The effects of wheat seed quality are greatest in high yielding environments

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Abstract
The size and composition of seed varies considerable between sites and seasons and it is often suggested that plump seed with a high nutrient concentration will benefit yield. There have been few field experiments that have examined this idea critically. Experiments were conducted over three years at low and medium rainfall sites in South Australia to examine the relative effects of seed source and seed size on yield. Seed was selected from National Variety Trials (NVT) sites based on differences in grain nutrient concentrations and graded into two or three size categories. Grain nutrient concentrations varied considerably between sites and grading the seed did not influence seed nutrient concentrations. Seed source influenced yield in only two of the eight experiments and the effects of seed source varied with variety. The effect on yield varied from about 4% up to 28%. Seed P concentration was the nutrient most commonly associated with yield variation. Using large seed improved crop establishment and crop vigour but yield benefits of large seed were only achieved at higher yielding sites where the benefit was about 5%. When grain yields were less that 2 – 2.5 t/ha, there was no yield benefit from using large seed and in one instance yields were reduced. The results suggest that seed size has a smaller, but more consistent effect on yield compared to seed source, and the effects of seed source varied with variety. The benefits from improved seed quality were only achieved at sites where yields were higher than approximately 3 t/ha.

Keywords
Grain nutrients, seed size, seed source.

Introduction
Rapid germination and good crop establishment provide an important foundation for high crop yield and water use efficiency. In general terms, high quality seed can improve establishment and produce more vigorous seedlings (Richards and Lukacs 2002; Sharma and Anderson 2003) and this may increase yield, but the effect may be seasonally-dependent (Bolland and Baker 1990; Burnett et al. 1997). The effect of high seed nutrient concentration is potentially of greatest value on soils that have a low concentration of available nutrients (Yilmaz et al. 1998). As well as seed nutrient concentration, the temperature during seed development may affect seedling vigour (Grass and Burris 1995).

Seed size can also influence germination and seedling vigour. Seed size and seed nutrient concentration may not be completely independent. Large seeds may contain higher concentrations of some mineral nutrients and protein, and high seed protein concentration is frequently associated with higher concentrations of Zn and Fe. Much of the work on seed quality has focussed in seedling vigour and there have been few studies on the effect of seed composition and seed size on yield over different sites and seasons.

Methods
Field experiments were conducted between 2012 and 2014. Seed from National Variety Trials (NVT) sites from SA were used as the source of seed. Initially a sample of ‘Mace’ seed from a number of NVT sites was analysed for grain nutrient concentration and protein and these results were used to select the seed sources for the year’s work. Seven sites were selected in 2012 and five sites were used in 2013 and 2014. The seed from selected site was graded into two sizes (> 2.8 mm and 2.5 – 2.8 mm) in 2012 and 2013 and three sizes (2.2 – 2.5, 2.5 – 2.8 and > 2.8 mm) in 2014. The protein concentration and grain nutrient concentration was measured for each size class. Between three and seven varieties were grown in the experiments. The trials were grown at Minnipa and Turretfield (2012 – 2014) and Karoonda (2013 – 2014). Each experiment was designed as a split-plot, with the seed source and variety as whole plots and seed size as subplots, and with 3 or 4 replicates. In a separate experiment, seed of ‘Mace’ wheat was graded into two size classes (2.5 – 2.8 mm and > 2.8 mm) and, along with an ungraded control sample, were sown at the three sites.

Seeding rates were adjusted for seed size so that the same number of seeds/m^2 to achieve a target plant population of 180 plants/m^2. The whole plot was harvested after trimming the ends of the plots and samples of grain were used to measure thousand grain weight, screenings and grain protein concentration (GPC).

Results

Seed source and grain nutrient concentrations

Average values for nutrient concentrations of 'Mace' wheat were consistent with previously reported concentrations from SA, but there was up to a 3-fold variation in nutrient concentrations among the sites (Table 1). Unsurprisingly, the S concentration and GPC were significantly and positively correlated across sites in each year as were the concentrations of P and K. Grading seed into different sizes did not affect nutrient concentrations in the grain.

Table 1. Average, standard deviation (SD) and the minimum and maximum values for kernel weight (KWt), grain protein concentration (GPC) and mineral nutrient concentration of grain of 'Mace' wheat sampled from NVT sites in SA in 2011 – 2013. The averages for South Australia from an earlier survey by Norton (2012) and the critical values for grain nutrients reported by Reuter and Robinson (1997) are also shown.

	Kwt	GPC	Mineral nutrient concentration (mg/kg)									
	(mg)	(%)	Fe	Mn	B	Cu	Zn	Ca	Mg	K	P	S
Mean	36.9	11.0	29	40	1.7	3.9	18	326	1154	3909	2715	1434
SD	3.6	1.71	4.7	8.5	0.74	1.08	4.2	49.4	105.3	435.0	535.0	162.1
Min	27.9	8.0	16	26	0.9	1.4	9	325	990	3300	1600	1090
Max	46.0	15.0	38	62	3.6	5.3	29	220	1340	5000	4000	1720
SA ave			30	41	1.9	4.9	23	423	1278	4641	3354	1729
Crit value				20	<2	1-2.5	5-15			5000	2700	1200

Some sites showed consistent differences in mineral nutrient concentrations. For example, seed from Nangari in the SA Mallee consistently had the lowest grain nutrient concentrations and seed from Turretfield generally had the highest nutrient concentrations (Table 2). The difference in nutrient concentration between the sites could be largely explained by the differences in seed weight, except for Zn, K and P.

Table 2. Mean kernel weight (KWt), and grain nutrient composition in 'Mace' wheat from 2011 – 2013 at two NVT sites. Both the nutrient concentrations (mg/kg) and the mass of nutrients (mg/seed) are shown.

NVT site	KWt	GPC	Mineral nutrient								
	(mg)	(%)	Fe	Mn	B	Cu	Zn	Mg	K	P	S
Nutrient concentration (mg/kg)											
Nangari	37.8	9.8	27.8	34.6	2.3	4.2	10.8	1047	3300	1863	1390
Turretfield	32.7	12.2	31.8	45.4	1.1	4.8	19.0	1260	4467	3467	1543
Mass of nutrients (mg/seed)											
Nangari		3.70	1.05	1.3	0.087	0.159	0.408	39.6	124.7	70.4	52.5
Turretfield		3.99	1.04	1.5	0.036	0.157	0.621	41.2	146.1	113.4	50.5

Effects of seed quality on grain yield

The strongest and most consistent influence on grain yield was variety (Table 3). Over the eight experiments, seed source significantly influenced yield in only two experiments, either as a main effect or interacting with seed size, and seed size affected yield in six experiments. At Turretfield 2012, the effects of seed source varied from 8% in 'Gladius' to 25 – 28% in 'Emu Rock' and 'Estoc'. There were no differences among varieties at Minnipa in 2013 and the average effect of seed source was a 4% yield difference. The concentrations of P and K in the grain were significantly associated with grain yield where source was a significant factor. In the trial at Turretfield, seed sourced from Nangari produced the lowest yield in most varieties, but the highest yield was produced from seed sourced from five different sites. At Minnipa, seed sourced from Nangari produced the lowest yield and the highest yield was produced by seed from Turretfield. Where there was an interaction with seed size, seed source did affect yield when the largest grain sample (> 2.8 mm) was used, suggesting very plump grain can compensate for differences in seed nutrient concentrations. The results showed that the effect of seed source on grain yield is variable and inconsistent.

Table 3. Summary of analyses of variance for grain yield for field experiments at Karoonda, Minnipa Agricultural Centre (MAC) and Turretfield (T'field), and the mean yield for each experiment.

Source of variation	Year and site							
	2012		2013			2014		
	MAC	T'field	Karoonda	MAC	T'field	Karoonda	MAC	T'field
Variety	<0.001	<0.001	<0.001	<0.001	<0.001	ns	<0.001	0.07
Source	ns	0.041	ns	0.006	ns	ns	ns	ns
Size	0.049	0.012	0.007	ns	0.034	ns	<0.049	0.010
Var x Source	ns	0.032	ns	ns	ns	ns	ns	ns
Var x Size	ns	ns	ns	ns	ns	ns	ns	ns
Source x Size	ns	ns	ns	ns	ns	ns	ns	ns
Var x Source x Size	ns	ns	ns	0.032	ns	ns	0.01	ns
Mean yield (t/ha)	1.34	3.21	1.81	2.89	3.43	1.43	3.45	4.24

The effect of seed size on grain yield varied with the site (Table 3). Significant effects of enhanced establishment and vegetative growth were frequently observed by sowing large seed (data not presented), but often these did not result in increases in grain yield. Large seed increased yields in each year at Turretfield in two of the three years at Minnipa, but at Karoonda in 2013, sowing large seed reduced yield (Table 3, Figure 1). At Turretfield, using larger sized seed resulted in a 4 – 5% yield increase in 2013 and 2014, but using the same seed at Karoonda resulted in either no yield improvement or a 3% lower yield. These results suggest that the benefits from larger seed will be greatest and most consistently expressed in environments where yields greater than approximately 3 t/ha are achieved. The results in Figure 2 were reflected in the experiment with 'Mace' where yields from an ungraded seed sample were compared with seed graded into two classes. Again, using graded seed was only beneficial at Turretfield where yields were greater than 3.0 t/ha.

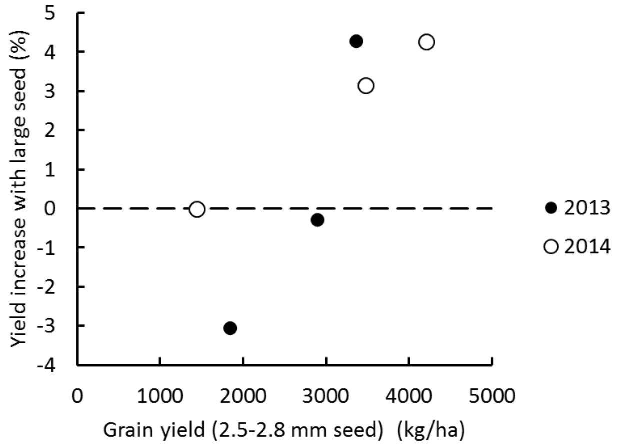

Figure 1. The grain yield increase from using large seed (> 2.8 mm) compared to using small (2.5 – 2.8 mm) seed in experiments at Karoonda, Minnipa and Turretfield in 2013 and 2014.

Conclusion

Both seed source and seed size influenced yield in wheat, but seed size had the more consistent effect. Large variation in yield can occur due to seed source, but the effect can be variety-specific and infrequent. The benefits of improved seed size were evident at high yielding sites rather than low yielding sites and it appears that the value of large seed will occur when yields are 3 t/ha or above.

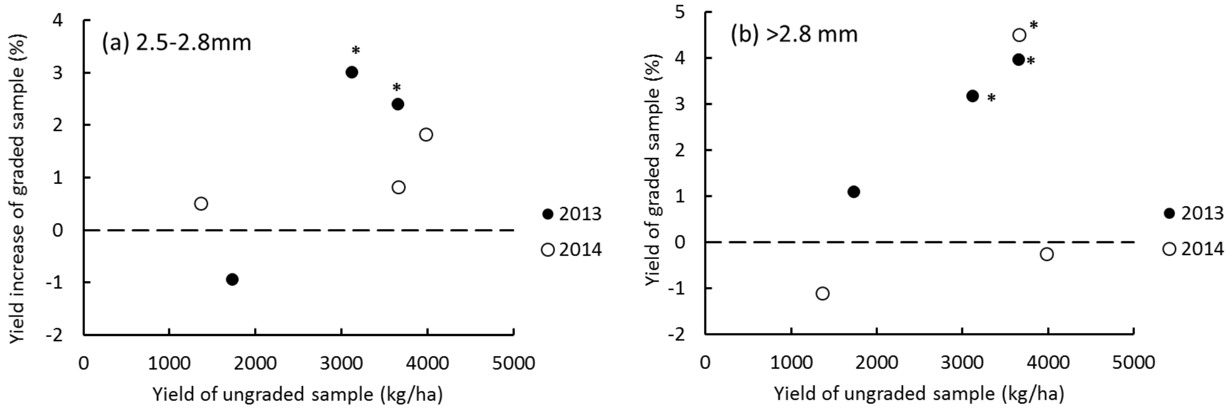

Figure 2. The increase in the grain yield of 'Mace' wheat graded into two seed sizes relative to the yield of the ungraded sample grown over two years at Karoonda, Minnipa and Turretfield. The asterisk (*) indicates significant increases in yield.

Acknowledgement

This work was supported by the SA Grains Industry Trust Fund. The technical support of Mr Leigh Davis and Mr Willie Shoobridge are gratefully acknowledged.

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