The Environmental Drivers of Wheat Screenings Loss and Low Hectolitre Weight in the Southern and Western Australian Production System

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Abstract

As a key determinant of gross return and therefore on-farm profitability, receival characteristics such as screening loss (ScrnL) and low hectolitre weight (LoHLW) are an important target for manipulation through both breeding and agronomic improvement. A desktop study using 2008 to 2010 National Variety Trial data from Western Australia, South Australia and Victoria has confirmed that some regions, such as Agzone 1 in WA, the Upper Eyre Peninsula in SA and the Wimmera in Victoria, are more likely to suffer from ScrnL than others such as Agzone 6 in WA and North East/Central regions of Victoria. Over the three years of the study, LoHLW appeared to be more consistently related to the region, with Agzone 1 suffering the lowest HLW. Although both ScrnL and HLW were affected by in season rainfall, radiation and temperature, high temperatures had the biggest effects on ScrnL and rainfall on HLW. The impact of heat on physical grain quality may have been perpetrated through increased evaporation and therefore a drop in plant available water, or directly through cellular heat stress. Varieties with a genetic predisposition to either LoHLW or high screenings loss were more affected by stressful growing conditions than their superior physical grain quality counter parts.

Introduction

Within the context of a Mediterranean environment and poor soils, southern and western Australian farmers are often faced with the prospect of reduced crop value through poor physical grain quality. Consequently, growers have adopted agronomic strategies that reduce the likelihood of downgrading at receival through high screenings loss (ScrnL) or low hectolitre weight (LoHLW). Adjusting seeding rate, timing and quantity of fertiliser application and sowing rate along with variety selection are all strategies that can be used to reduce ScrnL and maximize HLW.

Although selection of varieties with large grain and good packing density is a successful risk minimisation strategy, this is not always feasible. At times, for other unrelated reasons (ie. disease resistance, quality classification, yield performance), varieties with poorer physical grain quality are selected by growers. Additionally, it is likely that the minimum receival standards for HLW will increase from 74kg/hl to 76kg/hl in the near future, increasing the frequency of downgrading at point of delivery. Consequently, whilst the development of varieties with improved HLW and ScrnL is paramount, there is also a need to better understand the environmental drivers and regional risks of growing varieties with a propensity for lower HLW or higher ScrnL.

Approach

The desktop study was performed using physical grain quality data (screenings over a 2mm sieve and HLW) from the 2008 to 2010 National Variety Trials (NVT) in Western Australia, South Australia and Victoria (kindly supplied by Neale Sutton). Environmental characterisation data (derived from Bureau of Meteorology records) for each trial was sourced and calculated by Bangyou Zheng and Scott Chapman (CSIRO Plant Industry, St. Lucia).

The dataset

NVT results from the 2008 to 2010 seasons in WA, SA and Vic known or determined (from probe genotype performance) to be affected by severe rust infection were removed from the dataset prior to further analysis. In total 258 site-year combinations were used to investigate the environmental impacts on ScrnL, and 253 for HLW. Each environment was classified with respect to rainfall, temperature and radiation related variables (Table 1) during the vegetative, flowering, grain fill and ripening stages of growth. The average ScrnL and HLW for a set of probe genotypes were also calculated for each trial (Table 2).

The impact of poor physical grain quality

Grain size and shape related defects can be devastating to farm profitability. Slipping from AH1 to AUH or GP over the last three years cost growers an average $42/t and $71/t respectively. With cliff face pricing, this may have occurred simply because a load of wheat had 6% rather than 5% screenings, or a hectolitre of 73 kg/hl rather than 74 kg/hl. In real terms, this represents a 24% reduction in income for a single unit change in grains size/shape. Those of us not directly affected can only imagine the impact this has on growers psychologically, let alone economically.

Table 1. A description of the environmental variables used to assess the impact of growing environment on physical grain quality.

Environmental Variable	Description
avgt	average temperature
sumtt	sum of the thermal time
avgmint	average minimum temperature
avgmaxt	average maximum temperature
sumrain	sum of the rainfall
avgevap	average evaporation
avgradn	average solar radiation
sumradn	sum of the radiation
hotdays	number of hot days (>30°c)
veryhotdays	number of very hot days (>35°c)
frostdays	number of frost days (=<0°c)
vpd	vapour pressure deficit
biowater	water limited potential biomass production
biott	biomass per unit thermal time
bioradn	radiation limited potential biomass production
ptq	photo-thermal quotient
avdiffuseradn	average diffused radiation

Table 2. A description of the physical grain quality attributes assessed for each of the NVT sites.

Environmental Variable	Description
HLW	The average hectolitre weight of varieties in the trial
LoHLW	The average hectolitre weight of varieties with a known propensity for low hectolitre weight (Axe$^{\phi}$, Correll$^{\phi}$, Espada$^{\phi}$, Gladius$^{\phi}$, Westonia)
HiHLW	The average hectolitre weight of varieties with a known propensity for high hectolitre weight (AGT Katana$^{\phi}$, Frame, Wyalkatchem$^{\phi}$, Yitpi$^{\phi}$)
ScrnL	The average screenings loss of varieties in the trial
LoScrnL	The average screenings loss of varieties with a known propensity for low screenings loss (Frame, Yitpi$^{\phi}$, Wyalkatchem$^{\phi}$)
Cre1ScrnL	The average screenings loss of varieties that carry Cre1 (a CCN resistance gene linked to small grain)* (Annuello$^{\phi}$, Bullet, Derrimut$^{\phi}$, Guardian$^{\phi}$, Peak$^{\phi}$)
JnzScrnL	The average screenings loss of varieties with small grain derived from Janz* (Janz, CF JNZ$^{\phi}$, Carinya$^{\phi}$)

*due to an unbalanced dataset for these PGQ attributes, WA was excluded from the regional analysis

The analysis

This study proceeded through four steps, using the linear regression or REML functions in Genstat:

1. The impact of state, region, year, state-by-year and region-by-year on each of the physical grain quality (PGQ) attributes was determined.

2. Each of the environmental variables (EVs) were assessed independently for their impact on the PGQ attributes at each of the four growth stages.

3. A multiple linear regression was used to determine the combined impact of the EVs on the PGQ attributes at each of the four growth stages.

4. The differential response of the HLW and ScrnL genotype groups to EVs was assessed using REML.

Outcomes of the study

Regional risks of growing varieties with poor physical grain quality

As one may expect, PGQ was affected by both regional and seasonal variation in growing conditions. For HLW, NVT region had the single largest effect (23% of between trial variation), and the year effect was the smallest (3.1% of between trial variation). The relative importance of the sources of variation was similar for the three HLW groups (HLW, LoHLW and HiHLW), suggesting that the drivers of HLW are likely to be similar regardless of the variety being grown (Table 3). A similar observation was made for the ScrnL groups, although region did not explain as much of the variation between sites for the Janz related lines as for the other ScrnL groups. The role of region in determining ScrnL was lower than for HLW. This suggests that although there is a large unpredictable component to HLW and ScrnL due to year and year interaction effects, selecting low ScrnL and high HLW lines will be more important in some cropping regions.

Over the three years of this study, WA Agzone1 achieved the lowest average HLW and second highest ScrnL (Table 4). Interestingly, the Upper Eyre Peninsula in SA achieved the highest average HLW, but suffered from a relatively high level ScrnL. Overall, the environmental correlation between HLW and ScrnL was 12%, indicating that although they respond to some similar environmental variables, they need to be considered as independent PGQ attributes.

Of particular interest in this study, is the response of genotypes with known PGQ problems. We asked the question: do these lines respond to environmental

Table 3. The percentage of variation between trials accounted for by the five different spatial-temporal terms.

Model	HLW	LoHLW	HiHLW	ScrnL	LoScrnL	Cre1ScrnL	JnzScrnL
year	3.1	2.6	3.8	3.0	5.1	4.1	3.5
region	23.2	22.1	20.9	13.5	12.9	13.7	4.5
state	8.4	7.7	6.7	0.0	0.0	0.5	1.1
year.region	29.1	30.2	27.2	21.8	20.3	21.9	18.2
year.state	6.3	6.4	4.5	5.5	2.2	5.4	5.8

Table 4. The average HLW and ScrnL performance at NVT regions in WA, SA and Vic from 2008 to 2010.

State	Region	HLW	ScrnL
WA	Agzone1	73.2	8.1
WA	Agzone2	76.2	4.4
WA	Agzone3	75.8	2.7
WA	Agzone4	74.2	8.4
WA	Agzone5	76.2	2.5
WA	Agzone6	74.2	2.0
SA	Lower EP	79.3	2.4
SA	Mallee	78.5	1.5
SA	Mid North	76.7	2.9
SA	South East	76.4	4.4
SA	Upper Eyre Peninsula	79.3	4.1
SA	Yorke Peninsula	78.6	2.1
Vic	Murray Mallee	77.7	4.5
Vic	North Central	75.6	1.5
Vic	North East	75.4	1.5
Vic	Wimmera	73.5	5.6

stresses differently than lines known to be superior for PGQ? Figures 1-3 show that for both HLW and ScrnL, lines with poor PGQ are likely to be relatively worse than their superior PGQ counterparts at sites where average PGQ is poor. In other words, where ScrnL is already high, varieties carrying the Cre1 gene suffered their worst relative ScrnL (Figure 2). This GxE pattern is often described as a scale effect, but highlights for growers that the importance of variety selection is not linear. The relationship for HLW (Figure 1) was not as strong as that observed for ScrnL (Figures 2 & 3). Although LoHLW lines performed relatively worse at sites where the average HLW was low, other factors appear to be acting on these lines as compared to their higher HLW counterparts.

Environmental variables exert their influence on physical grain quality over the whole wheat life cycle

Significant relationships were observed between PGQ and temperature, light and rainfall related EVs at each of the four growth stages. When included in a multiple linear regression model, significant EVs during grain fill explained nearly 30% of the variance between sites for ScrnL (Figure 4).

In a Mediterranean environment where yield potential, established during wet winters, is rarely met during dry springs, it is not surprising that the conditions during grain fill are critical to determining grain size and therefore ScrnL. Interestingly, it is not rainfall that drove ScrnL during grain fill in this dataset; it was the number of hot days experienced at each site, vapour pressure deficit and diffuse radiation. For every day over 30°C during grain fill, the proportion of grain less than 2mm increased by 0.6%. So the difference between making AH and GP could be

Figure 1. The relationship between site HLW achievement and the relative performance of HiHLW and LoHLW genotypes

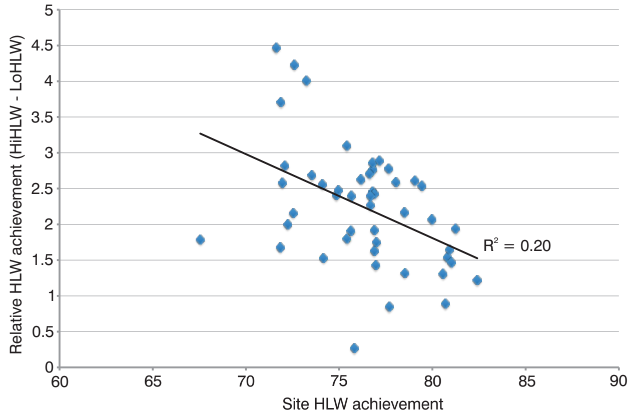


Figure 2. The relationship between site ScrnL and the relative performance of LoScrnL and Cre1ScrnL genotypes

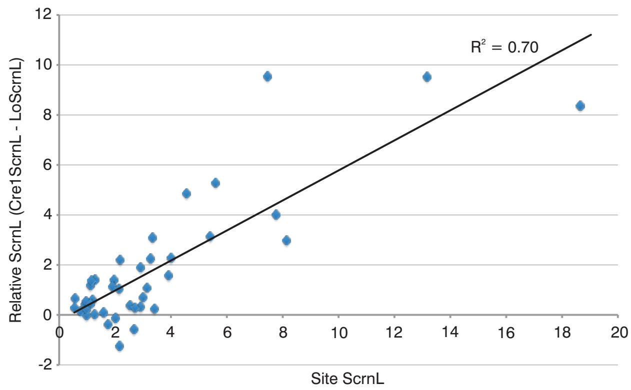
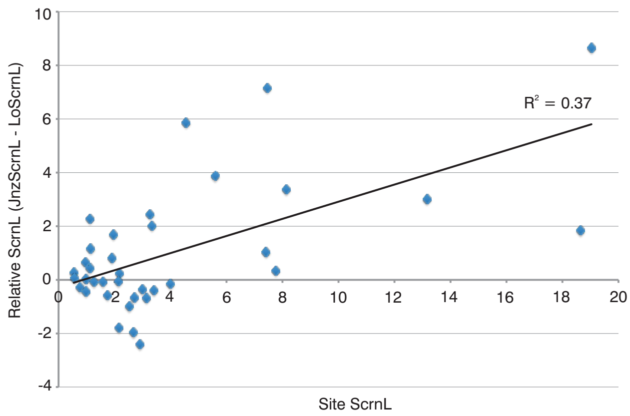


Figure 3. The relationship between site ScrnL and the relative performance of LoScrnL and JnzScrnL genotypes



two hot days! Although the effect of the rainfall related EVs during each growth stage was less than the temperature related terms, more than 11% of the difference between ScrnL at sites could be explained by the ratio between reproductive and vegetative rainfall. When vegetative (corresponding approximately to winter) rainfall is proportionally greater than reproductive (spring) rainfall, the ScrnL at a site increases.

The story for HLW was similar to ScrnL. However, grain ripening was the most critical stage for the relationship between EVs and site HLW performance. In the multiple linear regression model average evaporation and the sum of the thermal time explained over 20% of the variation observed for HLW between sites. According to the simple linear regression models the number of hot days experienced at a site over flowering actually increased HLW, whereas the same EV over ripening led to a slight decrease in HLW.

Varieties with higher inherent screenings loss have a larger response to environmental variables

A comparison of the responses of the subgroups for ScrnL showed that genotypes derived from Janz, or genotypes with Cre1 had a much greater response to the level of evaporation at a site during grain fill (Figure 5).

During flowering the Cre1 genotypes also suffered a greater increase in ScrnL than the LoScrnL and JanzScrnL groups as the average maximum temperature increased. During the vegetative and ripening growth stages, there was no difference in the response of the genotypic subgroups. For HLW there were no significant differences in the response of the LoHLW and HiHLW groups to the EVs.

Figure 4. The contribution of environmental variables to HLW and ScrnL during the wheat life cycle.

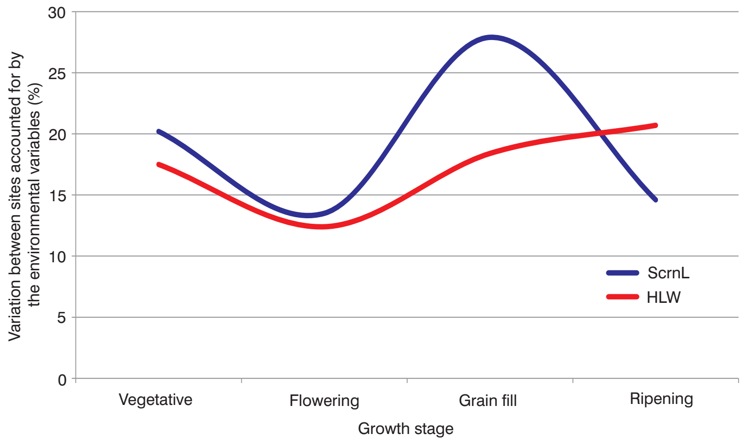
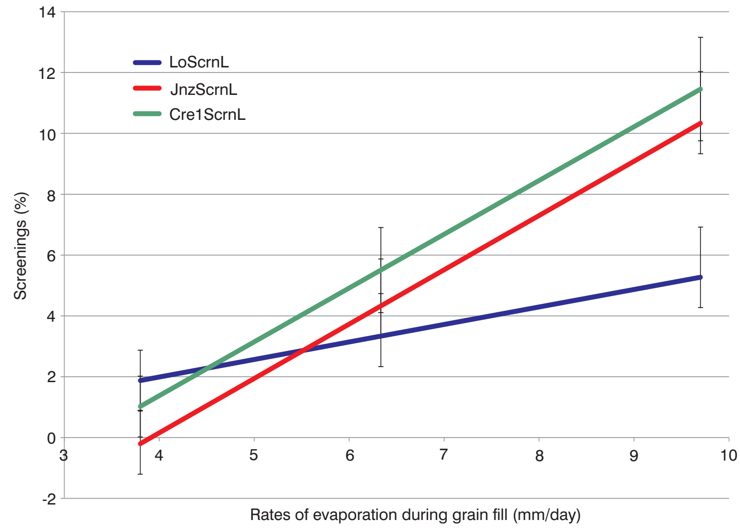


Figure 5. The differential response of genotypes to evaporation rates during grain fill.



Some take home messages

- Small changes in the inherent PGQ of a wheat variety can have big impact on on-farm profitability.
- Not surprisingly, growing conditions during grain fill have the largest impact on PGQ, although the impacts of these conditions on PGQ are not the same for all wheat varieties.
- The largest driver of ScrnL during grain fill was the number of hot days (>30°C).
- Some regions are more prone to down grading through screenings loss or low hectolitre weight. In particular Agzones 1, 2 and 4 in WA and intriguingly the South East of SA and Victorian Wimmera suffer from either elevated screenings loss or low hectolitre weight.
- At sites where HLW is low, the difference between high and low HLW wheat varieties is greatest; increasing the relative risk of growing a variety with inherently low HLW achievement.
- Varieties derived from Janz, and those carrying the Cre1 CCN resistance gene, had a greater negative response to high evaporation rates during grain fill than varieties with inherently low screenings loss.

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