using fungicides. Therefore, the use of fungicidal seed treatment and resistant varieties in crop protection would be potential source of sustainability and thus, economically and environmentally rewarding for many sorghum producers.

## MATERIALS AND METHODS

The experiment on the effects of cultivars and fungicidal seed treatment on gray leaf spot disease of sorghum was laid out on flat at the Research farm of the Department of Crop Protection, University of Maiduguri (Lat 11° 15′ N 13° 05′ E), which is located in the Sudan Savanna of Nigeria and has an annual rainfall of 450 – 600 mm per annum. The field experiment in both locations were laid out using Randomized Complete Block Design (RCBD) in a split plot arrangement whereby Four sorghum cultivars (ICSV111, ICSV400, ICSH89002NG and ICSH89009NG) recommended for Northern Guinea and Sudan Savanna and a gray leaf susceptible check Q-L INDIA, were assigned to the main-plots; while Seed dressing fungicides Apron plus 50Ds (CIBA GEIGY), Stylor C (CAPL), Vincit P (CAPL), Benlate (CIBA GEIGY) and an untreated control (5 sub-treatments) were tested in the sub-plots. The trade names, names of the active ingredients and doses of the seed dressing fungicides tested are presented in Table 1. Dusting method of seed treatment was employed by mixing the seeds with appropriate dosage of fungicide. This was then followed by vigorous shaking until the surfaces of the seeds were uniformly coated with the fungicide. Treated seed lots were planted within 48 hours.

The sub plot size was 5 m x 4 m with inter- and intra-row spacing of 0.9 m x 0.4 m respectively. The experimental design was randomized complete block in a split plot arrangement with three replicates. About six seeds were sown in each planting hole and at two weeks after planting, the emerging seedlings were thinned to two plants per stand. At land preparation compound fertilizer (NPK 15:15:15) was applied at the recommended rate of 259 $kgha^{-1}$ (BOSADP, 1989). This was followed by application of Urea at the rate of 100 $kgha^{-1}$ by side dressing at four weeks after planting. Weeding was done when necessary.

**Observations and data recording.**

Gray leaf spot disease severity: Assessment of severity of the disease was also done at 10 days intervals starting at 50 DAS. Ten plants were tagged in each plot on which disease severity (determining overall score according to percentage leaf area coverage) and yield related data were recorded. Severity was assessed using scale 1-5.

Table 1. Trade and common names of active ingredients (a.i) and doses of the fungicides used for seed dressing.

| Trade Name | Common Name of active ingredients | Doses of product per kg seed | a.i/kg seed |
|---|---|---|---|
| Apron plus 50DS | Metalaxyl 10%<br>Carboxin 6%<br>Furathiocarb 34% | 10 g | 5.0 g |
| Stylor C | Flutriafol 1.8%<br>Anthraquinone 37.5%<br>Captan 22.5% | 6 g | 1.0 kg |
| Vincit P | Flutriafol 2.5%<br>Thiobendazole 2.5% | 6 g | 1.5 g |
| Benlate | Benomyl | 6 g | 3.0 g |

a.i = Active ingredient

The percentage leaf area covered as related to disease score is presented below:

1= 0 – 20% leaf area covered by gray leaf spot

2= 21 – 40 % leaf area covered by gray leaf spot

3= 41 – 60% leaf area covered by gray leaf spot

4= 61 – 80% leaf area covered by gray leaf spot

5= 81 – 100% leaf area covered by gray leaf spot

The incidences of resistance used in the present study are incidence and severity of gray leaf spot infection (Anahosur, 1992) where:

<40% incidence of leaf area covered by gray leaf spot was considered resistant.

41 – 60% incidence of leaf area covered by gray leaf spot was considered moderately susceptible

>60% incidence of leaf area covered by gray leaf spot was considered highly susceptible.

**Logistic infection Rate**

This was determined using the modified Vander plank (1963) formula and according to Zadock and Scheim (1979) as follows:

$$R = \frac{1}{t_2 - t_1} \left[ \text{logit } X_1 - \text{logit } X_2 \right]$$

Where:

$X_1$ and $X_2$ are the incidences of diseases at the days $t_1$ and $t_2$ respectively. This is expected to measure the speed of the epiphytotic process in each treatment.

**Establishment count.**

This was done at 14 Days after sowing (DAS) by counting the number of plants per plot. This aimed at determining whether seed dressing fungicides had effect on seedling establishment or not.

**Grain yield.**

When matured, the sorghum heads from each plot were cut, sun dried, threshed and winnowed. The grains were weighed. The figures were later converted to kilograms per hectare.

**Data analysis.**

All data collected were statistically analyzed according to the Split Plot Design and the means separated using Duncan's Multiple Range test (DMRT) according to Gomez and Gomez (1984).

## RESULTS

The combined mean of the effects of cultivars and seed dressing fungicides on severity of gray leaf spot disease of sorghum at 60 DAS in Table 2 presented a highly significant difference. Apron plus 50Ds was more effective in reducing severity of gray leaf spot disease on sorghum than untreated check. Similarly cultivars (ICSV111, ICSV400, ICSH89002NG, and ICSH89009NG) had genetic potential to reduce severity of gray leaf spot than susceptible check Q-L INDIA. Interaction effects between cultivars and seed dressing fungicides at 60 DAS in 2000 and 2001 revealed that treatment combinations of cultivars (ICSV111, ICSV400, ICSH89002NG, and ICSH89009NG) and seed dressing fungicide (Apron plus 50Ds) significantly reduced severity of gray leaf spot disease infection from 40% to 25-26% compared with the susceptible check Q-L INDIA and other treatment combinations.

Table 3 shows the effects of cultivars and seed dressing fungicides on logistic infection rate of gray leaf spot disease on sorghum. Sorghum cultivars (ICSV111, ICSV400, ICSH89002NG, and ICSH89009NG) significantly slow down the rate of epiphytotic process than the susceptible check Q-L INDIA. There was also significant effect of seed dressing fungicides on logistic infection rate in 2000 and 2001. the combined analysis of the two year result showed that Apron Plus 50Ds significantly gave the lowest speed of gray leaf spot infection than the other seed treatments. There was also significant interaction between seed dressing fungicides and sorghum cultivars on logistic infection rate. The lowest infection rate of gray leaf spot disease was obtained from plants grown from seeds of ICSV111, ICSV400, ICSH89002NG, and ICSH89009NG treated with Apron Plus 50Ds seed dressing fungicide.

The effects of cultivars and fungicidal seed treatment on sorghum seedling establishment in 2000 and 2001 are shown in Table 4. Mean of the two-year results indicated that ICSV111, ICSV400, ICSH89002NG, and ICSH89009NG gave significantly ((P=0.01) better establishment than the susceptible check Q-L INDIA. Combined mean of the two-year results also showed that seeds treated with Apron plus 50Ds gave better seedling establishment than seedlings grown from seeds treated with other seed dressing fungicides. There was also a highly significant interaction between cultivars and seed dressing fungicides on sorghum seedling establishment. The combined analysis of the two-year results showed that seeds of ICSV111, ICSV400, ICSH89002NG, and ICSH89009NG treated with Apron plus 50Ds established significantly (P=0.01) better than those of the other treatment combinations.

Seedlings of the different sorghum cultivars (ICSV111, ICSV400, ICSH89002NG, and ICSH89009NG) treated seed dressing (Apron plus 50Ds) gave significant reduction in severity and slow down speed of infection of gray leaf spot disease. This culminated in to better establishment and subsequently higher yield (Table 5). The combined effect of the two year results revealed that Apron plus 50Ds treated seeds of either of ICSV111, ICSV400, ICSH89002NG, or ICSH89009NG gave significantly more mean grain yield of 1472-1625 $kgha^{-1}$ than those treated with the other seed dressing fungicides and the susceptible check Q-L INDIA.

## DISCUSSION

In absence of durable resistance an integrated approach that involves resistant or moderately resistant varieties and seed dressing fungicides extracts can offer some reasonable level of control of the disease. Gray leaf spot is one of the most important diseases that seriously reduce sorghum production in Nigeria. In this field study, attempts were made to control Gray leaf spot disease of sorghum seed dressing fungicides and host resistance of five sorghum varieties. The severity and logistic infection of CLS was low in plots treated with seed dressing fungicides. Seed dressing fungicides are used for controlling pathogens carried by the seeds, for protecting the seeds from soil borne pathogens and protecting the seedlings from both soil and air borne pathogens. The fungicide (Metalaxyl) was found to be more effective in reducing the plant infection with Gray leaf spot. Similar works by Akpa and Manzo (1991); Marley (1997); Mtisi (1996) and Gwary *et al.* (2007) demonstrated the effectiveness of systemic fungicide, Apron plus 50% dust in reducing the risk of sorghum diseases. Gwary and Asala (2007) reveals the positive returns per hectare from the use metalaxyl followed by foliar benomyl which gave about 136% increase in yield due mainly to the reduction in disease infection, which translated into a net profit (return) of N37255.00 per hectare equivalent to US $372.55. The results also inferred that ICSV111, ICSV400, ICSH89002NG, and ICSH89009NG are moderately resistant cultivars to gray leaf spot disease. Earlier works by ICRISAT in India (Anahosur, 1992) led to release of varieties like IS 3443, IS 347 and VG 146 as resistant to gray leaf spot disease. These results also show that synergistic effect of seed dressing fungicides and host resistance has a strong capacity to reduce incidence of Gray leaf spot on sorghum plants. Works by Izge *et al.* (2009) revealed that ICSV 111, ICSV 400 and Bauchi Early Selection (BES) sorghum varieties dressed with fungicide Apron Star 42 WS performed better in reducing incidence and severity of disease. The research work which resulted in the best combination of Apron plus 50Ds treated seeds of ICSV111, ICSV400, ICSH89002NG, and ICSH89009NG has provided better information on the four sorghum varieties in terms of their relative individual resistance to gray leaf spot disease. These varieties therefore can serve as test materials for further future research work and can also serve as sources of resistance for genetic improvement. Seed treatments use only small amount of pesticides. The use of seed dressing fungicide and host resistance will hence provide disease management strategies that give maximum flexibility and more user friendly to farmers.

Table 2. Combined mean severity of gray leaf spot recorded on five sorghum cultivars treated with four seed dressing fungicides at Maiduguri, Nigeria in 2000 and 2001

| | Sorghum cultivars | | | | | |
|---|---|---|---|---|---|---|
| Seed dressing fungicides | ICSV 111 | ICSV 400 | ICSH89002NG | ICSH89009NG | Q-L INDIA | Mean |
| Apron plus 50DS | 25.33[g] | 25.33[g] | 26.67[fg] | 26.67[fg] | 40.00[bc] | 28.80 |
| Stylor C | 26.67[g] | 32.00[e] | 40.00[bc] | 37.33[cd] | 40.00[bc] | 35.20 |
| Vincit P | 29.33[ef] | 28.00[f] | 37.33[cd] | 36.00[d] | 44.00[a] | 34.93 |
| Benlate | 28.00[f] | 29.33[ef] | 40.00[bc] | 37.33[cd] | 40.00[bc] | 36.33 |
| Check | 29.33[ef] | 37.33[cd] | 40.00[bc] | 40.00[bc] | 44.00[a] | 38.33 |
| Mean | 27.73 | 28.44 | 36.80 | 35.47 | 41.60 | 34.01 |

SE(±) common to all treatment combinations = 2.00

DAS = Days after sowing

Means within a column followed by the same letter(s) are not significantly different at 5% level using DMRT

Table 3. Combined mean logistic infection rate *(calculated from severity) of gray leaf spot recorded on five sorghum cultivars treated with four seed dressing fungicides at Maiduguri, Nigeria in 2000 and 2001

| | Sorghum cultivars | | | | | |
|---|---|---|---|---|---|---|
| Seed dressing fungicides | ICSV 111 | ICSV 400 | ICSH89002NG | ICSH89009NG | Q-L INDIA | Mean |
| Apron plus 50DS | 0.0003[gh] | 0.000[h] | 0.000[h] | 0.000[h] | 0.019[c-f] | 0.0039 |
| Stylor C | 0.009[f-h] | 0.010[e-h] | 0.000[h] | 0.015[d-g] | 0.023[c-e] | 0.011 |
| Vincit P | 0.010[e-h] | 0.017[c-f] | 0.000[h] | 0.009[f-h] | 0.029[bc] | 0.013 |
| Benlate | 0.013[d-h] | 0.018[c-f] | 0.000[h] | 0.006[f-h] | 0.041[ab] | 0.016 |
| Check | 0.014[d-g] | 0.010[e-h] | 0.006[f-h] | 0.025[b-d] | 0.051[a] | 0.021 |
| Mean | 0.0093 | 0.011 | 0.0012 | 0.011 | 0.033 | 0.013 |

SE(±) common to all treatment combinations = 0.004

*per unit per day

Means within a column followed by the same letter(s) are not significantly different at 5% level using DMRT

Table 4. Combined mean establishment count recorded on five sorghum cultivars treated with four seed dressing fungicides at Maiduguri, Nigeria in 2000 and 2001

| Seed dressing fungicides | Sorghum cultivars | | | | | Mean |
|---|---|---|---|---|---|---|
| | ICSV 111 | ICSV 400 | ICSH89002NG | ICSH89009NG | Q-L INDIA | |
| Apron plus 50DS | 72.67$^{a-c}$ | 71.67$^{a-c}$ | 74.00$^{ab}$ | 76.00$^{a}$ | 64.33$^{cd}$ | 71.73 |
| Stylor C | 55.33$^{de}$ | 40.83$^{e}$ | 70.00$^{a-c}$ | 63.67$^{cd}$ | 38.67$^{e}$ | 53.07 |
| Vincit P | 44.67$^{de}$ | 43.67$^{de}$ | 67.33$^{a-d}$ | 65.00$^{cd}$ | 25.67$^{f}$ | 49.27 |
| Benlate | 41.00$^{e}$ | 41.67$^{de}$ | 63.00$^{cd}$ | 66.67$^{a-d}$ | 25.67$^{f}$ | 47.60 |
| Check | 39.33$^{e}$ | 38.67$^{e}$ | 61.00$^{cd}$ | 66.33$^{b-d}$ | 21.33$^{f}$ | 45.33 |
| Mean | 50.60 | 47.30 | 67.07 | 67.53 | 35.13 | 53.53 |

SE(±) common to all treatment combinations = 3.30; Means within a column followed by the same letter(s) are not significantly different at 5% level using DMRT

Table 5. Combined mean grain yield (kgha$^{-1}$) recorded on five sorghum cultivars treated with four seed dressing fungicides at Maiduguri, Nigeria in 2000 and 2001

| Seed dressing fungicides | Sorghum cultivars | | | | | Mean |
|---|---|---|---|---|---|---|
| | ICSV 111 | ICSV 400 | ICSH89002NG | ICSH89009NG | Q-L INDIA | |
| Apron plus 50DS | 1472.83$^{a-d}$ | 1542.16$^{ab}$ | 1500.17$^{a-c}$ | 1625.17$^{a}$ | 965.17$^{g-i}$ | 1421.1 |
| Stylor C | 1346.33$^{b-e}$ | 1322.17$^{c-e}$ | 1426.33$^{a-d}$ | 1297.67$^{c-f}$ | 848.83$^{hi}$ | 1248.266 |
| Vincit P | 1276.17$^{c-f}$ | 1314.67$^{c-e}$ | 1245.33$^{d-g}$ | 1291.99$^{c-f}$ | 962.83$^{g-i}$ | 1218.198 |
| Benlate | 1002.33$^{f-i}$ | 1353.83$^{b-e}$ | 1271.33$^{c-f}$ | 1062.00$^{e-h}$ | 877.67$^{hi}$ | 1113.432 |
| Check | 868.67$^{hi}$ | 1012.67$^{f-i}$ | 1214.33$^{d-g}$ | 950.16$^{hi}$ | 784.83$^{i}$ | 966.132 |
| Mean | 1193.27 | 1309.10 | 1331.50 | 1245.40 | 887.87 | 1193.42 |

SE(±) common to all treatment combinations = 73.03; Means within a column followed by the same letter(s) are not significantly different at 5% level using DMRT

## References

[1] Akpa, A.D. and S.K. Manzo, (1991). Chemical seed treatment for the control of loose smut disease of sorghum. *Tests Agrochemicals Cultivars,* 12: 56–7

[2] Anahosur K.H. (1992). Sorghum diseases *in India: Knowledge and research needs. Pages 45-56 in Sorghum and Millets Diseases: a second World Review* (de milliano, W.A.J.; Frederksen, R.A. and Bengston, G.D., eds) Patancheru, A.P. 502324, India: International Crops Research Institute for the semi-Arid Tropics.

[3] Anon. (1993). *ICRISAT West African Programs Annual Report*. Pp 70-89

[4] Anon. (1996). *International sorghum and millets Newsletter* No. 37. Sorghum improvement conference of Northern America (SICNA) and ICRISAT.

[5] BOSADP (Borno Agricultural Development Programme) (1989). *Cropping Recommendations*, 31pp.

[6] Gwary D.M. and Asala S.W. (2006). Cost-benefit of Fungicidal Control of Anthracnose on Sorghum in Northern Nigeria. *International Journal of Agriculture and Biology* 1560–8530/2006/08–3–306–308. http://www.fspublishers.org

[7] Gwary D.M., Obida Ali and Gwary S.D. (2007). Management of Sorghum Smuts and Anthracnose Using Cultivar Selection and Seed Dressing Fungicides in Maiduguri, Nigeria. *International Journal of Agriculture and Biology* 1560–8530/2007/09–2–324–328 http://www.fspublishers.org

[8] Gomez, K.A. and Gomez, A.A. , (1984) *Statistical procedures for Agricultural Research*; 2nd ed. John Willey and Sons: pp 306 – 308.

[9] ICRISAT, (1982). Sorghum in the eighties. *In: Proc. of the Int. Sym. On Sorghum,* Pp: 263–82. November 2-7 81, Pantancherus A.P. India.

[10] Izge A.U., Richard B.I. and Degri M.M. (2009). Varietal resistance and the use of fungicide for the integrated management of sorghum Anthracnose in parts of North-East Nigeria. *The African Journal of Plant Science and Biotechnology*. Pp 1-6.

[11] Mann J.A., Kimber C.T. and Miller F.R. (1993). The origin and early cultivation of sorghum in Africa. *Bulletin No. 1454. Texas A and M University College Station*, Texas USA.

[12] Marley, P.S., (1997). *Report on Survey for Prevalence of Panicle Anthracnose in Nigeria,* P: 8. A technical report submitted to ICRISAT, 1997

[13] Marley P.S., Elemo K.A., Aba D.A., Onu I. and Akintayo I. (2001). Reactions of sorghum genotypes to Anthracnose and gray leaf spot under sudan and sahel savannah field conditions of Nigeria. *Journal of Sustainable Agriculture* 18:105-116.

[14] Mtisi, E., (1996). Evaluation of systemic Seed dressing for the control of covered kernel smut on sorghum in Zimbabwe. *In*: Leouschner, K. and C.S. Manthe (eds.), *Drought - Tolerant Crops for Southern Africa: Proceeding of the SADC/ICRISAT Regional Sorghum Botswana,* Pp: 185–8.

Patancherus 502324, Andhra Pradesh, India: International Crops research Institute for the semi-Arid Tropics

[15] Obilana A.T., Ajayi O. and Manzo S.K. (1984). Sorghum improvement in Nigeria in : *Proceedings of the regional Workshop on sorghum improvement in West Africa*. Ouagadougu, Burkonaso Faso ICRISAT 169-186

[16] Odvody, G.N. (1981). Sporulation techniques for *Cercospora sorghi*. Pages 80-81 *in Proceedings of the Twelft Biennial Grain Sorghum Research and Utilization Conference*, 25-27 Feb 1981, Lubbock, TX. Teaxas Grain Sorghum Producers Board, Box R, Abernathy, TX 79311, USA.

[17] Van der plank, J.E., (1963). *Plant disease epidemics and their control*. New York and London: Academic Press.

[18] Zadocks, J.C. and Schein, R.D., (1979). *Epidemiology and plant Disease Management*. Oxford University Press, 427pp.