FINAL REPORT

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PROJECT DETAILS

Project number		P05000013 (102163)
Project title		Evaluation of sorghum cultivars for susceptibility to economically important sorghum diseases
Project manager		E Ncube
Co-worker(s)	Internal	NY Maila, DP Nkoko, AEJ Du Toit
	External	University of the Free State (UFS), Grain South Africa
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Abstract Report

Trial sites planted at producers' fields to screen sorghum cultivars for leaf diseases and grain mould were utilised at Koppies (Free State Province), Settlers (Limpopo Province), Sannieshof (North West Province) and Platrand (Mpumalanga Province during the 2016/17 season. Sorghum cultivars were evaluated for leaf diseases and grain mould at Cedara and Potchefstroom during the 2017/18, 2018/19, 2019/20 and 2020/21 seasons for the ARC-Grain Crops cultivar trials. PAN8945, PAN8816, PAN8625, PAN8944, PAN8706 (all supplied by Pannar Seed), Bullet, Avenger, Enforcer, NS551, Titan, Swift (all supplied by Agricol), and Mr Buster (supplied by Klein Karoo Seed Marketing) were the cultivars that were evaluated. The trials were planted in a split plot design with two treatments: fungicide-sprayed with Amistar® Top, a broad-spectrum strobilurin and triazole fungicide and non-sprayed trials replicated three times. The rows were 8 m long with 80 plants in each row and inter-row spacing of 1.2 m. Grain yield and leaf blight data were subjected to ANOVA using Genstat® 19th Edition. Disease severity on producers' cultivar trials during the 2016/17 season was very low because producers had sprayed various types of agrochemicals on cultivar trials for disease control. Nevertheless, symptoms of rust, bacterial streak and leaf blight were observed. Results for the ARC-Grain Crops cultivar evaluation trials during the 2017/18 season indicated that Exserohilum leaf blight was the disease of concern in Cedara throughout the season while sorghum rust was of concern in Potchefstroom late in the season. The cultivar with most resistance to leaf blight was Titan and fungicide application did not result in a significant reduction in leaf blight in this cultivar. This project has indicated that leaf disease incidence varies seasonally and environmentally. For example, only the 2017/18 season had the high incidence of Exserohilum leaf blight at Cedara compared to other seasons possibly due to the changes in the presence of *Exserohilum turcicum* races. Moreover, anthracnose leaf blight caused by *Colletotrichum sublineola* was predominant in Cedara during the 2020/21 season possibly due to high rainfall resulting from the tropical cyclone Eloise**.** Grain yield results for the 2018/19 season showed that eight of the eleven cultivars planted

did not differ significantly in yield at both Cedara and Potchefstroom in non-sprayed trials while three cultivars namely PAN8944, NS5511 and Mr Buster significantly yielded more grain at Cedara than in Potchefstroom. Only one cultivar Bullet had significantly high leaf disease at Potchefstroom compared to Cedara in both non-sprayed and sprayed trials. The rest of the cultivars namely PAN8945, PAN8816, PAN8625, PAN8944, PAN8706, Avenger, Enforcer, NS551, Titan and Mr Buster did not differ significantly between the two localities in both non-sprayed and sprayed. Results from the 2019/20 season indicated that three cultivars PAN8816, PAN8944 and Enforcer did not differ significantly in yield at both Cedara and Potchefstroom in non-sprayed and sprayed trials while rest of the cultivars yielded more grain in Cedara compared to Potchefstroom in the non-sprayed trials. For the sprayed trials, five cultivars PAN8816, PAN8944, Bullet, Enforcer and Swift did not differ significantly in yield at both Cedara and Potchefstroom whereas six cultivars yielded more grain in Cedara compared to Potchefstroom. Results for the 2020/21 season in the non-sprayed trials indicated that cultivars PAN8945 and Avenger significantly yielded more grain in Cedara compared to Potchefstroom. Conversely, cultivar PAN8625 yielded significantly more in Potchefstroom than in Cedara. There were no significant differences between both localities for the rest of the cultivars. For the sprayed trials, cultivar NS5511 significantly yielded more grain in Cedara than at Potchefstroom. There were no significant differences between both localities for other cultivars. Grain mold symptoms were not visible in all cultivars at both localities in this study. Ergot was however, highly prevalent in trials that were planted late in the season from mid-December onwards for each season. This study showed that the application of fungicides does not always have a significant effect on yield and leaf diseases. Therefore, producers should make informed decisions on the need for fungicide application based on factors such as scouting for disease levels prior to fungicide application as well as data from cultivar evaluation trials. Hence, this project has shown that seasonal cultivar evaluation trials need to be planted annually to support producers in cultivar selection.

Keywords: Sorghum, Leaf blight, grain mould, genotype x environment, cultivar evaluation, *Exserohilum turcicum*, *Colletotrichum sublineola, Claviceps africana*

INTRODUCTION

Based on discussions between representatives from Grain SA and ARC-Grain Crops (ARC-GC) during September 2016 at the Sorghum Trust's Research Evaluation Committee, the sorghum industry expressed the need for disease screening studies on commercially available grain sorghum (*Sorghum bicolor* L, Moench) cultivars. In order to reduce operational costs, ARC-GC adhered to requests by the Sorghum Trust, to utilise trial sites that were planted by Grain SA to screen sorghum cultivars for Leaf blight and grain mould. A decision was taken that a sorghum disease project be initiated by ARC-GC in collaboration with the University of the Free State in order to address specific voids that exists regarding the susceptibility of commercially available sorghum cultivars to the most economically important sorghum diseases in South Africa.

International research has estimated that annual yield losses due to pest and pathogens can be as high as 30% (Chandrashekar and Satyanarayana, 2006). The release of new sorghum cultivars into the South African market necessitates the need to evaluate such cultivars for disease susceptibility not only to Exserohilum leaf blight but also to all known sorghum diseases that also include grain moulds.

Grain sorghum is currently the fifth most important grain crop in South Africa after maize (*Zea mays* L.), wheat (*Triticum aestivum* L.), sunflower (*Helianthus annuus* L.) and soybeans (*Glycine max* L.), with the Free State and Mpumalanga provinces being the largest contributors to the area planted to sorghum and sorghum production. In addition to Exserohilum leaf blight caused by *Exserohilum turcicum*, fungal leaf diseases such as sooty stripe (*Ramulispora sorghi*), downy mildew caused by (*Peronosclerospora sorghi*) and anthracnose (*Colletotrichum sublineola*) occur in sorghum. Stalk rots of note include charcoal rot (*Macrophomina phaseolina*) as well as Fusarium stalk rot, whilst diseases associated with the panicles include ergot (*Claviceps africana*), head smut (*Sphacelotheca reiliana)* and grain mold caused by several fungal species interacting parasitically as well as saprophytically with developing grain. Each of these diseases requires specific environmental conditions in order to manifest on susceptible cultivars. Not all are, however, of equal importance to the South African industry.

Downy mildew is more prominent in Oranjeville, Free State province but its occurrence is sporadic. Anthracnose is more common in the eastern production areas (Mtisi and McLaren, 2002), but is in general not as big a problem within South Africa as Exserohilum leaf blight (personal communication - Prof McLaren UFS). Ergot is more common in cold wet conditions and is prominent in later plantings that flower late during the season. During 1996, yield losses due to ergot were estimated to be 10-15% in South Africa, with the Heilbron, Free State (32%), Klerksdorp, North West (43%) and

Standerton, Mpumalanga (45%) areas affected the most. During the 1999/2000 season, the disease was again prominent in sorghum hybrid and seed production fields (Mtisi and McLaren, 2002). Due to better cultivar screenings, seed companies and producers were able to minimize, or eliminate yield losses emanating from this disease using resistance as well as through agricultural practices such as avoiding late planting dates.

Care should be taken that diseases such as ergot, do not again become a major problem to the industry due to highly susceptible material flooding the market. In addition, a lack of knowledge regarding susceptibility or resistance of certain cultivars to diseases such as Exserohilum leaf blight, could result in producers currently spraying preventatively for this disease (such is common practice in areas such as Standerton) and incurring unnecessary spraying expenses as the cultivar in question might have natural resistance to the disease.

Unlike diseases such as leaf blight, which is caused by a single fungus, the term “grain mold” refers to diseased sorghum grains due to infection by one or more pathogenic/saprophytic fungi. The disease tends to be important on short and medium sorghum cultivars that mature during the rainy season in humid, tropical and subtropical climates. Species of the genera *Fusarium, Curvularia, Alternaria, Phoma, Bipolaris* and *Colletotrichum* have been associated with grain mold (Thakur *et al*., 2003) of which the *Fusarium* spp. are considered to be the most prominent within the grain mold complex (Sharma *et al*., 2010). The various fungi associated with grain mold interact differentially with genotype x environment and thus their incidence and associated mycotoxins differ depending on seasonal conditions. Some grain mold fungi are prevalent pre-harvest whilst others become problematic post-harvest. Members of the *Fusarium graminearum* species complex (FGSC) are pathogens that infect both maize and sorghum. The FGSC not only causes root and crown rot of maize, but can also result in grain mold on sorghum. Therefore, newly released sorghum cultivars should also be evaluated for their susceptibility to infection by grain mold associated fungi.

Sorghum yield has increased from less than 2 tons/ha to above 3.5 tons/ha (Fig. 1) over the duration of this project with the exception of the 2018/19 season, which was a drought season. The seasonal area planted to sorghum has remained stable at between 40 000 - 50 000 ha (Fig. 2). Seed companies continue to develop new sorghum cultivars, or import cultivars from Australia and USA breeding programmes. The suitability of these cultivars for the South African climate and sorghum industry needs to be determined.

MATERIALS AND METHODS

Localities

Trials were planted (Photo 1) at the ARC-Grain Crops Experimental Farm, Potchefstroom (-26.73171 27.06481) in the North West province (Photo 2) as well as at Cedara (-29.54428 30.26148) in KwaZulu-Natal province (Photo 3). It should be noted that the project was initially premised on the utilisation of trial sites at farmer fields during the first year of funding. However, results could not be obtained since farmers applied fungicides to their crops. As a result, the Sorghum Trust Research Evaluation Committee resolved that the trials must be planted at two localities namely Potchefstroom and Cedara since farmers applied fungicides to their fields, thereby confounding the results.

Trial Design

The trials were planted in a split plot design with two treatments: Fungicide-sprayed and non-sprayed trials replicated three times. The rows were 8 m long with 80 plants in each row. Inter-row spacing was 1.2 m. Amistar® Top; a broad-spectrum strobilurin and triazole fungicide was applied according to the manufacturer's instructions.

Early and late planting at each locality was performed wherein 10-12 cultivars were screened depending on the availability of seed for each cultivar. Planting took place in mid-October and mid-January to ensure a range of flowering dates. Soil analyses was performed prior to planting at the ARC Soil Laboratory (ARC-Industrial Crops, Rustenburg). Trials were fertilized as per soil analyses results and maintained until flowering with insect and weed control performed as required. Developing sorghum heads/panicles were covered with mono bags to deter bird feeding.

A single triazole fungicide (Amistar® Top) was applied at early boot stage and leaf blight was evaluated at soft dough stage. Leaf blight and grain mold were visually rated according to Price *et al*. (2016) and Bandyopadhyay and Mughogho, (1988), respectively. After harvest, yield was determined by first cutting heads and putting them in brown paper bags with labelling including replicate number and treatment. The moisture level was determined using a Draminski® moisture meter and the heads were threshed, grain weighed, and the data recorded. Grain yield and leaf blight data were subjected to ANOVA using Genstat® 19th Edition (VSN International, UK).

2016/17 Season

Trial sites that were planted by Grain SA to screen sorghum cultivars for leaf diseases and grain mould were utilised at Koppies (Free State Province), Settlers (Limpopo Province), Sannieshof (North West Province) and Platrand (Mpumalanga Province).

2017/18 Season

Eleven cultivars were evaluated for leaf diseases and grain mould at Potchefstroom and Cedara during the 2017/18 season. PAN8945, PAN8816, PAN8625, PAN8944 (all supplied by Pannar Seed), Dominator, Bullet, Avenger, Enforcer, Swift, Titan (all supplied by Agricol), and Mr Buster (supplied by Klein Karoo Seed Marketing) were the cultivars that were evaluated. Disease ratings were performed at 60, 90, 120 and 150 days after planting for this season, which had severe Exserohilum leaf blight.

Problems Encountered

Cultivar Bullet was the only cultivar that showed resistance to bird damage. Land under netting was requested and allocated for the 2018/19 season at Potchefstroom to protect from bird damage.

2018/19 Season

Eleven cultivars were evaluated for leaf diseases and grain mould at Potchefstroom and Cedara. Four trials were planted, two in mid-October and two in mid-January in both Potchefstroom and Cedara. PAN8945, PAN8816, PAN8625, PAN8944, PAN8706 (all supplied by Pannar Seed), Bullet, Avenger, Enforcer, NS551, Titan (all supplied by Agricol), and Mr Buster (supplied by Klein Karoo Seed Marketing) were the cultivars that were evaluated. The fungicide was applied at Potchefstroom and Cedara according to the manufacturer's instructions. Leaf disease ratings were performed visually at the soft dough stage. The trials were harvested at physiological maturity and moisture levels determined, grain threshed and weighed.

Problems Encountered

The second planting made in mid-January at both localities was damaged by frost, which confounded leaf disease ratings.

2019/20 Season

Twelve cultivars were evaluated for leaf diseases and grain mould at Cedara and Potchefstroom. Four trials were planted, two in November 2019 and two in December 2019 at both localities. PAN8945, PAN8816, PAN8625, PAN8944, PAN8706 (all supplied by Pannar Seed), Bullet, Avenger, Enforcer, NS551, Titan, Swift (all supplied by Agricol), and Mr Buster (supplied by Klein Karoo Seed Marketing) were the cultivars that were evaluated. The fungicide was applied at Potchefstroom and Cedara according to the manufacturer's instructions. Leaf disease ratings were performed visually at the soft dough stage. The trials were harvested at physiological maturity and moisture levels determined, grain threshed and weighed.

Problems Encountered

The trials in Potchefstroom had poor germination during the 2019/20 season and as a result; they were re-planted three times in November 2019. Moreover, the second planting was severely affected by waterlogging due to high rainfall during December and January of the 2019/20 season. The second planting in Cedara was severely affected by ergot infection (Photo 4) and it was not harvested. Moreover, the COVID-19 pandemic severely curtailed travelling to visit trial sites.

2020/21 Season

Twelve cultivars were planted at Potchefstroom and Cedara in November 2020. One trial was planted at each locality and the cultivars planted were PAN8945, PAN8816, PAN8625, PAN8944, PAN8706 (all supplied by Pannar Seed), Bullet, Avenger, Enforcer, NS5511, Titan, Swift (all supplied by Agricol), and Mr Buster (supplied by Klein Karoo Seed Marketing). The fungicide was applied at Potchefstroom and Cedara according to the manufacturer's instructions. Leaf disease ratings were performed visually at the soft dough stage. The trials were harvested at physiological maturity and moisture levels determined, grain threshed and weighed.

Problems Encountered

Trials were re-planted due to low seed vigour, which resulted in poor germination.

RESULTS

2016/17 Season Leaf Blight Results

Disease severity on national cultivar trials was very low because farmers had sprayed various types of agrochemicals on cultivar trials for disease control. However, symptoms of rust, bacterial streak and leaf blight were observed. Severe infections of leaf blight were only observed in Platrand. Mr Buster and MFBI were most susceptible to leaf blight in three localities, namely Koppies, Settlers and Sannieshof for Mr Buster, and Koppies, Settlers and Platrand for MFBI 8816 (Table 1). PAN 8816 was least susceptible to leaf blight in all four localities. Bacterial streak disease was significant only in two cultivars (PAN8940T and PAN8816) in Sannieshof and three cultivars (Titan, PAN8804 and Mr Buster) in Platrand (Table 2). Farmers had sprayed fungicides for disease control on cultivar trials and as a result, this affected the development and appearance of diseases in all the localities.

2017/18 Season Leaf Blight Results

Exserohilum leaf blight (Photo 5) was the disease of concern in Cedara throughout the season while sorghum rust (Photo 6) was of concern in Potchefstroom late in the season. The cultivar with most resistance to leaf blight was Titan (Table 3). The area under disease progress curve (AUDPC) also showed that cultivar Titan was the most resistant cultivar to leaf blight followed by Swift (Table 3; Fig. 3). The AUDPC showed that PAN8945, PAN8816, PAN8625, Dominator, Enforcer and Mr Buster were highly susceptible to leaf blight whereas PAN8944, Bullet and Avenger were moderately susceptible (Fig. 3). A single fungicide application per season decreased leaf blight by between 8-16% in all cultivars except Titan (Fig. 4). This indicate that a second application is needed a month after the first application under climatic conditions in Cedara during 2017/18 (Fig 4). Fungicide application did not result in the immediate control of leaf blight in PAN8816, PAN8625 and Dominator (Fig. 5), indicating that the fungicide should be applied promptly upon the attainment of the requisite disease threshold as indicated in the manufacturer's instruction in order to effectively control leaf blight. Rust developed late into the season in Potchefstroom (Figs. 6 and 7). Mr Buster followed by Swift and PAN8945 were highly susceptible to rust (Table 4; Fig. 8) whereas the rest of the cultivars were moderately susceptible (Table 4; Fig. 8). Even fungicide application had 43% leaf blight developing on Mr Buster (Table 4). Application of the fungicide reduced rust by 4-43% for the cultivars (Table 4). This indicate that at least one fungicide application per season, depending on the cultivar planted, effectively controlled rust in Potchefstroom during 2017/18. No single cultivar was resistant to both diseases. Cultivar Titan was resistant to leaf blight but moderately susceptible to rust. Cultivar Mr Buster was highly susceptible to both diseases, while nine cultivars were moderately susceptible to both diseases. Cultivar Dominator had poor pollination and grain fill. While cultivar Bullet was the only cultivar that did not suffer any bird damage.

2018/19 Season Leaf Blight and Grain Yield Results

Leaf blight: *Potchefstroom vs. Cedara - non-sprayed trial* ***(Fig. 9)***

Only one cultivar Bullet had significantly high leaf disease at Potchefstroom compared to Cedara. The rest of the cultivars namely PAN8945, PAN8816, PAN8625, PAN8944, PAN8706, Avenger, Enforcer, NS551, Titan and Mr Buster did not differ significantly between the two localities.

Leaf blight: *Potchefstroom vs. Cedara - sprayed trial* ***(Fig. 10)***

Only one cultivar Bullet had significantly high leaf disease at Potchefstroom compared to Cedara despite fungicide application. The rest of the cultivars namely PAN8945, PAN8816, PAN8625, PAN8944, PAN8706, Avenger, Enforcer, NS551, Titan and Mr Buster did not differ significantly between the two localities.

Leaf blight: *Potchefstroom (non-sprayed vs. sprayed) trial* ***(Fig. 11)***

Fungicide application did not make a significant difference in leaf disease in all cultivars at Potchefstroom indicating that leaf blight was not a problem this season. However, cultivar Bullet was still the most susceptible cultivar in both non-sprayed and sprayed trials.

Leaf blight: *Cedara (non-sprayed vs. sprayed) trial* ***(Fig. 12)***

Fungicide application significantly reduced leaf disease in five of the eleven cultivars namely PAN8945, PAN8944, Bullet, Avenger and Titan. PAN8625, however, had significantly higher leaf blight in the sprayed compared to the non-sprayed trial. PAN8816, NS5511, PAN8706, Enforcer and Mr Buster did not differ significantly between the sprayed and non-sprayed trials.

Yield: *Potchefstroom vs. Cedara – non-sprayed trial* ***(Fig. 13)***

Eight of the eleven cultivars did not differ significantly in yield at both Cedara and Potchefstroom in non-sprayed trials. PAN8944, NS5511 and Mr Buster were the cultivars that significantly yielded more grain at Cedara than in Potchefstroom.

Yield: *Potchefstroom vs. Cedara - sprayed trial* ***(Fig. 14)***

Five cultivars PAN8945, PAN8944, NS5511, Avenger and Mr Buster significantly yielded more grain at Cedara and Potchefstroom upon fungicide application, indicating the benefits of fungicide application at Cedara. The other six cultivars namely PAN8816, PAN8625, PAN8706, Bullet, Enforcer and Titan did not differ significantly between the two localities.

Yield: *Potchefstroom (non-sprayed vs. sprayed) trial* ***(Fig. 15)***

Fungicide application significantly increased yield in cultivar Mr Buster at Potchefstroom while two cultivars namely PAN8945 and Bullet had significantly less yield in the sprayed trial when compared to the non-sprayed trial. This could be due to other biotic and abiotic factors other than fungal infection. Therefore, more trials that are seasonal are needed to screen these cultivars. Moreover, fungicide application had no significant effect on yield in eight cultivars namely PAN8816, PAN8625, PAN8944, PAN8706, Avenger, Enforcer, NS5511 and Titan.

Yield: *Cedara (non-sprayed vs. sprayed) trial* ***(Fig. 16)***

Cultivar Avenger was the only cultivar, which responded to fungicide treatment resulting in significantly higher yield in the sprayed trial compared to the non-sprayed trials. There were no significant differences in the rest of the cultivars namely PAN8945, PAN8816, PAN8625, PAN8944, PAN8706, Bullet, Enforcer, NS5511, Titan and Mr Buster.

2019/20 Season Leaf Blight and Grain Yield Results

Leaf blight: *Potchefstroom vs. Cedara - non-sprayed trial* ***(Fig. 17)***

Leaf blight was more pronounced at Potchefstroom during this season with five cultivars PAN8816, PAN8625, PAN8944, NS5511 and Enforcer having significantly more leaf blight at Potchefstroom than at Cedara. There was, however, no significant difference in leaf blight between the two localities for cultivars PAN8945, Bullet, Avenger, PAN8706, Titan, Mr Buster and Swift.

Leaf blight: *Potchefstroom vs. Cedara - sprayed trial* ***(Fig. 18)***

Only cultivars NS5511 and Mr Buster had significantly high leaf blight symptoms at Potchefstroom compared to Cedara indicating that the fungicide had worked to reduce leaf disease in other cultivars. There were no significant differences between the localities for cultivars PAN8945, PAN8816, PAN8625, PAN8944, PAN8706, Bullet, Avenger, Enforcer, Titan and Swift.

Leaf blight: *Potchefstroom (non-sprayed vs. sprayed) trial* ***(Fig. 19)***

Fungicide application did not make a significant difference in leaf disease in nine of the 12 cultivars at Potchefstroom. However, the fungicide has a positive effect by significantly reducing leaf disease on PAN8625 and Bullet while cultivar NS5511 had significantly high leaf diseases despite fungicide application.

Leaf blight: *Cedara (non-sprayed vs. sprayed) trial* ***(Fig. 20)***

Fungicide application did not make a significant difference in leaf disease in 10 of the 12 cultivars at Cedara. Only cultivar PAN8625 and Mr Buster had significantly high leaf diseases in the non-sprayed compared to the sprayed trials.

Yield: *Potchefstroom vs. Cedara - non-sprayed trial* ***(Fig. 21)***

Three cultivars PAN8816, PAN8944 and Enforcer did not differ significantly in yield at both Cedara and Potchefstroom in non-sprayed trials. The results however showed that the rest of the cultivars yielded more grain in Cedara compared to Potchefstroom. These cultivars were PAN8945, PAN8625, PAN8706, Bullet, Avenger, NS551, Titan and Mr Buster.

Yield: *Potchefstroom vs. Cedara - sprayed trial* ***(Fig. 22)***

Five cultivars PAN8816, PAN8944, Bullet, Enforcer and Swift did not differ significantly in yield at both Cedara and Potchefstroom when the fungicides were applied. Moreover, PAN8816, PAN8944 and Enforcer were consistent in both non-sprayed and sprayed trials. The results however showed that six cultivars yielded more grain in Cedara compared to Potchefstroom. These cultivars were PAN8945, NS5511, Avenger, PAN8706, Titan and Mr Buster while PAN8625 was the only cultivar that significantly yielded more grain at Potchefstroom compared to Cedara.

Yield: *Potchefstroom (non-sprayed vs. sprayed) trial* ***(Fig. 23)***

The sprayed cultivar PAN8625, Bullet and Swift significantly yielded more grain than the non-sprayed treatment indicating that leaf diseases were a limiting factor to sorghum production during this season. Cultivar PAN8625 also had germination problems. There were no significant differences between treatments for cultivars PAN8945, PAN8816, PAN8944, PAN8706, Avenger, Enforcer, NS5511, Titan, and Mr Buster indicating that fungicide spray is of no economic benefit in these cultivars under environmental conditions obtaining in Potchefstroom during the 2019/20 season.

Yield: *Cedara (non-sprayed vs. sprayed) trial* ***(Fig. 24)***

Cultivar PAN8945 and PAN8706 positively responded to fungicide treatment with the sprayed treatment yielding significant more than the non-sprayed. However, for cultivars PAN8625, Bullet and Titan had poor and uneven germination and their non-sprayed treatments yielded significantly more than the sprayed treatment. This could be also due to other biotic factors such as virus infections that were observed at Cedara on this trial. There were no significant differences between treatments for cultivars PAN8816, PAN8944, NS5511, Avenger, Enforcer, Mr Buster and Swift thereby indicating that fungicide sprays should be applied cautiously in these cultivars.

2020/21 Season Leaf Blight and Grain Yield Results

Leaf blight: *Potchefstroom vs. Cedara - non-sprayed trial* ***(Fig. 25)***

Leaf blight was not visible at Potchefstroom. However, it was more pronounced at Cedara where Anthracnose leaf blight (Photo 7) was prevalent possibly due to high rainfall during this season. Cultivars PAN8816, PAN8625, PAN8944 and Avenger had significantly more leaf blight symptoms

at Cedara compared to Potchefstroom. There was, however, no significant difference in leaf blight between the two localities for cultivars PAN8945, Bullet, NS5511, Enforcer, Titan and Swift.

Leaf blight: *Potchefstroom vs. Cedara - sprayed trial* ***(Fig. 26)***

Only cultivars PAN8625 and NS5511 had significantly high leaf blight symptoms at Cedara compared to Potchefstroom despite fungicide treatments. This indicates that these cultivars are highly vulnerable to anthracnose leaf blight. There were no significant differences between the localities for cultivars PAN8945, PAN8816, PAN8944, Bullet, Avenger, Enforcer, Titan and Swift.

Yield: *Potchefstroom vs. Cedara - non-sprayed trial* ***(Fig. 27)***

Cultivars PAN8945 and Avenger significantly yielded more grain in Cedara compared to Potchefstroom conversely; cultivar PAN8625 yielded significantly more in Potchefstroom than in Cedara. It should be noted that cultivars Bullet, PAN8706 and Mr Buster did not germinate in Cedara. There were no significant differences between both localities for cultivars PAN8816, PAN8944, NS5511, Enforcer, Titan and Swift. Moreover, cultivar NS5511 was a high yielding cultivar at both localities.

Yield: *Potchefstroom vs. Cedara - sprayed trial* ***(Fig. 28)***

Cultivar NS5511 significantly yielded more grain in Cedara and was one of the high yielding cultivars at Cedara. Cultivar PAN8625 had germination problems at Potchefstroom, which interfered with the yield potential. Cultivars Bullet, PAN8706 and Mr Buster also did not germinate at Cedara. Cultivar PAN8944 marginally performed better at Potchefstroom. There were no significant differences between both localities for cultivar PAN8945, PAN8816, Avenger, Enforcer, Titan and Swift.

Yield: *Potchefstroom (non-sprayed vs. sprayed) trial* ***(Fig. 29)***

The non-sprayed cultivar PAN8945 significantly yielded more grain than the sprayed treatment possibly due to other biotic factors such as sporadic damage by stem borers. Cultivar Mr Buster responded well to fungicide treatment and it significantly yielded more grain compared to the non-sprayed treatment. Cultivar PAN8625 also had germination problems. There were no significant differences between treatments for cultivars PAN8816, PAN8944, NS5511, Bullet, Avenger, Enforcer, PAN8706, Titan and Swift indicating that fungicide spray is of no economic benefit in these cultivars under environmental conditions obtaining in Potchefstroom.

Yield: *Cedara (non-sprayed vs. sprayed) trial* ***(Fig. 30)***

Cultivar PAN8816, Bullet, PAN8706 and Mr Buster were not harvested due to fewer panicles and poor germination. Cultivar PAN8625 responded to fungicide treatment with the sprayed treatment

yielding significant more than the non-sprayed. However, for cultivars PAN8944, Avenger and Enforcer had the non-sprayed treatment yielded significantly more than the sprayed treatment. This could be due to other biotic factors such as virus infections that were observed at Cedara on this trial. There were no significant differences between treatments for cultivars PAN8945, NS5511, Titan and Swift thereby indicating that fungicide sprays should be applied cautiously in these cultivars.

DISCUSSION

Disease severity on national cultivar trials was very low during the 2016/17 season because farmers had sprayed various types of agrochemicals on cultivar trials for disease control. As a result, this affected the development and appearance of diseases in all the localities. Despite the application of these agrochemicals, leaf diseases were still observed in the producers' fields in the Free State, Limpopo, Mpumalanga and North West provinces.

A single fungicide application during the 2017/18 season reduced leaf blight by between 8-16% in all cultivars except Titan. This indicate that a second application is needed under climatic conditions and disease pressure that occurred in Cedara during 2017/18. However, fungicide application did not result in the immediate control of leaf blight in indicating that producers should regularly scout for disease symptoms so that fungicides should be applied as recommended by the manufacturer's instruction for effective control of leaf blight. Rust developed late into the season in Potchefstroom, in some cases after the soft dough stage, which may not have a significant impact on yield. Fungicides are important in the integrated management of leaf diseases of sorghum; however, the timing of each application is very significant if economic benefits of fungicides is to be realised. Grain mould was not observed in any cultivar. However, 3% of cultivar Dominator had poor pollination and grain fill while cultivar Bullet was the only cultivar that did not suffer any bird damage.

Results 2018/19 season confirmed the findings of the previous season indicating that Exserohilum leaf blight is the disease of concern in Cedara while sorghum rust is occurring in Potchefstroom. However, the incidence of leaf blight at Cedara was very low compared to the 2017/18 season possibly because different races of leaf blight-causing fungus, *Exserohilum turcicum,* are present in South Africa. It is known that cultivars demonstrate different levels of resistance, depending on the area and prevailing climatic conditions as well as pathogen races. Grain mould symptoms were not visible in all cultivars at both localities. Ergot was, however, highly prevalent in the second planting at Cedara. It is thus important that producers plant sorghum earlier in the planting window.

Exserohilum leaf blight caused by *Exserohilum turcicum* incidence did not exceed the recommended 3% threshold that is necessary for farmers to start fungicide application during the 2019/20 season. This indicates that the plant-pathogen interactions and disease incidence are impacted by seasonal environmental conditions. Cultivars yielded more grain at Cedara compared to Potchefstroom possibly due to differences in abiotic factors such as rainfall. According to the Köppen-Geiger climate classification, Cedara is classified as a dry-winter humid subtropical climate (Cwa) region, whereas Potchefstroom is a semi-arid (steppe) climate (BSk) region. This classification takes into account temperature and rainfall associated with each region, the average annual temperature in a Cwa

region is approximately 18.2˚C and annual average precipitation of 897 mm, contrasting with BSk region annual average temperature of approximately16.9˚C and annual average precipitation of 615 mm. The higher rainfall at Cedara may contribute to greater yield potentials than those observed at Potchefstroom. Again, the second planting (December) in Cedara was severely affected by ergot infection caused by *Claviceps africana* and it was not harvested. Anthracnose leaf blight leaf blight caused by *Colletotrichum sublineola* was dominant at Cedara during the 2020/21 season. This disease did not occur in the other seasons; this is possibly due to due to high rainfall during 2020/21 season attributed to tropical cyclone Eloise. Ergot again affected the trials that were planted in December. Thus, producers should be aware that sorghum plantings planted in December are more likely to be affected by ergot infections. Therefore, sorghum should be planted early in the planting window e.g. in October and November.

CONCLUSIONS

Cultivar evaluation trials indicate that sorghum diseases vary seasonally due to the genotype x environment interactions at different localities. For example, leaf blight caused by *Exserohilum turcicum* is usually the predominant disease at Cedara, however, during 2020/21 season, Anthracnose leaf blight was the predominant disease possibly due to high rainfall during this season. Disease incidence also varies because of different races of leaf blight-causing fungus, *Exserohilum turcicum,* that are present in South Africa.

Fungicides are therefore important in the integrated management of leaf diseases of sorghum. Nevertheless, this project also showed that fungicides do not work the same across cultivars and leaf diseases develop despite fungicide application due to differences in cultivar susceptibility. This is important in assisting producers to decide which cultivars to plant and the frequency of fungicide application expected for each cultivar. In addition, other biotic and abiotic factors other than fungal infection play a role in cultivar performance. Therefore, cultivar evaluation should be performed on a continuous basis.

RECOMMENDATIONS

This study therefore, recommends that cultivar evaluation be performed every season in order to improve the competitiveness of sorghum production in South Africa. For example, the maize and soybeans industries have continuous cultivar evaluation trials every season. The ARC-Grain Crops and the University of the Free State Consortium has the capacity and expertise to perform this work. Cultivar evaluation need to be broadened to cover a wide range of biotic and abiotic constraints to sorghum production in a changing climate in South Africa.

OUTPUTS

BOOK CHAPTERS

CORNEL, A. & NCUBE, E., 2020. Options for improving stored product protection in Southern Africa. In: Sikora, R.A., Terry, E.R., Vlek, P.L.G. & Chitja, J., eds. Transforming Agriculture in Southern Africa: Constraints, Technologies, Policies and Processes. London: Routledge, 114-123.

CONGRESS PRESENTATIONS

NCUBE, E. & SAAYMAN-DU TOIT, J., 2019. Screening sorghum cultivars for leaf diseases in South Africa. Proceedings of the 51st Congress of the SASPP, 20-24 January 2019, Langebaan, South Africa. (Poster)

NKOKO, D.P., NCUBE, E., SAAYMAN-DU TOIT, J. & METHO, L.A., 2020. Evaluation of sorghum (*Sorghum bicolor* (L.) Moench) cultivars for grain yield at two localities in South Africa. Proceedings of the13th South African Plant Breeding Symposium, 8-11 March 2020, Future Africa Conference Centre, University of Pretoria, Pretoria, South Africa. (Poster)

NCUBE, E. & NKOKO, D.P., 2021. ARC - Grain Crops' sorghum cultivar evaluation trials for the 2020/21 season. Proceedings of the North West Department of Agriculture Arable Farming Symposium 2021. 28 October 2021 (Oral)

TECHNOLOGY TRANSFER

NCUBE, E. & NKOKO, D., 2021. ARC - Grain Crops - Sorghum Cultivar Evaluation Trials for the 2020/21 season at Potchefstroom and Cedara. *SA Graan/Grain*, September 2021. (*in press*)

NCUBE, E., NKOKO, D. & ROTHMANN, L., 2020. TRIAL RESULTS - these cultivars can adapt. *SA Graan/Grain*, October 2020, p. 57-59.

NCUBE, E. & SAAYMAN-DU TOIT, J., 2019. Sorghum cultivar evaluation for leaf diseases in South Africa. *SA Graan/Grain*, September 2019, p. 78-80.

FARMER'S DAYS PRESENTED

NCUBE, E., 2019. Post Harvest handling and storage of Grain. Limpopo Department of Agriculture and Rural Development, Mopani District, Greater Giyani Municipality (101 farmers attended).

SKILLS DEVELOPMENT

This work will form part of Mr D.P. NKOKO's MSc at Tshwane University of Technology, Pretoria.

ACKNOWLEDGEMENTS

Dr E Ncube (ARC-GC) is grateful and appreciative of the funding received from the Sorghum Trust for this work. Dr Ncube further thanks Dr LA Rothmann & Prof NW McLaren (UFS) for their outstanding collaboration in this project. Co-operation from the ARC-GC teams at Potchefstroom and Cedara is hereby acknowledged.

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PRICE, T., PURVIS, M., & PRUIT, H., 2016. A quantitative disease severity rating scale for northern corn leaf blight. *Plant Health Progress* 17: 49-50.

SHARMA, R., THAKUR, R.P., SENTHILVEL, S, NAYAK, S., REDDY, S.V., RAO, V.P & VARSHNEY, R.K., 2010. Identification and characterization of toxigenic Fusaria associated with sorghum grain mold complex in India. *Mycopathologia*, 171: 223 - 230.

THAKUR, R.P., RAO, V.P., NAVI, S.S., GARUD, T.B., AGARKAR, G.D. & BHARATI, B., 2003. Sorghum grain mold: Variability in fungal complex. *International Sorghum and Millets Newsletter* 4: 104 - 108.

TABLES

Table 1: ANOVA for Leaf blight (%) occurrence in sorghum cultivars across four localities

Cultivar	Locality			
	Koppies	Settlers	Sannieshof	Platrand
PAN 8940T	6.67 a*	6.67 a	16.67 d	**nr
PAN 8816	6.67 a	6.67 a	6.67 ab	3.33 a
PAN 8906	8.33 ab	8.33 ab	nr	11.67 b
PAN 8944	8.33 ab	6.67 a	13.33 cd	11.67 b
PAN 8933	nr	nr	5.00 a	8.33 ab
PAN 8804	nr	nr	nr	6.67 ab
DOMINATOR	6.67 a	8.33 ab	11.67 bcd	nr
TITAN	13.33 bc	13.33 b	6.67 ab	5.00 a
MFBI 8816	16.67 cd	25.00 c	6.67 ab	11.67 b
ENFORCER	18.33 cd	21.67 c	8.33 abc	6.67 ab
MR BUSTER	21.67 d	21.67 c	16.67 d	6.67 ab

*Within each column, means bearing the same letter(s) are not significantly different using Genstat ($P \leq 0.05$)

**nr, not rated/not planted

Table 2: ANOVA for Bacterial streak (%) occurrence in sorghum cultivars in two localities

Cultivar	Locality	
	Sannieshof	Platrand
PAN 8940T	5.00 b	**nr
PAN 8816	5.00 b	3.33 ab
PAN 8906	nr	1.67 a
PAN 8944	1.67 ab	6.67 abc
PAN 8933	1.67 ab	5.00 ab
PAN 8804	nr	8.33 bc
DOMINATOR	1.67 ab	nr
TITAN	0.00 a	11.67 c
MFBI 8816	0.00 a	5.00 ab
ENFORCER	3.33 ab	6.67 abc
MR BUSTER	3.33 ab	11.67 c

*Within each column, means bearing the same letter(s) are not significantly different using Genstat ($P \leq 0.05$)

**nr, not rated/not planted

Table 3: Cultivar x fungicide treatment interaction on sorghum leaf blight incidence (%) at the hard dough stage in Cedara during the 2017/18 season

Cultivar	Fungicide treatment	No fungicide treatment
PAN8945	15.0ab	90.0e
PAN8816	15.0ab	90.0e
PAN8625	8.3a	88.3de
PAN8944	10.0a	53.3c
Agricol-Dominator	12.3a	90.0e
Agricol-Bullet	11.7a	73.3d
Agricol-Avenger	6.7a	50.0c
Agricol-Enforcer	6.7a	86.7e
Agricol-Swift	8.3a	25.0b
Agricol-Titan	5.0a	8.3a
Mr Buster	16.7ab	83.3de

$LSD_{(0.05)}$ = 11.9

*Means bearing the same letter(s) are not significantly different using Tukey's 95% confidence interval.

Table 4: Cultivar x fungicide treatment interaction on the incidence (%) sorghum rust at the hard dough stage in Potchefstroom during the 2017/18 season

Cultivar	Fungicide treatment	No fungicide treatment
PAN8945	13.3a	60.0cd
PAN8816	4.0a	18.3ab
PAN8625	10.0a	53.3c
PAN8944	5.0a	16.7a
Agricol-Dominator	4.0a	20.0ab
Agricol-Bullet	5.0a	40.0b
Agricol-Avenger	13.3a	46.7bc
Agricol-Enforcer	8.3a	31.7b
Agricol-Swift	30.0ab	63.3cd
Agricol-Titan	14.0a	40.0b
Mr Buster	43.3b	81.7d

$LSD_{(0.05)}$ = 17.8

*Means bearing the same letter(s) are not significantly different using Tukey's 95% confidence interval

FIGURES

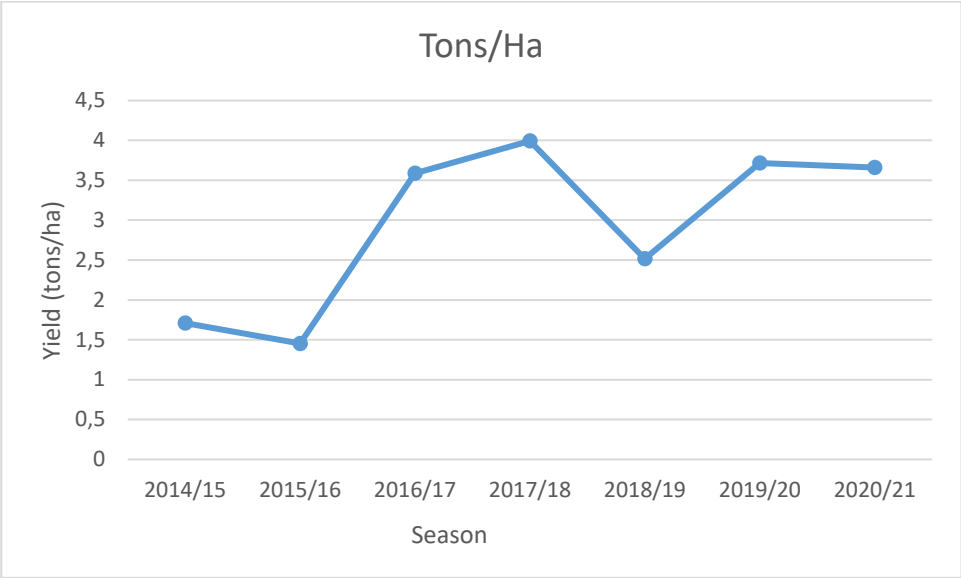

Figure 1: Seasonal (2014/15 - 2020/21) sorghum grain yield in South Africa (CEC, 2021)

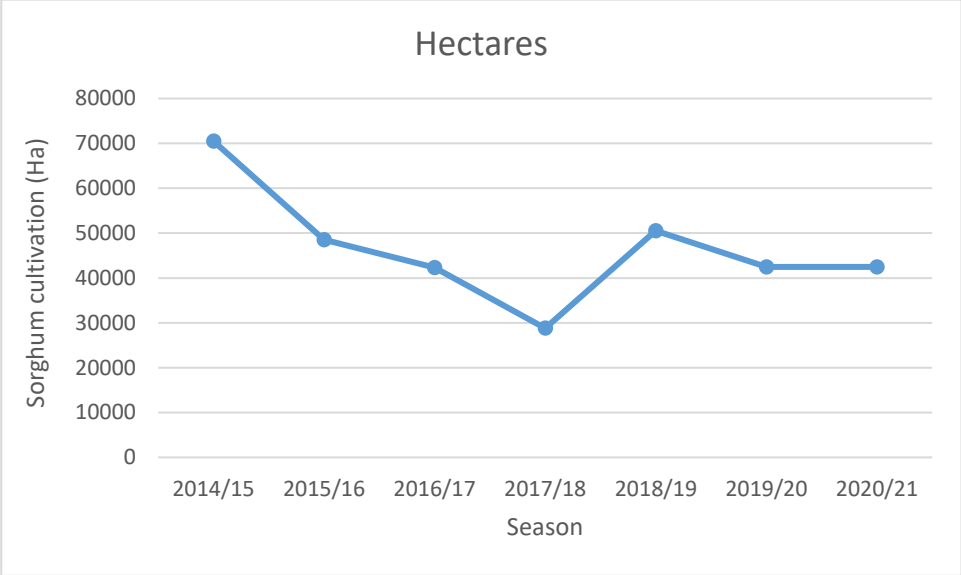

Figure 2: Seasonal (2014/15 - 2020/21) area planted (Ha) to sorghum in South Africa (CEC, 2021)

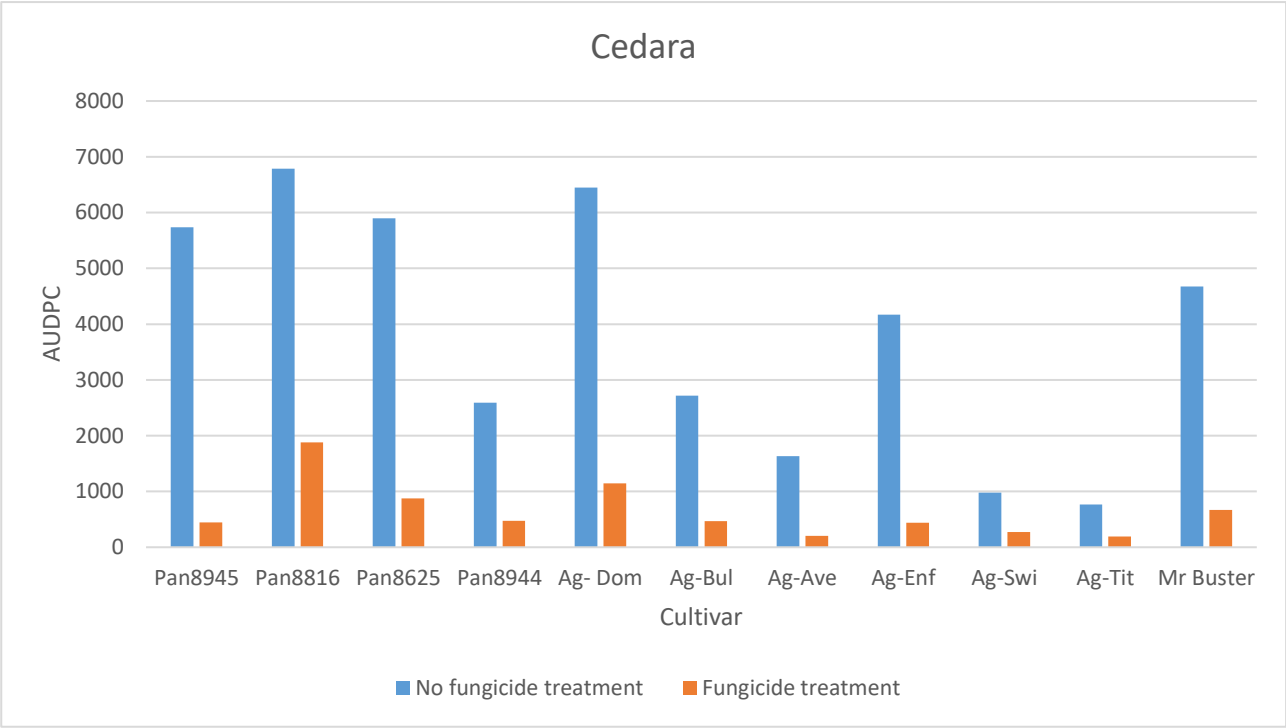

Figure 3: Area under leaf blight disease progress curve (AUDPC) for sorghum cultivars (sprayed and non-sprayed trials) in Cedara.

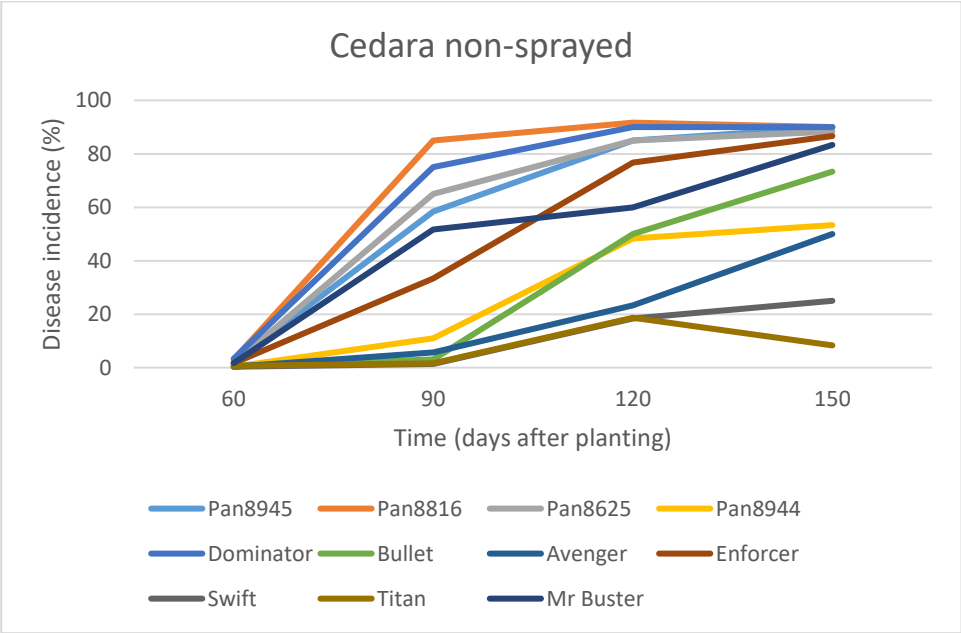

Figure 4: Leaf blight disease progress curves of sorghum cultivars at Cedara - non-sprayed trials.

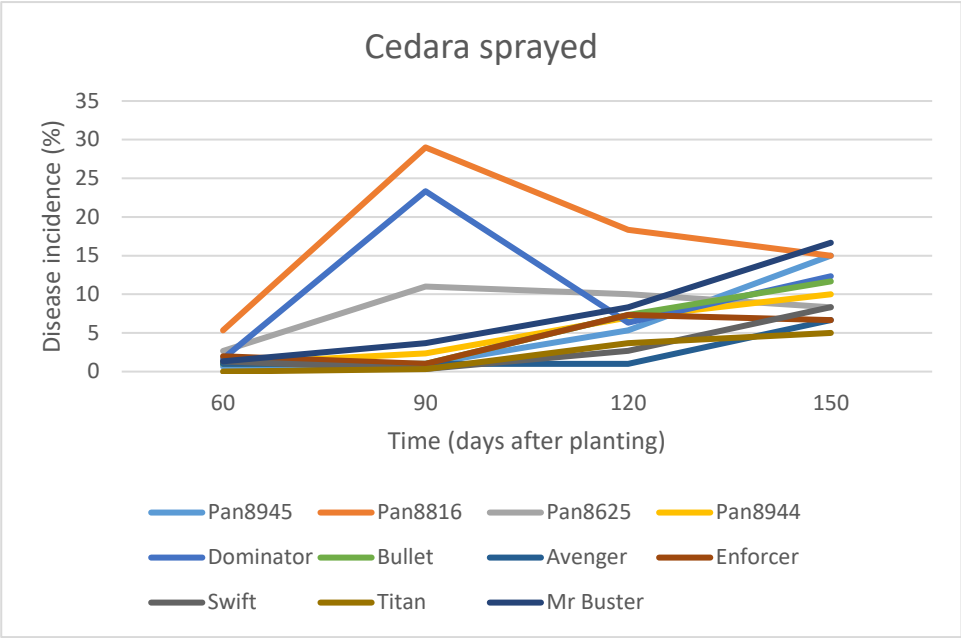

Figure 5: Leaf blight disease progress curves of sorghum cultivars at Cedara - sprayed trials.

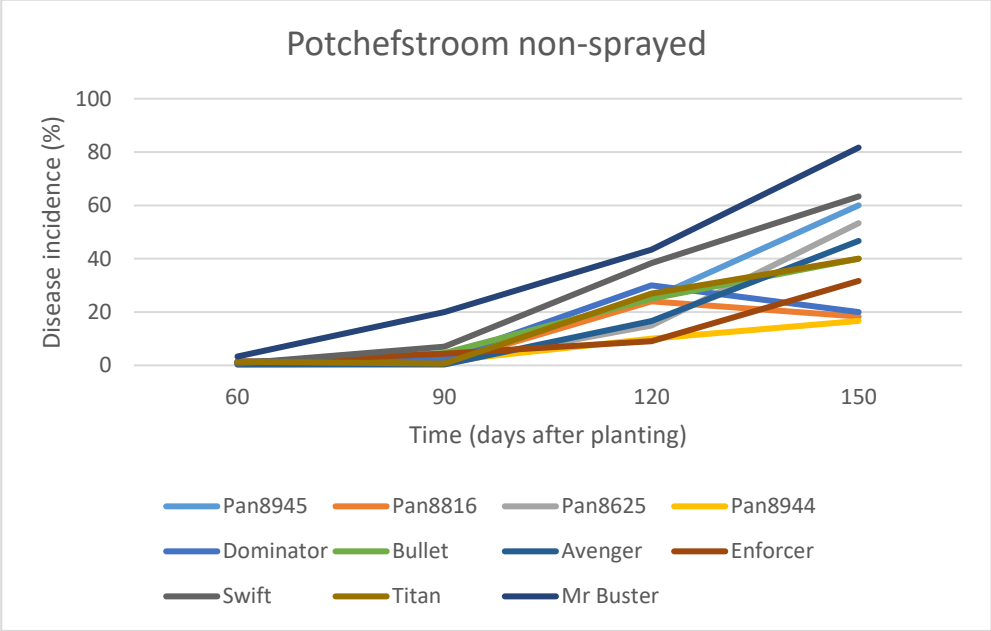

Figure 6: Sorghum rust disease progress curves of sorghum cultivars at Potchefstroom – non-sprayed trials.

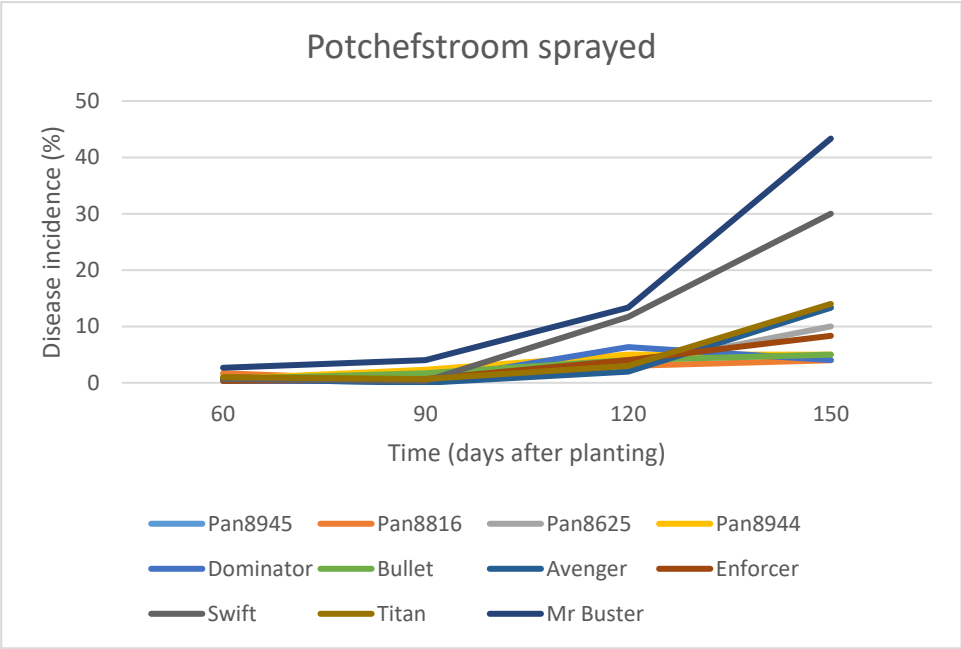

Figure 7:. Sorghum rust disease progress curves of sorghum cultivars at Potchefstroom – sprayed trials

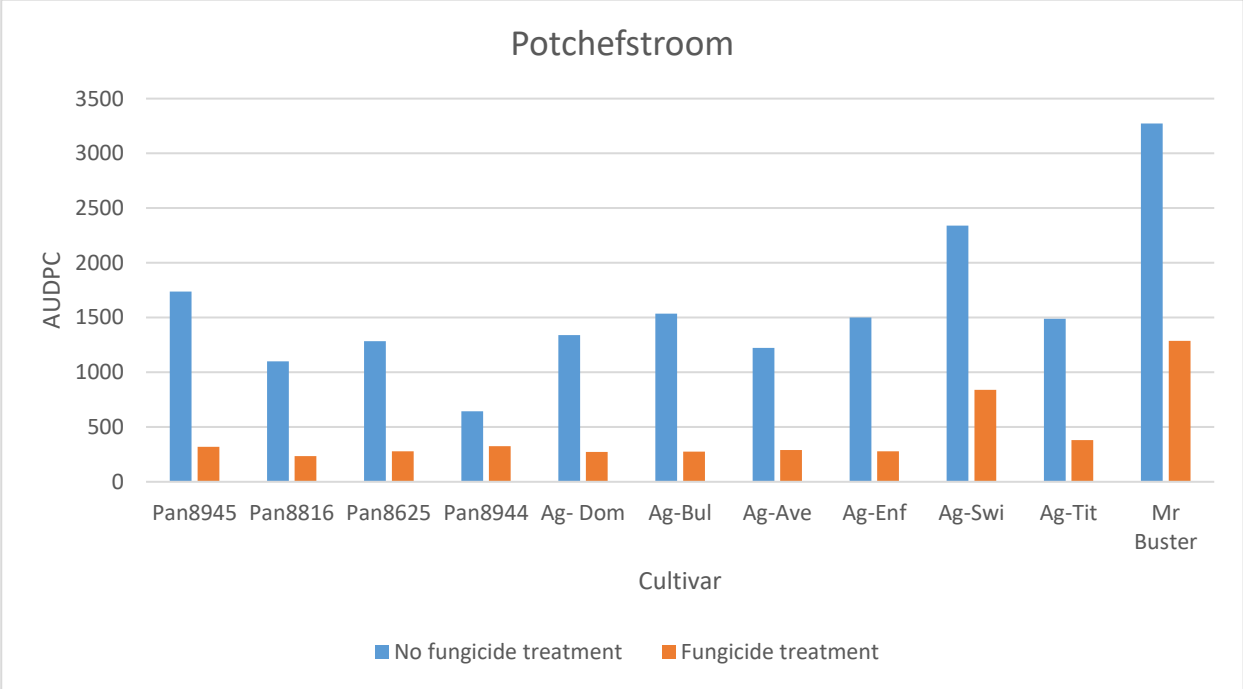

Figure 8: Area under sorghum rust disease progress curve (AUDPC) for sorghum cultivars (sprayed and non-sprayed trials) in Potchefstroom.

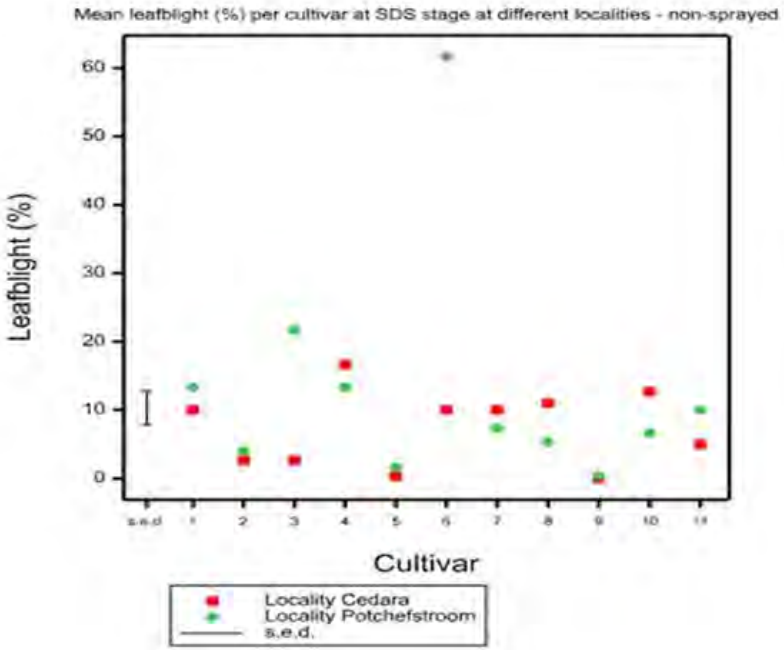

Figure 9

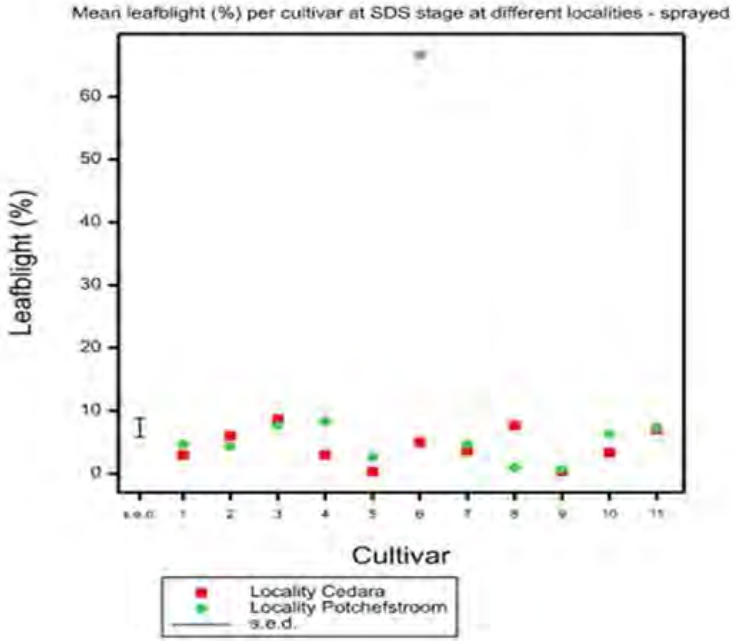

Figure 10

CULTIVARS: **1** = PAN8945, **2**= PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **6** = Bullet, **7** = Avenger, **8** = Enforcer, **9** = PAN8706, **10** = Titan, **11** = Mr Buster

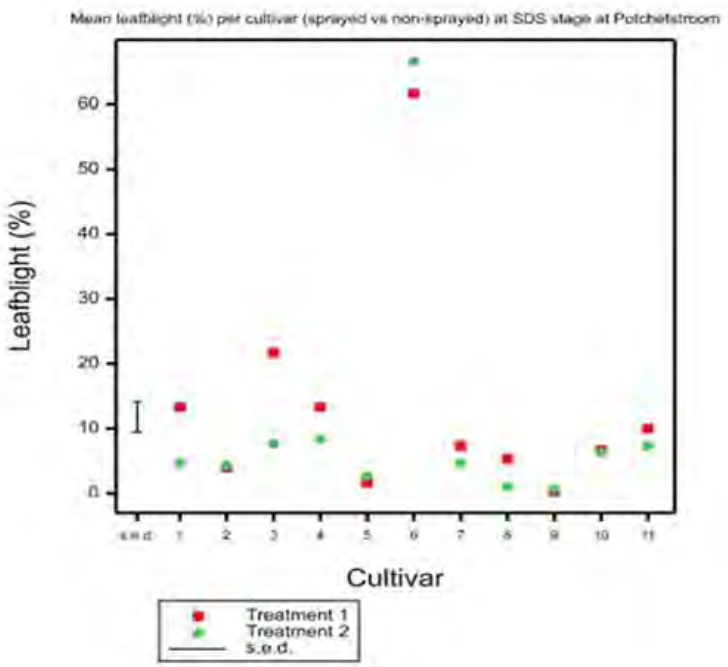

Figure 11

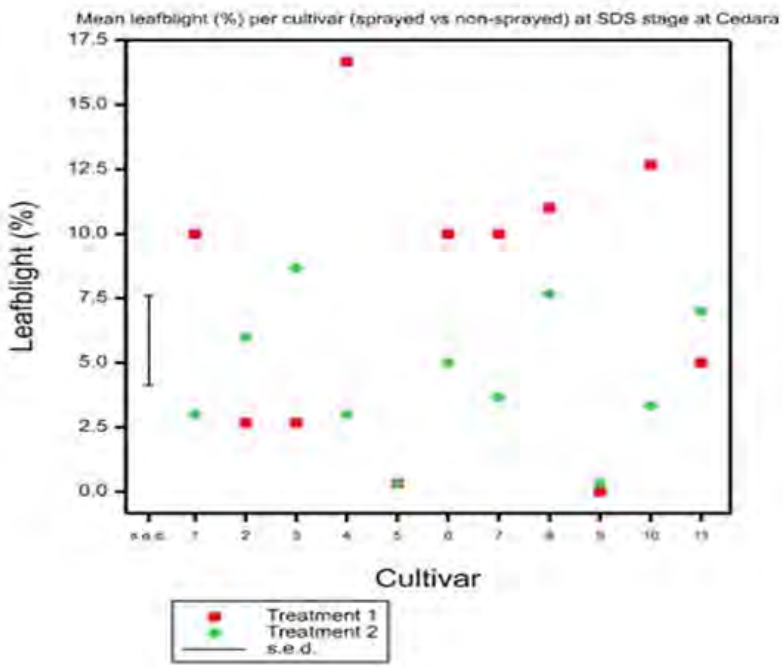

Figure 12

Treatment 1 = non-sprayed, ***Treatment 2*** = sprayed
CULTIVARS: **1** = PAN8945, **2**= PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **6** = Bullet, **7** = Avenger, **8** = Enforcer, **9** = PAN8706, **10** = Titan, **11** = Mr Buster

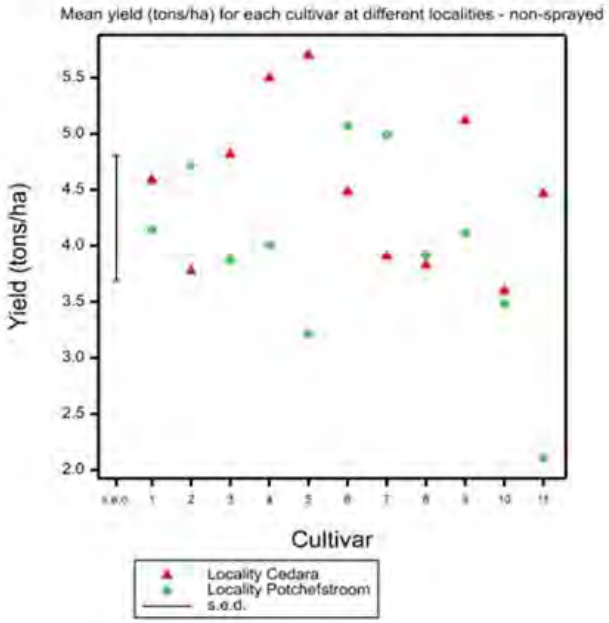

Figure 13

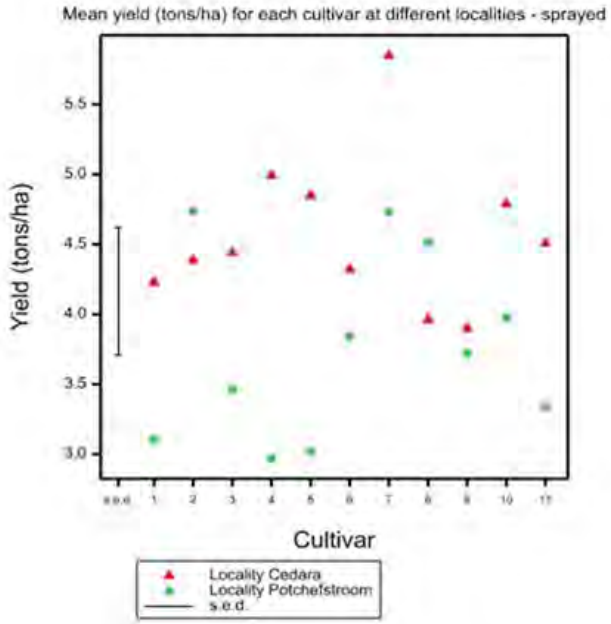

Figure 14

Cultivars: **1** = PAN8945, **2**= PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **6** = Bullet, **7** = Avenger, **8** = Enforcer, **9** = PAN8706, **10** = Titan, **11** = Mr Buster

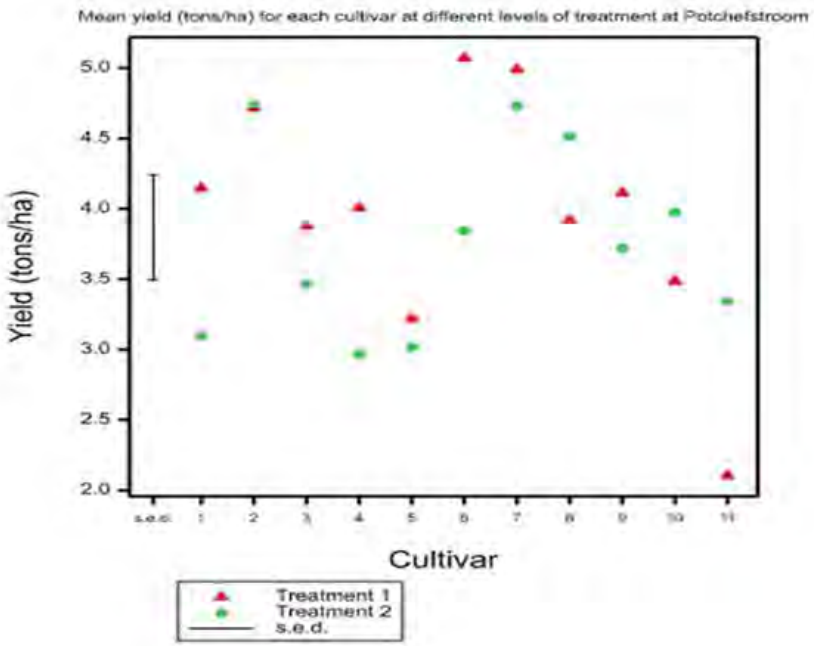

Figure 15

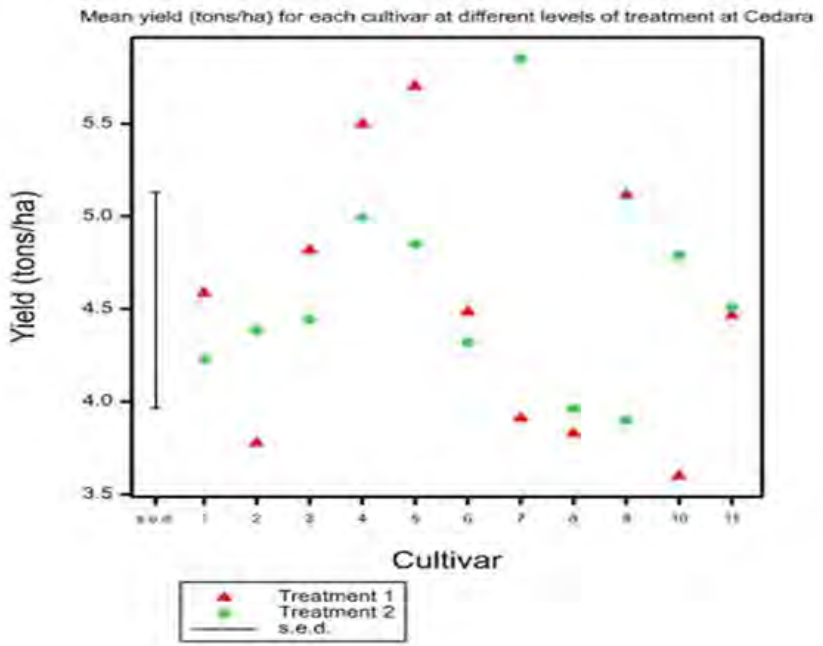

Figure 16

Treatment 1 = non-sprayed, ***Treatment 2*** = sprayed
CULTIVARS: **1** = PAN8945, **2**= PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **6** = Bullet, **7** = Avenger, **8** = Enforcer, **9** = PAN8706, **10** = Titan, **11** = Mr Buster

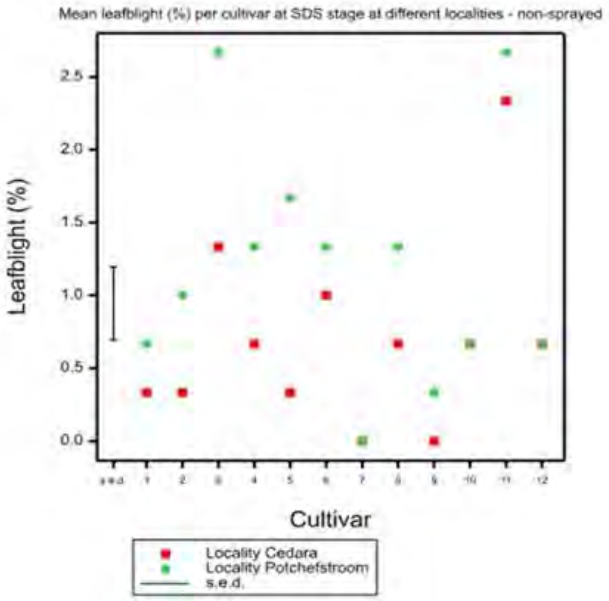

Figure 17

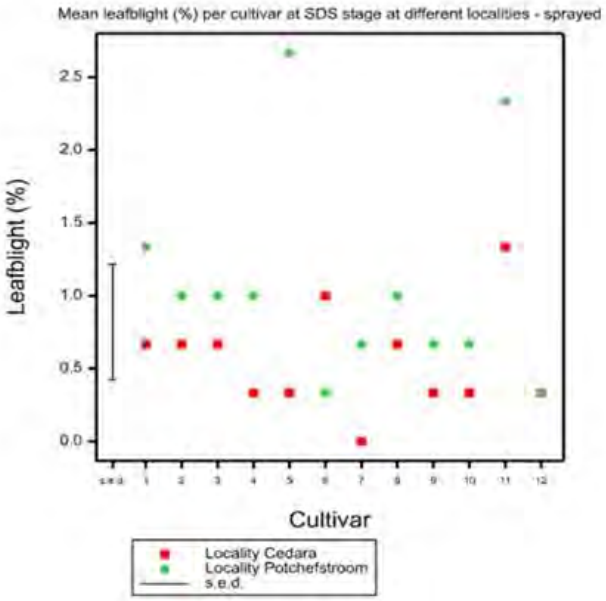

Figure 18

CULTIVARS: **1** = PAN8945, **2**= PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **6** = Bullet, **7** = Avenger, **8** = Enforcer, **9** = PAN8706, **10** = Titan, **11** = Mr Buster, **12** = Swift

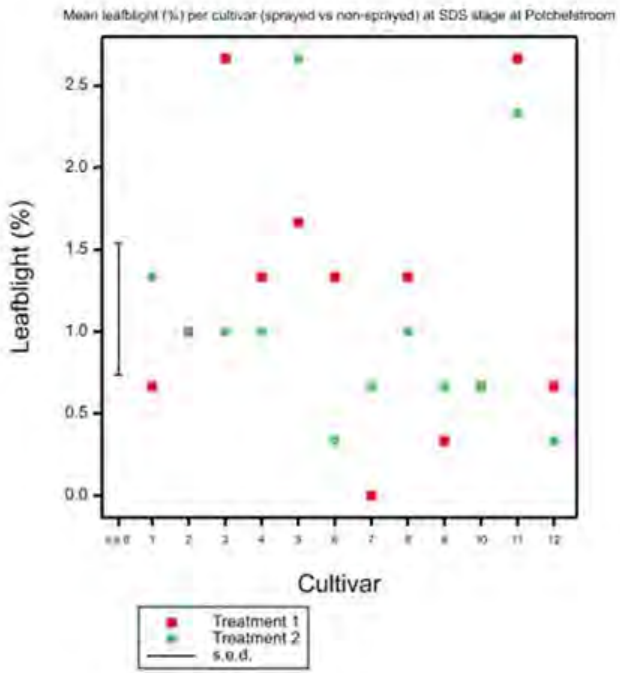

Figure 19

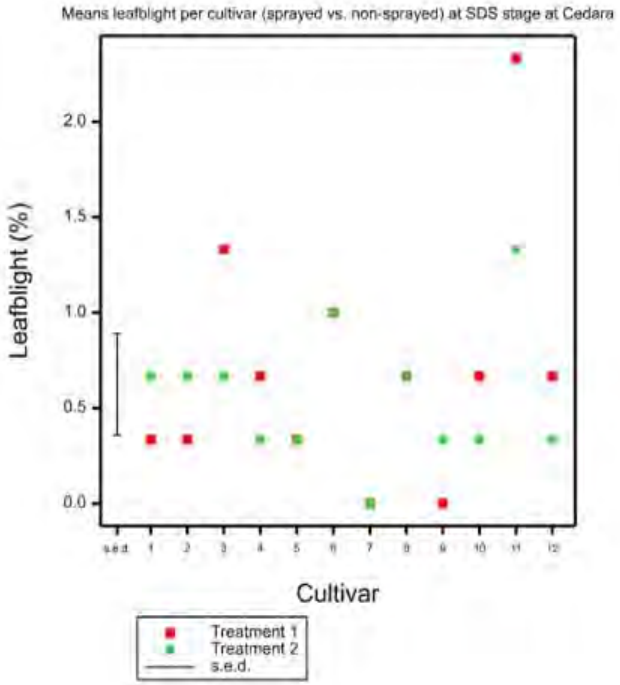

Figure 20

Treatment 1 = non-sprayed, ***Treatment 2*** = sprayed

CULTIVARS: **1** = PAN8945, **2**= PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **6** = Bullet, **7** = Avenger, **8** = Enforcer, **9** = PAN8706, **10** = Titan, **11** = Mr Buster, **12** = Swift

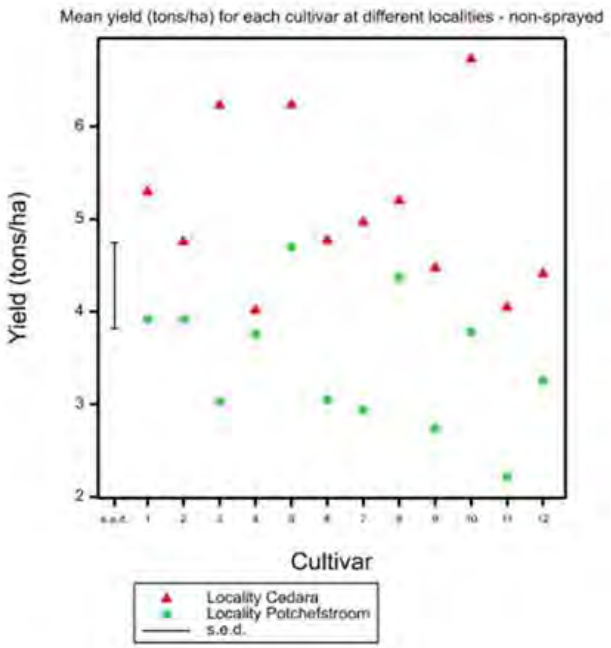

Figure 21

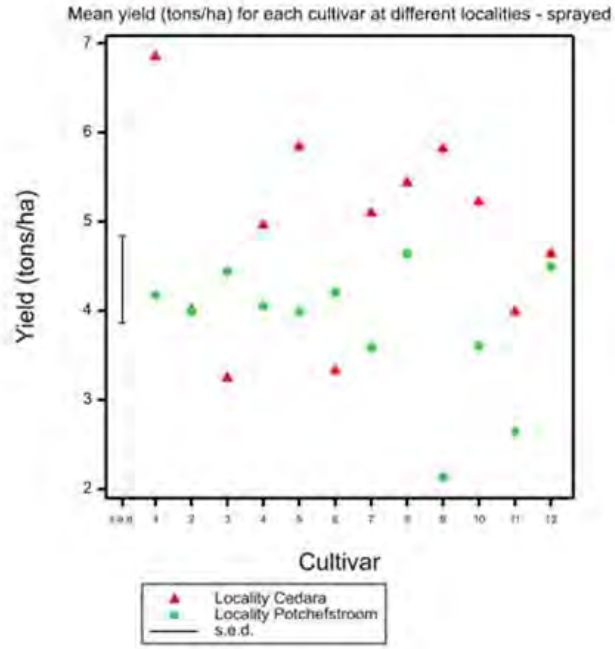

Figure 22

CULTIVARS: **1** = PAN8945, **2**= PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **6** = Bullet, **7** = Avenger, **8** = Enforcer, **9** = PAN8706, **10** = Titan, **11** = Mr Buster, **12** = Swift

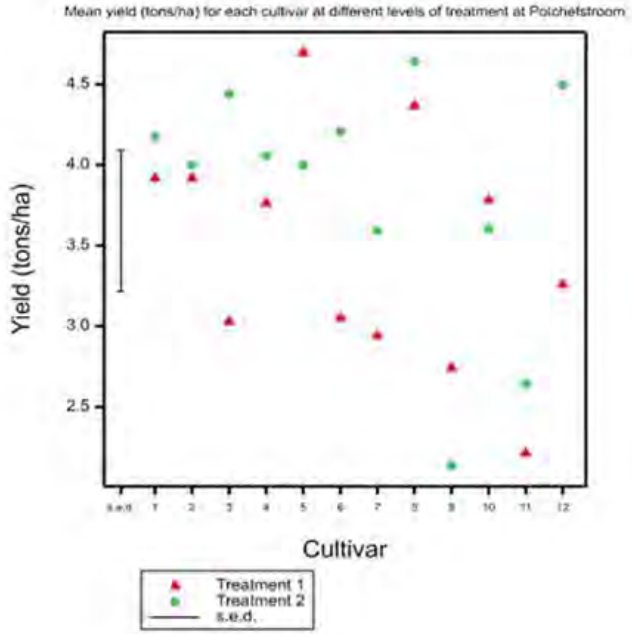

Figure 23

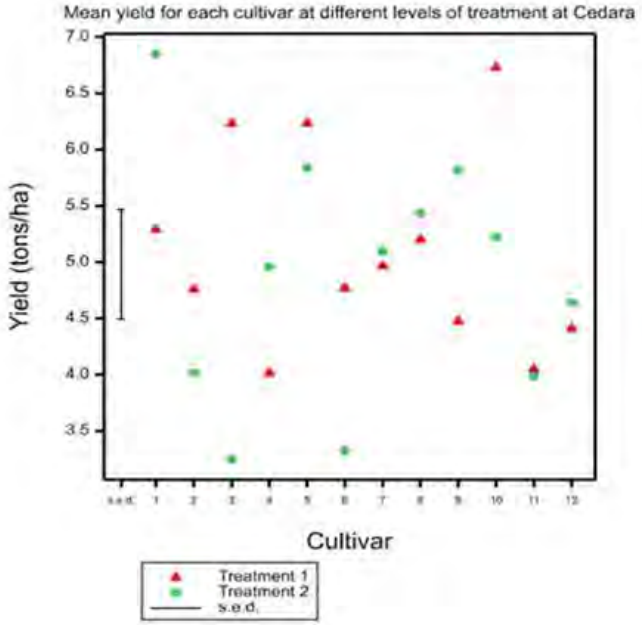

Figure 24

Treatment 1 = non-sprayed, ***Treatment 2*** = sprayed

CULTIVARS: **1** = PAN8945, **2**= PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **6** = Bullet, **7** = Avenger, **8** = Enforcer, **9** = PAN8706, **10** = Titan, **11** = Mr Buster, **12** = Swift

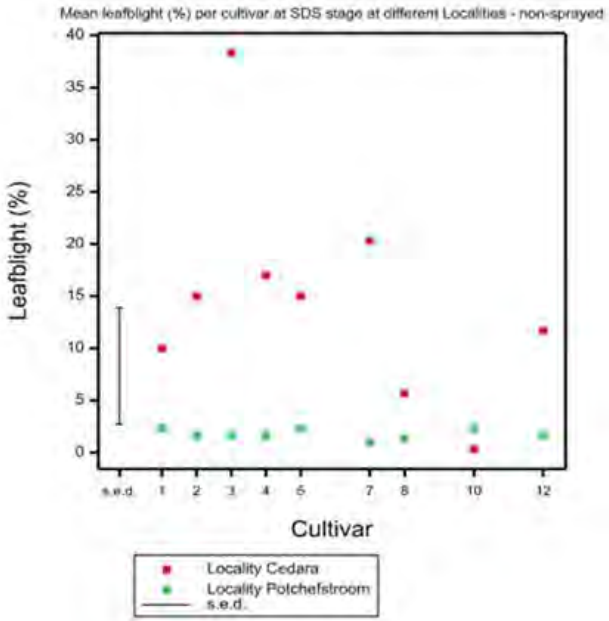

Figure 25

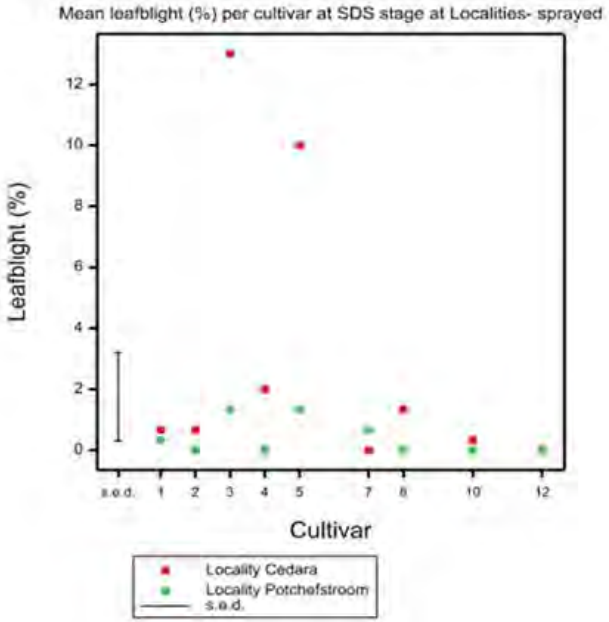

Figure 26

CULTIVARS: **1** = PAN8945, **2** = PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **7** = Avenger, **8** = Enforcer, **10** = Titan, **12** = Swift

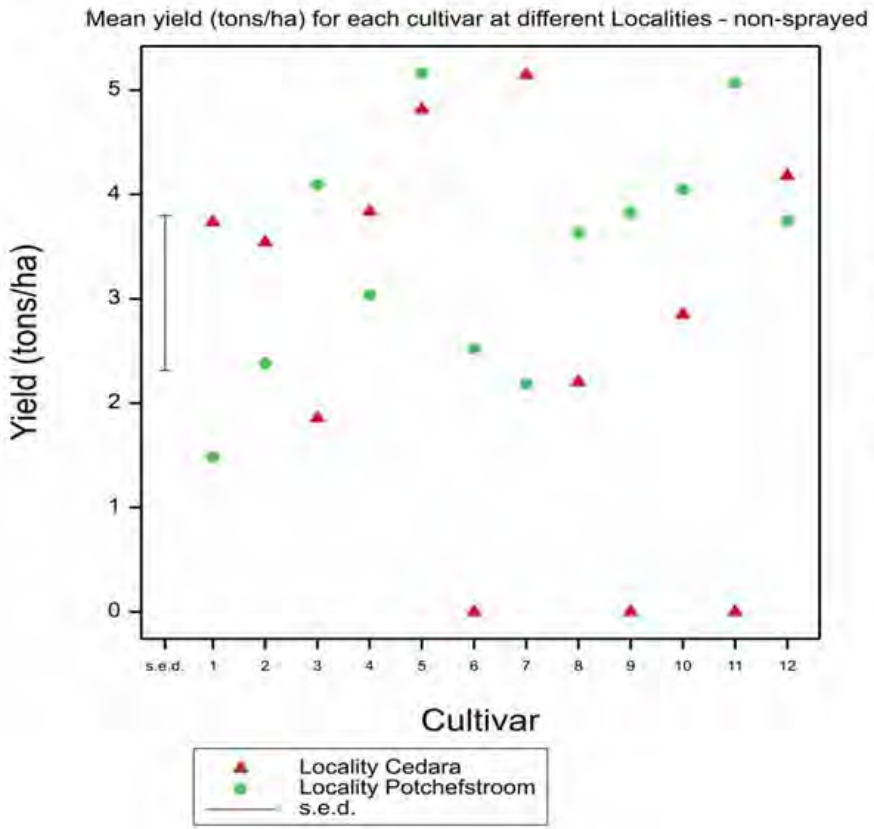

Figure 27

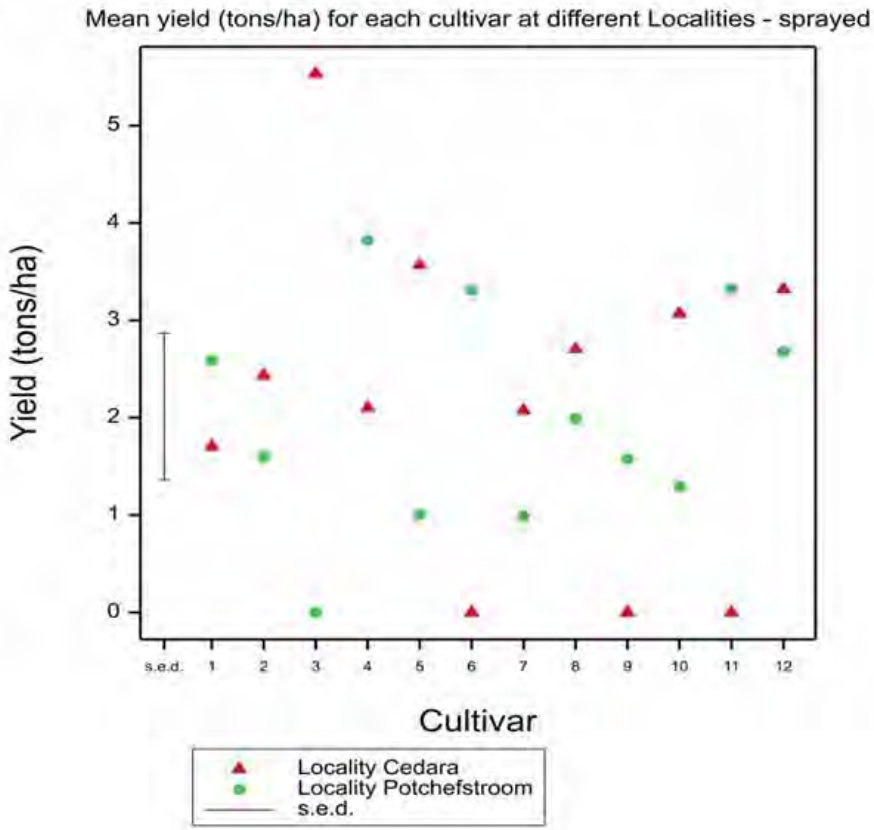

Figure 28

CULTIVARS: **1** = PAN8945, **2** = PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **6** = Bullet, **7** = Avenger, **8** = Enforcer, **9** = PAN8706, **10** = Titan, **11** = Mr Buster, **12** = Swift

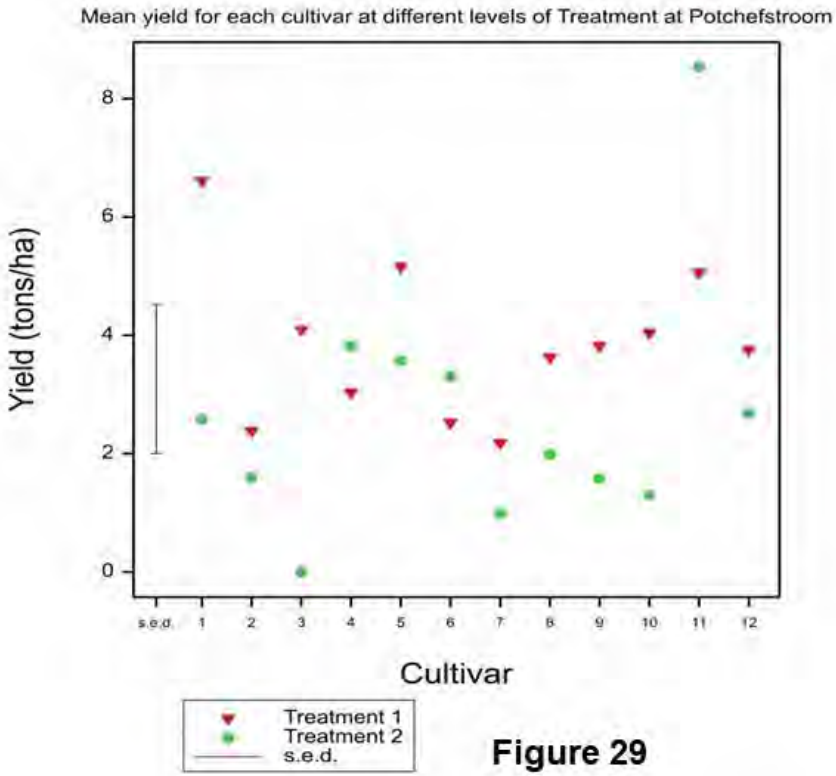

Figure 29

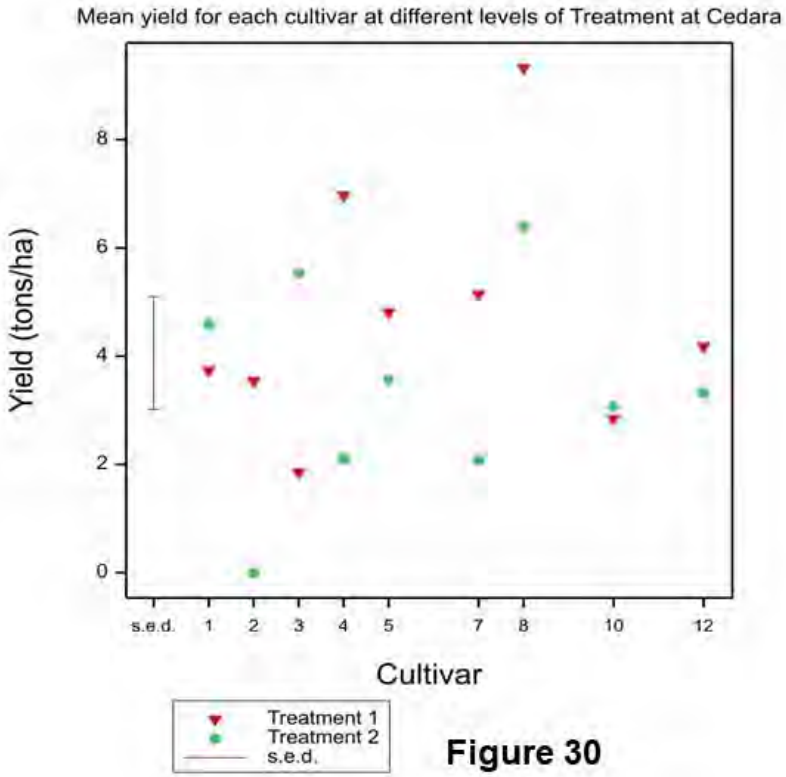

Figure 30

Treatment 1 = non-sprayed, ***Treatment 2*** = sprayed

CULTIVARS: **1** = PAN8945, **2**= PAN8816, **3** = PAN8625, **4** = PAN8944, **5** = NS5511, **6** = Bullet, **7** = Avenger, **8** = Enforcer, **9** = PAN8706, **10** = Titan, **11** = Mr Buster, **12** = Swift

PHOTOS

Photo 1 - Planting

Photo 2 - Trials at Potchefstroom

Photo 3 - Trials at Cedara

Photo 4 - Ergot (E Ncube)

Photo 5 - Exserohilum leaf blight (E. Ncube)

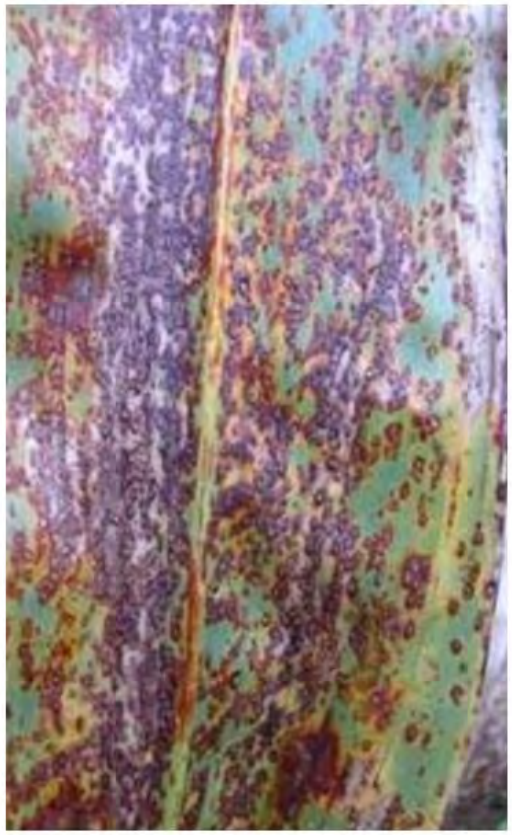

Photo 6 - Rust

Photo 7 - Anthracnose leaf blight (NW McLaren)