Genetic variation for post-anthesis drought resistance traits in grain sorghum

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Abstract

Stay-green, or delayed foliar senescence, is a key crop trait in combating post-anthesis drought. Sorghum genotypes with stay-green continue to fill their grain normally under water-limited conditions, exhibit increased resistance to charcoal rot and lodging, and contain more cytokinins and basal stem sugars than do senescent genotypes. Field studies were undertaken in north-eastern Australia on a cracking and self-mulching gray clay to assess seven indices of post-anthesis drought resistance: biomass production between anthesis and maturity, crop growth rate between anthesis and maturity, length of grain filling, rate of grain growth, grain size, rate of leaf senescence, and green leaf area at maturity. All of these indices are associated with stay-green. Four integrators of pre- and post-anthesis drought were also studied: biomass production at maturity, crop growth rate, grain yield, and harvest index. Sixteen hybrids varying in these traits were grown under a fully irrigated control, post-anthesis water deficit, and terminal (pre- and post-anthesis) water deficit (TD). Under TD, genetic variation was observed for five indices of post-anthesis drought resistance: biomass production between anthesis and maturity, crop growth rate between anthesis and maturity, length of the grain filling period, rate of grain growth, and grain size. Genetic variation was also observed in three integrators of pre- and post-anthesis drought resistance: crop growth rate, biomass at maturity, and grain yield. Genotype and water regime interacted in 4 of 7 indices of post-anthesis drought resistance: length of the grain filling period, grain size, rate of leaf senescence, and green leaf area at maturity. No genotype x water regime interaction was observed for the four integrators of pre- and post- anthesis drought resistance. Four of the indices of post-anthesis drought resistance were correlated phenotypically with grain yield under TD: post-anthesis biomass ($r=0.71^{***}$, N=16), crop growth rate between anthesis and maturity ($r=0.71^{***}$, N=16), rate of grain growth ($r=0.97^{***}$, N=16), and green leaf area at maturity ($r=0.51^{*}$, N=16).

Key Words

Sorghum bicolor, post-anthesis, stay-green, drought resistance traits

Introduction

Stay-green, or delayed foliar senescence, is a key trait in combating post-anthesis drought (1, 2, 3). Symptoms of susceptibility to post-anthesis drought include premature leaf and stem senescence, stalk collapse and lodging, charcoal rot (*Macrophomina phaseolina*) in the stalk, and reduced seed size (4, 5, 6).

In this paper, seven indices of post-anthesis drought resistance will be discussed: biomass production between anthesis and maturity, crop growth rate between anthesis and maturity, length of grain filling, rate of grain growth, grain size, rate of leaf senescence, and green leaf area at maturity. Four integrators of pre- and post-anthesis drought will also be discussed: biomass production at maturity, crop growth rate, grain yield, and harvest index.

This study had three objectives. First, to determine the extent of genetic variation in seven indices of post-anthesis drought resistance among 16 related sorghum hybrids. Second, to assess the contribution of male and female parents to hybrid performance for these indices under post-anthesis drought. Third, to determine the association between indices of post-anthesis drought resistance and grain yield under water-limiting conditions.

Methods

Experiment site

A field experiment was undertaken at Hermitage Research Station (altitude 480m, 28? 10'S, 152? 02'E) on the Darling Downs in Australia's northern grain belt during a wet season. The experiment design was a split plot with three replicates. Three irrigation treatments were applied to main plots and 16 hybrids varying in rate of leaf senescence were allocated to subplots. Main plots were 6 x 33.6 m, with a 2.1 m buffer zone between them, and subplots were 2.1 (3 rows) x 6 m. Replicates were separated by a 4 m roadway adjoining a 4 m cropped buffer zone.

Treatments

The water regimes treatments were No Deficit (ND), Post-Anthesis Deficit (PAD) and Terminal (pre-and post-anthesis) Deficit (TD).

Sixteen hybrids were examined from crosses of three males varying in the KS19 source of stay-green with various females varying in the B35 source of stay-green (Table 1). A35 is the male-sterile version of B35. The B35 and KS19 sources of stay-green are derived from sorghum lines native to Ethiopia and Nigeria, respectively.

Table 1: Sixteen hybrids varying in rate of leaf senescence were examined in this study and, based on previous field assessment, each hybrid was given a stay-green rating prior to the experiment.

Female parent	Senescence rating	Male parent	Senescence rating	Hybrid	Senescence rating
AQL39	Senescent	R69264	Senescent	AQL39/R69264	Senescent
72399-2-3-1	Intermediate	R69264	Senescent	72399-2-3-1/R69264	Intermediate/Senescent
72112-1-1-1	Intermediate	R69264	Senescent	72112-1-1-1/R69264	Intermediate/Senescent
87151-3-4	Intermediate	R69264	Senescent	87151-3-4/R69264	Intermediate/Senescent
AQL41	Intermediate	R69264	Senescent	AQL41/R69264	Intermediate/Senescent
A35	Stay-green	R69264	Senescent	A35/R69264	Stay-green/Senescent
AQL39	Senescent	RQL36	Intermediate	AQL39/RQL36	Senescent/Intermediate
72389-1-1-	Intermediate	RQL36	Intermediate	72389-1-1-	Intermediate

3				3/RQL36	
AQL41	Intermediate	RQL36	Intermediate	AQL41/RLQ36	Intermediate
AQL39	Senescent	RQL12	Stay-green	AQL39/RQL12	Senescent/Stay-green
72399-2-3-1	Intermediate	RQL12	Stay-green	72399-2-3-1/RQL12	Intermediate/Stay-green
72389-1-1-3	Intermediate	RQL12	Stay-green	72389-1-1-3/RQL12	Intermediate/Stay-green
72112-1-1-1	Intermediate	RQL12	Stay-green	72112-1-1-1/RQL12	Intermediate/Stay-green
87151-3-4	Intermediate	RQL12	Stay-green	87151-3-4/RQL12	Intermediate/Stay-green
AQL41	Intermediate	RQL12	Stay-green	AQL41/RQL12	Intermediate/Stay-green
A35	Stay-green	RQL12	Stay-green	A35/RQL12	Stay-green

Results and Discussion

Genetic variation was observed for five indices of post-anthesis drought resistance: biomass production between anthesis and maturity, crop growth rate between anthesis and maturity, length of the grain filling period, rate of grain growth, and grain size.

Two female parents containing the B35 source of stay-green, A35 and AQL41, contributed significantly (P<0.05) to post-anthesis drought resistance in this study, supporting earlier findings in the USA (5) and Australia (3, 7). The main effect of A35 across two males, and of AQL41 across three males, was high for post-anthesis biomass production, crop growth rate between anthesis and maturity, biomass at maturity, and grain yield.

Genetic variation was also observed in three integrators of pre- and post-anthesis drought resistance: crop growth rate, biomass at maturity, and grain yield. An analysis of the contribution of female and male parents to hybrid performance found that among the females, yield and biomass were higher (P<0.05) in A35 and AQL41 hybrids compared with hybrids derived from 3 of the other 4 females, and that among the males, biomass, crop growth rate and yield were higher (P<0.05) in R69264 hybrids compared with RQL12 hybrids, and biomass was higher in RQL36 and R69264 hybrids compared with RQL12 hybrids.

Genotype and water regime interacted (P<0.05) in 4 of 7 indices of post-anthesis drought resistance: length of the grain filling period, grain size, rate of leaf senescence, and green leaf area at maturity. No genotype x water regime interaction was observed for the four integrators of pre- and post- anthesis drought resistance: grain yield, biomass at maturity, crop growth rate, and harvest index.

Four of the seven indices of post-anthesis drought were correlated with grain yield under terminal deficit (Table 2): rate of grain growth (r=0.97***, N=16), post-anthesis biomass production (r=0.71***, N=16), crop growth rate between anthesis and maturity (r=0.71***, N=16), and green LAI at maturity (r=0.51*, N=16).

Table 2: Phenotypic correlations for a range of post-anthesis yield determinants grown under Terminal Water Deficit (N=16). Correlation significant at *P<0.05* (*), *P<0.01* (**), *P*<0.001 (***)

	Biomass (a-m)	Crop growth rate (a-m)	Length of grain filling	Rate of grain growth	Grain size	Rate of leaf senescence	Green LAI at maturity	Biomass at maturity	Harvest index	Grain yield
Biomass (a-m)	1.00									
Crop growth rate (a-m)	0.81***	1.00								
Length of grain filling	0.19	-0.20	1.00							
Rate of grain growth	0.66**	0.73***	-0.22	1.00						
Grain size	-0.15	-0.03	-0.13	0.28	1.00					
Rate of leaf senescence	-0.19	-0.13	-0.44	0.08	-0.07	1.00				
Green LAI at maturity	0.75***	0.81***	0.01	0.48*	0.01	-0.51*	1.00			
Biomass at maturity	0.79***	0.99***	0.30	0.77***	0.01	-0.05	0.77***	1.00		
Harvest index	0.31	0.15	0.29	0.71***	0.29	-0.04	0.05	0.15	1.00	
Grain yield	0.71***	0.71***	0.02	0.97***	0.26	-0.02	0.51*	0.71***	0.80***	1.00

(a-m) = anthesis to maturity interval

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