Grain size distribution: computation, interpretation and utilisation for minimising small grain screenings in cereals

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Abstract

Small grain screenings, grain narrower than 2 mm, is a major constraint to profits from rainfed wheat and barley crops grown in Australia and overseas. Drying and warming climate as predicted for most parts of WA wheatbelt is likely to further increase this risk. Screenings for a variety can be higher for any one of three reasons; inadequate average grain weight, faulty grain shape and grain position effects due to asynchronous kernel growth. Kernel weight, the traditionally used parameter for classifying cultivars has often failed and we have previously proposed the use of the Grain Size Distribution (GSD) for overcoming this limitation. We now have developed functions in the R Statistical System ready for placing in public domain that cereal breeders and agronomists can use. The new set of scripts is usable irrespective of whether the distribution data was collected using a physically grading machine such as Sortimat or an electronically measuring machine such as Single Kernel Characterisation Systems (SKCS). In this paper, we will demonstrate i) how these functions can be used to calculate the parameters of the GSD; ii) how the GSD can be used to separately capture the defects of size, shape and position of kernels; iii) the strategies that breeders can use from the resulting information for screening breeding material; and iv) strategies on how agronomists and farmers can use the GSD parameters for matching inputs and crop management levels of new varieties in order to minimise the risk of small grain screenings.

Key Words

Screenings, wheat, grain size, cereals, grain size distribution, rainfed agriculture, seasonal conditions

Introduction

Cereal grain narrower than certain width (2.0 mm for wheat) is called screenings and its percentage (by weight) in the delivered lot is a major determinant of price that a grower would get (The Malsters Association of Great Britain 2006, Department of Agriculture and Food 2007, CBH 2011). Demonstrating a reduction in screenings level has been recommended as one of the three targets for export quality wheat in a recent stakeholders analysis (Quail et al 2011). Also, the Climate is drying and warming in most parts of Western Australian wheatbelt and both these factors lead to high screenings (Sharma and Anderson 2004). As such, an important aim of cereal breeders, agronomists and farmers is to minimise the level of screenings in their crops.

Low grain weight, faulty grain shape and grain position effect leading to heterogeneity of grain size are the known causes of small grain screenings but capturing these effects separately and acting accordingly has always been a challenge given that their genetic control and agronomic management implications are different. We have previously proposed the use of grain size distribution (GSD) for this purpose (Sharma et al 2006, 2009) but its use has been limited for the want of adequate details on computation of parameters and their interpretation for utilisation by breeders, consultants and farmers. Also, the calculation protocols needed to be extended to include data from single kernel characterisation systems (SKCS) common with most plant breeding labs in Australia; however, this information has not been placed in public domain. Therefore, objectives of this paper comprise: i) demonstration of the protocols to calculate parameters of the GSD; ii) tabulate parameter combinations to separately capture the defects of size, shape and position of kernels; iii) suggesting strategies that breeders can use from the resulting information for screening breeding material; and iv) suggesting how agronomists and farmers can use the GSD parameters for matching inputs and crop management levels in order to curtail the risk of small grain screenings.

The technique

Mathematical details and relationship of GSD parameters with small grain screenings was published earlier (Sharma et al 2006, 2009). Low levels of the parameters μ and $1/\alpha$ indicate high screenings.

Computation: protocols for calculation of the parameters of GSD

The latest version of the R functions, notes and examples can be downloaded from the biometrics page on Department of Agriculture and Food Western Australia website (http://www.agric.wa.gov.au/biometrics/gsd). There are two parts to the download. Read the 'readme.gsd.txt' file for instructions. The notes below assume that you have a Windows platform. The functions should also work on MacOSX and Linux platforms and will be provided in the future version.

1. Installation of R and the R functions

Follow the instructions in the WORD files provided in the distribution.

2. Running GSD

There are two sub-folders: i) SORTIMAT and ii) SKCS; depending what type of machine was used to collect data on the grains.

Open the appropriate folder and read the WORD file located inside your chosen folder and follow the instructions. If you are already familiar with the program, simply double click the respective batch file ('sortimat.bat' or 'skcs.bat'). There is a provision to change the number and width of screens used for sorting grains. Output will appear in the respective output folder.

Interpretation: capturing the three causes of screenings

Combination of GSD parameters and average kernel weight when used together can distinguish the three causes of high screenings. Low values of μ and $1/\alpha$ without a low average kernel weight indicate defects of grain shape and grain position respectively; while a combination of low kernel weight along with a low μ leaves imply low kernel weight as possible defect.

Utilisation: strategies for breeding and agronomy work

A risk assessment matrix based on combination of GSD parameters and mean kernel weight is shown in Figure 1.

		Kernel weight= High			Kernel weight= Medium			Kernel weight= Low		
μ	*Low*	Med-Low	Moderate	Med-High	Moderate	Med-High	High	Med-High	High	Extreme
	Medium	Low	Med-Low	Moderate	Med-Low	Moderate	Med-High	Moderate	Med-High	High
	High	Very low	Low	Med-Low	Low	Med-Low	Moderate	Med-Low	Moderate	Med-High
		High	***Medium***	***Low***	***High***	***Medium***	***Low***	***High***	***Medium***	***Low***
		$1/\alpha$			**$1/\alpha$**			**$1/\alpha$**		

Extreme	Almost sure to produce some screenings even under soft conditions
High	Highly likely to produce screenings with even a slight stress
Med-High	Likely to produce screenings under moderate environments
Moderate	Likely to produce moderate level under tight conditions
Med-Low	Less likely to produce screenings under moderate conditions
Low	Highly unlikely to produce screenings under most environments
Very low	Almost sure to be tolerant to tight finishing conditions

Figure 1. Risk categories depending values of GSD parameters and mean kernel weight

Depending upon the eight possible combinations resulting from low and high values of mean kernel weight, μ and 1/α, site and seasonal conditions and risk aversion attitude of individuals, strategies for selecting breeding material and managing cultivars can be devised. Based on previously published work (for example, Sharma and Anderson 2004), some suggestions as applicable to variety development and variety specific crop management aspects are given in Table 1.

As a guideline, it is suggested that varieties with one of the three defects may be released but variety brochure should include recommendations on managing crops of such cultivars while those with two defects should not be targeted in the marginal areas. Managing varieties with inefficient grain position can be managed by optimising seed rate and nitrogen fertiliser rates while low kernel weight may be managed though optimising sink size and time of sowing.

Table 1 Suggested strategies to minimise the risk of screenings according to parameters of GSD and mean kernel weight

Parameter			Grain			Possible solution	
μ	**Mean Kernel weight**	**1/α**	**Shape**	**Position**	**Size**	**Variety development**	**Crop management**
High	Low	Low	Very efficient	Problem	Sub-optimal	Avoid targetting in marginal areas. Grain shape may not be enough to offset risks posed by small grain and asynchrony	Build yield potential on seed rate rather than on extra nitrogen; Avoid late sowing
		High	Very efficient	OK	Sub-optimal	Take advantage of good grain shape to offset risk posed by small grain	Normal management should be fine
	High	Low	OK	Problem	OK	Variety brochure to include agronomic advice on restricting excessive tillering, spike and spikelet size	Build yield potential on seed rate rather than on extra nitrogen.
		High	OK	OK	OK	No problem	Can afford to make mistakes
Low	Low	Low	OK?	Problem	Sub-optimal	Do not target in marginal areas. Errors in input management can significanty exaggerate penalty due to small grain	Avoid recommending this variety
		High	OK	OK	Sub-optimal	Variety brochure to include agronomic advice on risks of delayed sowing	Avoid late sowing
	High	Low	Inefficient	Problem	OK	Do not target in marginal areas. Errors in input management can significanty exaggerate disadvantage due to grain shape	Recommend this variety only if you must; Build yield potential on seed rate rather than extra nitrogen
		High	Inefficient	OK	OK	Variety brochure to include agronomic advice on risks of delayed sowing. High kernel weight advantage is negated by inefficient grain shape	Avoid late sowing

Conclusion

Statistical protocols for computing parameters of GSD are now available irrespective of the machine used for recording grains size data. While most agronomy labs are generally equipped with a sortimat machine fitted with 3-4 sieves, plant breeding labs tend to use data obtained using SKCS machines. This ability to more clearly relate screenings propensity of a genetic stock with kernel weight, grain position and grain shape opens the possibility of targeting cultivars to suitable environments and more effectively curtailing the risk of high screenings.

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