Stay-green wheat for Australia's changing, dry environment

Christopher JT[1], **Manschadi AM**[2], **Hammer GL**[3], **Borrell AK**[4]

[1]DPI&F LRC, P.O. Box 2282, Toowoomba, Q 4350, Australia. [2]Center for Development Research (ZEF), University of Bonn, Walter-Flex Str. 3 53113 Bonn, Germany. [3]University of Queensland, Brisbane, Q 4072, Australia. [4]DPI&F HRS, 604 Yangan Road, Warwick, Q 4370, Australia

INTRODUCTION

The stay-green phenotype has been successfully used to select for yield and yield stability of sorghum in the Australian northern cereal belt and shows promise for selection in wheat. CIMMYT wheat line SeriM82 exhibits a stay-green phenotype by maintaining green leaf area longer during the grain filling period than the current northern cultivar Hartog. The subtropical northern cereal belt of Australia is characterised by summer dominant rainfall and deep clay soils with high water holding capacity. Winter cereals are often reliant on stored soil moisture from the previous summer for much of the growing season and suffer some degree of terminal drought stress in the majority of seasons. The reliance of winter cereals in the northern region on stored soil moisture suggests that access to soil moisture and the timing of soil moisture extraction could be important factors contributing to the high yielding, stay-green phenotype of wheat genotype SeriM82.

We aimed to identify physiological and developmental traits that underlie the adaptive advantage of SeriM82. Shoot- and root-related traits were examined using a variety of experimental systems. These included field experiments with detailed monitoring and a range of root observation chambers that allowed roots to be examined at developmental stages from seedling to maturity.

MATERIALS AND METHODS

In order to maximise the chances of detecting small differences between genotypes, detailed field measurements were made in a number of seasons at a single site with a well characterised, common soil type and used a single conventional management strategy (1). Water availability was varied by use of natural rainfall variation, rain excluding shelters and irrigation. Flag leaf greenness was measured using a Minolta SPAD 502 which expresses leaf greenness in arbitrary units. Values of 55 to 65 units are typical of new leaves while those with values below 10 are fully senesced.

Small gel-filled chambers were used to characterise the number and angle of seedling roots of 8 day old wheat seedlings. Soil-filled chambers with glass observation panels were used to characterise root systems of plants at various stages from tillering to maturity using digital imaging of roots and destructive sampling. Methods for root chamber experiments are described in detail elsewhere (2, 3).

RESULTS AND DISCUSSION

Yield of SeriM82 ranged from 6 to 28% greater than Hartog in 6 environments with differing moisture availability in the field (Table 1). The yield difference was greatest in the irrigated treatment of 2003 and was lower where rain was excluded using rainout shelters post anthesis. Significant differences were also observed in rain-fed environments in 2004 with a severe terminal drought and in 2005 where terminal drought was alleviated by natural rainfall events during the mid and late grain filling period. The yield difference was lowest in 2006 when soil moisture prior to sowing had been depleted by a previous summer crop (Table 1). SeriM82 exhibited a stay-green phenotype in most environments where yield was significantly greater than Hartog as indicated by its ability to maintain leaf greenness in the flag leaf for longer after anthesis (Figure 1). However, where the availability of deep soil moisture was limited in 2006, SeriM82 failed to exhibit significantly greater yield or to express the stay-green phenotype (Table 1; Figure 2). SeriM82 also failed to exhibit stay-green or a yield advantage in some root observation chamber experiments where soil moisture was fully extracted shortly after anthesis (data not shown). Thus, the availability of deep soil moisture late in the season was important for expression of the high-yielding, stay-green phenotype.

Table 1. Yield in Kingsthorpe field trials

Year	Treatment	Yield (g/m^2)		
		Hartog	Seri	Diff. (%)
2003	Irrigated	610	780	28*
	Rain excluded post anthesis	260	320	14*
2004	Rain-fed	390	460	18*
2005	Rain-fed	280	340	20*
2006	Profile moisture depleted at sowing	207	219	6

*Values significantly different ($P < 0.05$)

SeriM82 and Hartog differed in root architectural traits. In large soil-filled chambers where single plants were grown to maturity, SeriM82 had a narrower root system and extracted more soil moisture per soil volume, particularly deep in the profile and late in the growing season (3). In the computer simulation model APSIM, parameters were modified to generate a hypothetical genotype with similar differences in water extraction compared to Hartog to those observed in SeriM82.

Simulation modelling of this "root modified" genotype predicted that it would perform better than Hartog in a majority of seasons. It was further demonstrated that the marginal water use efficiency of extra soil moisture that becomes available post anthesis is nearly three times higher than that calculated over the whole growing season (3). Thus, small amounts of additional moisture extracted post anthesis can lead to relatively large differences in grain yield.

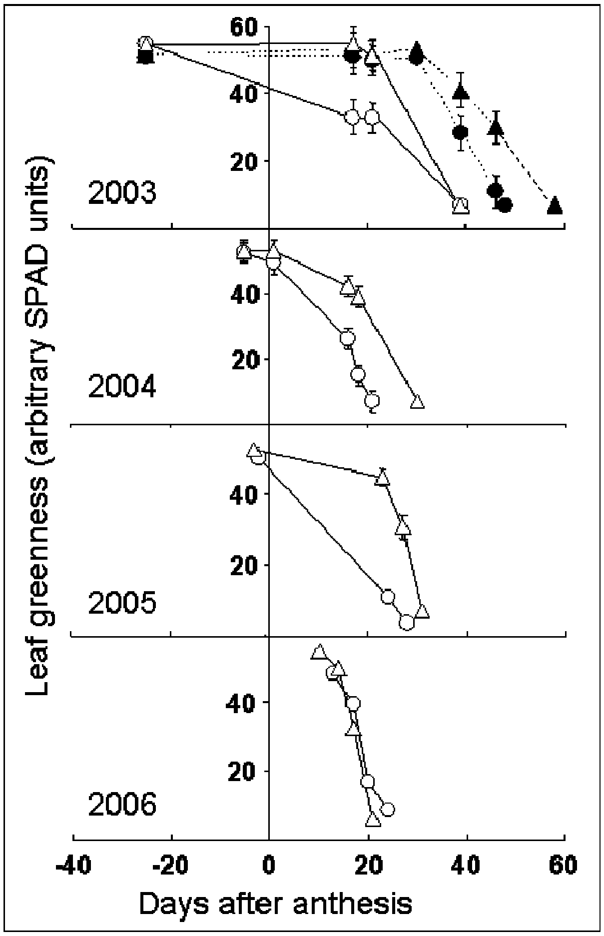

Figure 1. Flag leaf greenness measured using a Minolta SPAD 502 expressed in arbitrary SPAD units for Hartog (circles) and SeriM82 (triangles) in the field at Kingsthorpe. Filled symbols in 2003 represent the irrigated treatment. Error bars represent the standard error of means except for 2006 data which is for a single plot.

In small gel-filled chambers, SeriM82 exhibited a more vertical seedling seminal root angle indicating that seminal root angle is closely related to the vertical root distribution of mature plants (2). SeriM82 had narrower seminal root angle and narrower maximum lateral root distribution than Hartog. Gel-filled chambers provided a rapid and effective method of screening for seminal root angle. This screening technique is suitable for screening large numbers of genotypes in genetic mapping studies aimed at identifying the genetic regions controlling root angle.

CONCLUSION

We postulate that SeriM82 is able to extract a small amount of extra soil moisture from deep in the profile late in the season. The stay-green phenotype of SeriM82 involving a narrower root system would be expected to confer a yield advantage in areas where moisture is available in deep non-constrained soils as occur commonly in the Australian northern cereal belt. However wider angled, shallower root systems might prove advantageous where deep soil moisture is unavailable and where plants rely on smaller, in season rainfall events. In addition to seminal root angle, a number of shoot- and root- related traits are likely to be involved in the expression of the high-yielding, stay-green phenotype in SeriM82.

REFERENCES

1. Christopher JT, Manschadi AM, Hammer GL, and Borrell AK (2008) Australian Journal of Agricultural Research **59**: 354-364.
2. Manschadi AM, Hammer GL, Christopher JT, and DeVoil P (2008) Plant and Soil **303**:115-129.
3. Manschadi AM, Christopher JT, Peter deVoil P, Graeme L Hammer GL (2006) Functional Plant Biology **33**:823-837