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Research Application Summary

Response of sorghum genotypes to anthracnose and *Turcicum* leaf blight

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Abstract

The absence of cultivars with dual disease levels of resistance justifies the search for genotypes with diseases resistance genes in sorghum breeding programs. In this study, four field and two greenhouse experiments were carried out in sorghum growing regions of Sudan and Uganda to evaluate resistance to *Colletotrichum sublineolum*, causing anthracnose, and *Exserohilum turcicum*, causing *Turcicum* leaf blight. The genotype main effects and genotype x environment interaction effects (GGE) biplot analysis showed that Wad Medani in Sudan and Kabanyolo in Uganda were ideal sites for selecting for resistance to dual infection of anthracnose and *Turcicum* leaf blight as both sites had concomitant infection of both fungi. Combined analysis across multi-environment showed that cultivar Jesu 91-104DL, KARI mtama and Epuripuri had resistance to both pathogens across environments and were identified as new sources for dual diseases resistance to the two pathogens.

Key words: Anthracnose, dual resistance, genotype x environment interaction, Sorghum, *Turcicum* leaf blight

Résumé

L'absence des cultivars présentant des niveaux de résistance aux maladies justifie les moyens pour les recherches sur les génotypes présentant des gènes de résistance aux maladies dans les programmes de sélection du sorgho. Dans la présente étude, quatre expérimentations de terrain et deux en serre ont été conduites dans des régions productrices du sorgho au Soudan et en Ouganda pour évaluer la résistance au *Colletotrichum sublineolum* et *Exserohilum turcicum* causant respectivement l'anthracnose et la brûlure des feuilles. L'analyse bi-variée des effets génotypiques et d'interaction avec l'environnement a montré que Wad Medani au Soudan et Kabanyolo en Ouganda étaient des sites idéaux pour la sélection des génotypes résistants à une double infection de l'anthracnose et de la brûlure des feuilles. L'analyse combinée à travers plusieurs environnements a montré que le cultivar Jesu 91-104DL, KARI mtama et Epuripuri présentaient une résistance aux deux agents pathogènes et ont été identifiés comme de nouvelles sources de résistance aux deux pathologies.

Mots clés: Anthracnose, double résistance, interaction génotype x environnement, Sorgho, brûlure des feuilles

Background

Sorghum {*Sorghum bicolour* (L.) Moench (2n=2x=20)} is an ideal crop for the majority of resource poor farmers in the East and Sub-Saharan Africa (Kimber, 2000). The demand for sorghum implies that national sorghum programs need to increase and sustain high production levels. However, yield gap still remains large with grain yield declining by 1.0% annually (FAOSTAT, 2013). The fungal diseases, anthracnose and *Turcium* leaf blight (TLB), caused by *Colletotrichum sublineolum* and *Exserohilum turcicum,* respectively, are the most widespread causing major global threats to sorghum productivity (Reddy and Prasad, 2013). Deployment of varieties with dual resistant is the most cost effective way to manage both diseases which when integrated with appropriate agronomy, provide suitable protection levels. Unfortunately, most commercial varieties are mostly bred for either anthracnose (Tesso *et al*., 2012) or TLB (Reddy and Prasad, 2013) resistance. Indeed multiple disease resistance, a form of host resistance in which one locus or several loci may confer resistance to the different diseases has been reported (Ali *et al*., 2013) but there are very limited studies of such phenomena. Therefore, the objective of this study was to determine the reaction of sorghum lines to dual infection by *C. sublineolum* and *E. turcicum* in Sudan and Uganda.

Literature summary

Control of both diseases depend on the use of disease free seeds or seeds treated with chemicals and hot water, on a two to three year crop rotation when possible, use of resistant varieties and use of fungicides (Ramathani *et al.*, 2011). Most resistant varieties are developed for only one disease resistance (Beshir *et al*., 2012; Biruma *et al*., 2012; Martin *et al*., 2012). Both *C. sublineolum* (Dube *et al*., 2010) and *E. turcicum* (Ramathani *et al.*, 2011) can survive from season to season as mycelia, sclerotia or chlamydospores on infected crop debris or in the soil. Alternative hosts and volunteer crops may also provide sources of primary inoculum, and seed transmission has been reported for both *C. sublineolum* and *E. turcicum* (Ngugi *et al*., 2000). Conidia are heavily melanized and can be transmitted over long distances by wind (Ramathani *et al.*, 2011). Both diseases can cause extensive defoliation during grain filling period, resulting in grain yield losses of up to 50% or more (Ramathani *et al*., 2011; Biruma *et al*., 2012). On susceptible cultivars, losses may reach as high as 60% to 70% (Beshir *et al*., 2016).

The genotype x environment (GE) interaction that results from the differential responses of genotypes across a range of environments reduces the correlation between phenotypic and genotypic values and complicates the selection of the best genotypes (Ngugi *et al*., 2002). Thus, selection for TLB and anthracnose disease resistance should take GE interaction into consideration as well as relative to the magnitude of genotype and environment effects. Furthermore, the identification of genotypes that have less disease severity across a number of environments would be useful to breeders. Therefore, disease resistance research needs to be carried out over multiple environments in order to identify and analyze the major factors that are responsible for genotype adaptation (Beshir *et al*., 2012).

Study description

In Sudan, field experiments were conducted at Gezira Research Station in Wad Medani and Wad Elturabi during the rainy season of 2014 while in Uganda the study was conducted at Makerere University Agricultural Research Institute, Kabanyolo (MUARIK) in central Uganda and National Semi-Arid Resources Research Institute in Serere (eastern Uganda) during the rainy season of 2012. Greenhouse experiments were conducted at Wad Medani and MUARIK during the first rains of 2012 and the rainy season of 2014, respectively. Inoculum was prepared using single spore isolation following sporulation of *C. sublineolum* and *E. turcicum* from sorghum infected leaf lesions under aseptic conditions as described by Ramathani *et al*. (2011) and inoculation was done as described in Carson (1995). Fourteen cultivars were planted in the greenhouses and fields at MUARIK and Wad Medani during the first rains of 2012 and the rainy season of 2014, respectively. Cultivars were planted following a randomized complete block design. Due to the variation in diseases pressure all experiments in Uganda and greenhouse experiment at Wad Medani in Sudan were inoculated artificially while field experiments at Wad Medani and Wad Elturabi in Sudan were left for natural infection.

Disease assessments commenced and severities were recorded at weekly intervals from growth stage four till senescence as well as the Days to 50% flowering (Ramathani *et al*., 2011) across locations in Uganda and Sudan. Areas under disease progress curves (AUDPC) were computed using the weekly scores (Madden *et al*., 2007). All data were analysed using GenStat 12th Edition (VSN International Ltd., UK) and means were compared using LSD at $P<0.05$ (Steel and Torrie, 1997). The genotype main effects and genotype x environment interaction effects (GGE) were analysed and principal components (PC) 1 and 2 were calculated using breeding management systems (BMS) statistical package (Steel and Torrie, 1997).

Research findings

Reactions of sorghum cultivars to dual infection with *C. sublineolum* and *E. turcicum* are presented in Table 1. Sorghum cultivars exhibited significant ($P<0.05$) different reactions to both pathogens across locations. Both diseases had high severity environments. Sekedo had the lowest anthracnose severity and therefore, was considered resistant to anthracnose, while Arfa Gadamak had the highest severity and therefore was considered susceptible.

Table 1. Reactions of sorghum cultivars to *C. sublineolum* and *E. turcicum* at experimental sites in Uganda and Sudan

Cultivar	Anthracnose									*Turcicum* leaf blight									Days to 50% flowe-ring
	Severity at 40 days after inoculation					AUDPC[a]				Severity at 40 days after inoculation					AUDPC[a]				
	Uganda		Sudan			Uganda		Sudan		Uganda		Sudan			Uganda		Sudan		
	Green-house	Field	Green-house	Field		Green-house	Field	Green-house	Field	Green-house	Field	Green-house	Field		Green-house	Field	Green-house	Field	
Arfa Gadamak	8.0	25.0	15.0	20.0	MR	280.0	450.0	350.0	375.0	5.0	10.0	20.0	5.0	MR	154.9	150.0	273.3	150.0	54.4
Butana	5.4	12.8	6.8	0.0	MR	98.7	395.5	101.2	0.0	13.8	5.8	32.9	11.5	S	186.4	174.9	691.0	137.5	66.6
Epuripuri	7.0	10.2	1.7	10.0	R	77.1	322.3	40.8	241.7	5.0	5.5	22.5	4.3	MR	154.9	139.4	496.4	143.3	74.5
GA06/106	4.1	16.1	7.0	3.2	MR	42.4	386.4	124.0	87.5	5.6	6.2	32.4	23.3	MR	155.9	169.2	572.5	273.3	65.4
GA06/18	5.8	8.7	7.0	0.4	R	76.8	238.1	124.0	55.1	7.0	10.0	32.4	6.0	S	153.4	284.6	572.5	169.2	74.8
Gadam elhaman	4.9	12.8	15.1	8.3	MR	74.6	400.9	224.9	143.3	4.2	6.0	26.7	18.5	MR	146.0	185.5	511.0	227.5	68.6
HD1	3.6	10.9	5.3	12.0	R	89.7	327.9	131.3	165.0	7.5	6.2	37.2	5.0	S	161.6	154.7	672.8	150.0	66.4
Jesu 91-104DL	2.7	11.5	5.0	2.7	R	64.1	329.3	64.2	143.3	6.8	6.1	21.7	10.2	MR	178.1	206.4	539.6	215.8	72.6
KARI Mtama	10.2	13.0	13.3	5.0	MR	109.3	335.6	239.2	120.0	6.6	8.2	19.2	24.0	MR	170.0	243.7	347.1	425.0	71.0
MUC007/009	5.4	8.7	20.7	4.7	MR	82.3	263.6	337.8	100.5	5.3	10.2	26.7	20.0	MR	163.1	302.1	376.3	302.3	65.9
Sekedo	4.6	10.5	3.3	0.0	R	73.3	275.3	64.2	0.0	3.5	8.6	38.3	3.0	S	156.7	236.6	615.4	140.0	73.9
Tabat	6.6	13.3	7.3	4.3	MR	101.5	410.0	118.8	88.8	5.5	7.7	32.9	30.3	S	141.5	199.0	452.9	431.4	67.0
Wad Ahmad	8.6	11.6	1.7	18.5	MR	116.9	336.7	30.6	277.5	9.3	9.3	40.8	9.5	S	170.9	263.0	707.3	223.3	69.5
Yarwasha	2.0	10.0	5.0	7.5	R	58.1	279.0	122.5	112.5	4.9	9.2	38.3	20.0	S	125.9	309.0	672.6	425.0	63.7
SED (P<0.05)	2.5	2.8	16.6	21.7		23.6	1.0	212.4	156.2	2.9	2.7	30.5	85.1		18.2	79.7	430.6	68.8	7.9
LSD (P<0.05)	5.0	2.7	8.3	21.2		46.9	1.9	106.9	324.3	5.7	5.4	15.4	35.1		36.1	157.8	216.8	429.9	12.0

a = Area under disease progress curve. R = resistant (0-10%), MR = moderately resistant (10-25%) and S = susceptible (>25%)

Jesu 91-104DL had the lowest TLB severity with few lesions and therefore was considered resistant to TLB while Tabat had the highest severity with many lesions and therefore was considered susceptible. However, Arfa Gadamak had significantly ($P<0.05$) higher anthracnose and TLB severities indicating that this cultivar was susceptible to both diseases. Jesu 91-104DL and KARI mtama cultivars had significantly ($P<0.05$) low anthracnose and TLB severities were low in Jesu 91-104DL, KARI mtama and Epuripuri each indicating that the three cultivars were resistant to both diseases. Cultivars Wad Ahmed, Butana, HD1, Tabat, Yarwasha, GA06/18 and Sekedo showed low severities for TLB but had high severities for anthracnose indicating that these cultivars were resistant to TLB but susceptible to anthracnose.

Polygons of cultivars for anthracnose and TLB severities based on symmetrical scaling are presented in Figure 1 (a) and (b), respectively. Anthracnose polygons showed that MUARIK performed similarly to Wad Medani while Wad Elturabi performed similarly to NaSARRI. In terms of reactions to TLB, the polygons showed that MUARIK, Wad Elturabi and NaSARRI performed differently from Wad Medani. These results indicated that the locations in Uganda performed similarly while locations in Sudan performed differently. The results of the genotype main effects and genotype x environment interaction effects (GGE) showed that environments had high significant ($P<0.001$) influence on PC1 and PC2 for both diseases severities and across all locations indicating that the performance of the genotypes varied across environments.

The genotype main effects and genotype x environment interaction effects (GGE) biplot analysis was used to provide a focused dimension model that would indicate measured performance across environments among groups. Ahamadi *et al.* (2012) defined the ideal resistant genotype as the one showing the lowest disease severity and absolutely stable across test environments. Cultivar Jesu 91104DL showed the lowest anthracnose and TLB severities and was the most stable and therefore characterised as ideal genotypes for resistance to the two diseases. Large proportion of the total variation was explained by the first two principal components in all environments and also in the combined analysis. The reaction of sorghum genotypes to anthracnose and TLB varied across environments in Uganda and Sudan, while selecting for dual diseases resistance was equally effective across locations in Uganda but not in Sudan. This could be attributed to dominance of mating types of *E. turcicum* in Uganda (Ramathani *et al*., 2011) unlike Sudan where the dominant mating types are unknown. Efforts are needed to understand and determine the true economic impact of anthracnose and TLB resistance in sorghum.

Research application

Genetic materials identified in this research offering resistance to dual infection are useful germplasm that can be utilized in sorghum breeding programs in Uganda and Sudan.

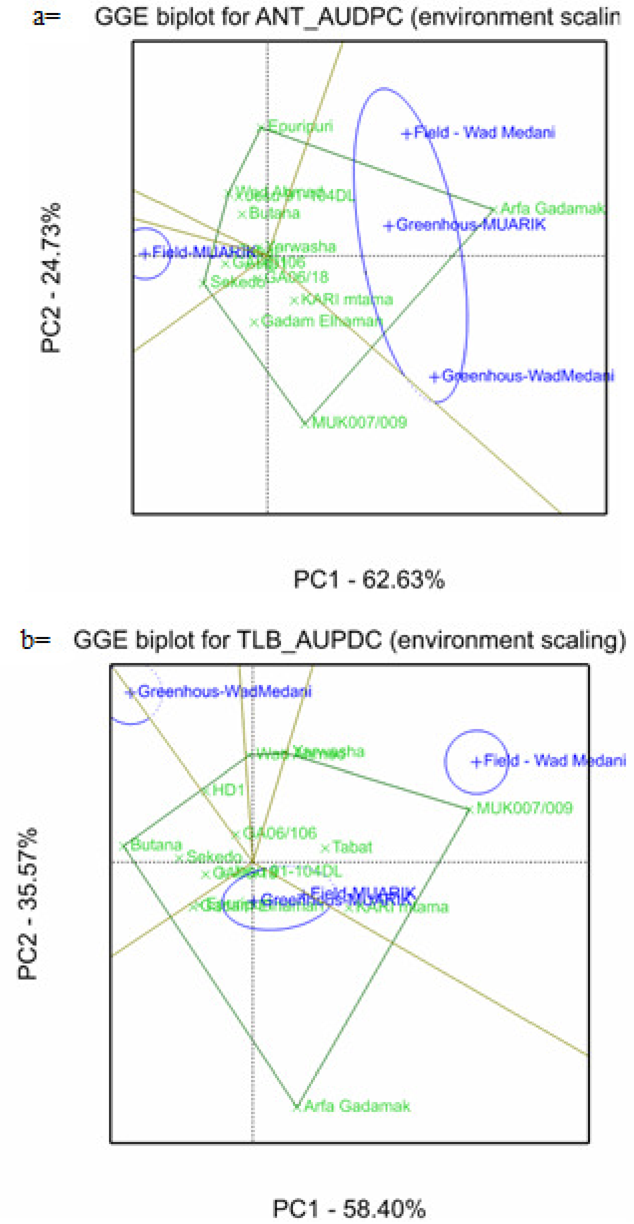

Figure 1. Polygon views of the GGE biplot analysis based on symmetrical scaling for genotypes and environments using area under disease progress curve (first rains of 2012 in Uganda and rains of 2014 in Sudan). PC = principal component

Recommendation

It is recommended that cultivars Jesu 91-104DL, KARI mtama and Epuripuri be used as new source for dual diseases resistance. Also Kabanyolo in Uganda and Wad Medani in Sudan should be considered as ideal sites for selection for dual resistance to anthracnose and TLB.

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References

Ahamadi, J., Vaezi, B. and Fotokian, M.H. 2012. Graphical analysis of multi-environment trials for barley yield using AMMI and GGE-biplot under rain-fed conditions. *Journal of Plant Physiology and Breeding* 2 (1):43-54.

Ali, F., Pan, Q., Chen, G., Zahid, K.R. and Yan, J. 2013. Evidence of multiple disease resistance (MDR) and implication of meta-analysis in marker assisted selection. *PLOS One* 8 (7):e68150.

Beshir, M.M. 2011. Development of molecular markers for introgression of resistance to turcicum leaf blight in sorghum. MSc dissertation, Makerere University, Kampala, Uganda pp. 26-50.

Beshir, M., Okori, P. and Ali, A.M. 2012. Inheritance of *Turcicum* leaf blight in Ugandan sorghum. *African Crop Science Journal* 20:155-162.

Beshir, M.M., Ali, A.M., Rubaihayo, P., Ahmed, N.E. and Okori, P. 2016. Simple sequence repeat markers associated with anthracnose and *Turcicum* leaf blight resistance in sorghum. *African Journal of Crop Science* 24 (1):97-107.

Biruma, M., Martin, T., Fridborg, I., Okori, P. and Dixelius, C. 2012. Two loci in sorghum with NB-LRR encoding genes confer resistance to *Colletotrichum sublineolum*. *Theoretical and Applied Genetics* 124:1005-1015.

Carson, M.L. 1995. A new gene in maize conferring the chlorotic halo reaction to infection by *Exserohilum turcicum*. *Plant Disease* 79:717-720.

Dube, S., Chifamba, O. and Mbanga, J. 2010. Effect of method of inoculation, moisture and seedling age on foliar anthracnose development in two varieties of *Sorghum bicolour* (Kadoma 332 and Marapansi). *Journal of Agronomy and Crop Science* 1: 12-18.

FAOSTAT. 2013. Food and agriculture organization of the United Nations, statistics division. online available at http://faostat3.fao.org.

Kimber, C.T. 2000. Origins of domesticated sorghum and its early diffusion to India and China. pp. 3-98. In: Smith et al. (Eds.) Sorghum: Origin, history, technology, and production. John Wiley and Sons, Inc., New York, USA.

Madden, L.V., Hughes, G. and van den Bosch, F. 2007. The study of plant disease epidemics. American Phytopathological Society. St. Paul Minnesota, USA.

Martin, T., Biruma, M., Fridborg, I., Okori, P. and Dixelius, C. 2011. A highly conserved NB-LRR encoding gene cluster effective against *Setosphaeria turcica* in sorghum. *BMC Plant Biology* 11:151.

Ngugi, H.K., Julian, A.M., King, S.B. and Peacocke, B.J. 2000. Epidemiology of sorghum anthracnose (*Colletotrichum sublineolum*) and leaf blight (*Exserohilum turcicum*) in Kenya. *Plant Pathology* 49:129-140.

Ramathani, I., Biruma, M., Martin, T., Dixelius, C. and Okori, P. 2011. Disease severity, incidence and races of *Setosphaeria turcica* on sorghum in Uganda. *European Journal of Plant Pathology* 131(3):383-392.

Reddy, T.R. and Prasad, V.R. 2013. *Turcicum* leaf blight: A review. *International Journal of Recent Scientific Research*. ISSN: 0976-3031.

Steel, R.G.D. and Torrie, J.H. 1997. Principles and procedures of statistics: a biometrical approach. McGraw-Hill, New York.

Tesso, T., Perumal, R., Little, C.R., Adeyanju, A., Radwan, G., Prom, L. and Magill, C. 2012. Sorghum pathology and biotechnology: A fungal disease perspective: Part 2. Anthracnose, stalk rot and downy mildew. *The European Journal of Plant Science and Biotechnology* 6 (1):31-44.