Optimising the quality and yield of spelt under organic production in SE Australia

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Abstract
Spelt (Triticum aestivum var. spelta), an ancient relative of modern bread wheat, is one of the oldest cultivated grains. Organically produced spelt is in high demand in the health food industry due to its nutritional, milling and taste attributes. However, supply constraints are frustrating industry expansion. Our research aims to identify new and higher yielding cultivars of spelt, better adapted to organic production and which exhibit superior quality attributes. Trials conducted during 2006 - 2007 at Cootamundra and Yanco in SW NSW and Rutherglen in Nth Victoria, evaluated the agronomic and quality characteristics of 20 spelt genotypes (from an initial selection of 82) compared to reference crops of common wheat, barley and triticale, when grown in an organic production system. Results showed differences between the agronomic indicators (phosphorus uptake, disease response, maturity, and yield) and quality (milling) characteristics between spelt genotypes and reference crops.

Keywords
Agronomic performance, phosphorus uptake, disease response.

Introduction
Spelt (Triticum aestivum var. spelta), is one of the oldest cultivated grains, preceded only by Emmer (T. dicoccon) and Einkorn (T. monococcum). Various historians trace spelt to origins in Egypt or Mesopotamia between 5,000 years and 9,000 years ago. From this putative origin, it made its way to Europe via the Black Sea and completed that part of its journey in Southern Germany and Switzerland probably about 1800 to 1200 B.C.

Research in Europe and North America shows spelt as a relatively hardy, versatile grain that has many uses for both human consumption and stockfeed. However, whilst spelt has higher protein content than common wheat, with reported averages of 12.1 – 17.1% (Abdel-Aal & Hucl 2005), it also has inconsistent yields, low test weights, a limited range of adapted cultivars and requires an expensive de-hulling process (Boland 2003). Some research suggests that spelt out-performs many traditional grains (such as wheat) under sub-optimal growing conditions (Ruegger et al 1990) and is able to better utilise nutrients when grown in a low-input system (Moudry and Dvoracek 1999). This suggests that spelt could play a greater role in Australian cereal rotations, particularly as phosphorus availability can be a limiting factor for yield performance.

In Australia, spelt grain production is currently estimated at 4,000 tonnes. The current estimated retail value of processed organic spelt products is $7.7 million. Estimates suggest that markets currently exist for approximately 10,000 tonnes of organic spelt grain per annum with an on-farm value of $10 million (de-hulled), and retail value of $19.2 million. While the greatest demand is for organically produced specialty grains, poor yields and market irregularities are frustrating industry expansion. Organic farmers may also strategically graze spelt crops during the growing season which may reduce grain yields.

A 3-year project being conducted by researchers from the EH Graham Centre for Agricultural Innovation (a collaborative alliance between NSW DPI and Charles Sturt University) aims to develop more reliable cultivars of spelt and other specialty grains for organic production. The project is supported by the Rural Industry Research and Development Corporation’s (RIRDC) Organic Produce Program along with the Department of Primary Industries, Victoria, organic farmers, and The Biological Farmers of Australia Co-op Ltd. (BFA).
Methods
In 2007, 20 spelt genotypes were selected from an original collection of 82 sourced from the Australian Winter Cereals Collection (Tamworth, NSW) and from organic farmers. The genotypes were evaluated for their agronomic (biomass production, grain yield, phosphorus utilisation and disease response) and quality characteristics on organic crop production sites at Yanco and Cootamundra in NSW and Rutherglen in Victoria.

Agronomic and quality attributes
Spelt lines were evaluated alongside wheat (cv. Wedgetail), barley (cv. Urambie), Kamut® (Triticum turanicum) and triticale (cv. Speedie). Plots (10m* 1.2m at Rutherglen and 4.2m*1.2m at Yanco) were sown into cultivated seedbeds on 25th May 2007 at Rutherglen and on 28th May at Yanco for the genetic evaluation. Combined yield data from Rutherglen and Yanco was analysed. Aluminium tolerance was determined using the haematoxylin root tip test (Polle et al, 1978). Quality assessments undertaken included 1000 grain weight (gms), % screenings and milling test weight (kg/hl).

Disease response
In 2006, field observations of spelt screening trials seemed to support anecdotal reports of spelt having good resistance to some common cereal diseases. To further test this hypothesis a collection of 21 spelt wheat genotypes were tested in greenhouse multi-pathotype tests (stripe rust) and observed for field response to stripe rust and stem rust at The University of Sydney, Plant Breeding Institute Cobbitty, 2007.

Phosphorus response
Preliminary glasshouse trials conducted in 2006 indicated that whilst the total P uptake (mgP / plant) is similar between traditional wheat and spelt, some spelt genotypes were able to produce a larger biomass. In 2007, a number of spelt genotypes and several varieties of wheat (Gregory, Wedgetail, ww12410) were grown in the glasshouse in pots of nutrient amended sand/peat mix. All nutrients including N (potassium nitrate + urea) were supplied in adequate amounts, except for P, the levels of which were adjusted using potassium di-hydrogen phosphate, to provide P rates equivalent to 75, 150, 225, and 375 kg/ha of superphosphate. Dry matter yields were obtained at anthesis and maturity, shoot P was measured at anthesis, and grain yield recorded at maturity. In addition, field trials conducted at Yanco (irrigated) and Rutherglen (rainfed) measured anthesis dry matter, plant P concentration (%P) and plant P uptake for a number of spelt genotypes in addition to barley, Kamut®, triticale and wheat.

Results
Agronomic and quality attributes
The 20 spelt genotypes evaluated in 2007 exhibited a wide variation in agronomic and quality attributes (Table 1).

The highest yielding spelt genotype (Line 19) yielded a mean aggregate (Yanco & Rutherglen) weight of 2.73 t/ha compared to wheat (3.77 t/ha) and barley (4.42 t/ha). Yanco out-yielded Rutherglen (by a factor of 1.67) most likely reflecting supplementary irrigation. Days to anthesis across all spelt genotypes ranged from 133 days to 153 days, compared to 138 days for wheat and barley. Preliminary results indicated that later maturing genotypes yielded less (Lines 22 and 23). This result was also noted in phosphorus trials.

Aluminium tolerance showed a range of responses ranging from Very Susceptible (VS) to Tolerant (T). Line 2 exhibited good aluminium tolerance, whilst Line 40 indicated susceptible (S) to VS tolerance.

Studies undertaken in wheat suggest a strong correlation between milling test weight and milling yield, but a negative correlation between grain size and milling yield (Marshall et. al. 1986). Preliminary quality data suggests most spelt lines had higher test weights and lower grain size relative to wheat, however the significantly greater % screenings could ultimately result in lower milling yields for most spelt lines.

Disease response
Spelt lines grown in the field and glasshouse showed a range of responses from resistant (R) to very susceptible (VS) to the cereal diseases stripe rust and stem rust (Table 1).
Phosphorus response glasshouse trials:

1. Critical P concentrations:

Plots of anthesis dry matter versus plant P uptake resulted in an initial arbitrary classification of spelt lines and wheat cultivars into three groups (Fig. 1). The mean maximal dry matter of Groups 1 and 2 were respectively 186% and 132% greater than Group 3. At 90% of maximal dry matter the mean tissue concentration of Groups 1, 2 and 3 were respectively 0.06%, 0.09% and 0.11% as estimated from the response curves: Group 1, \( \text{DM} = 32.8 \times (1 - e^{-0.129 \times P}), R^2 = 0.92; \) Group 2, \( \text{DM} = 23.2 \times (1 - e^{-0.121 \times P}), R^2 = 0.87; \) Group 3, \( \text{DM} = 17.6 \times (1 - e^{-0.128 \times P}), R^2 = 0.92 \), where DM is mgDM/pot and P is \( 10^{-1} \times \text{mgP/pot} \).

Group 1 had no representative wheat cultivar, of those tested.

Table 1. Yield, quality and agronomic features of spelt selections evaluated in 2007.

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<tr>
<th>Spelt ID</th>
<th>Combined yield data (Yanco, Rutherglen) t/ha</th>
<th>Days to anthesis</th>
<th>Head type</th>
<th>Aluminium m tolerance score</th>
<th>Field stripe rust (Yanco)</th>
<th>Field stripe rust (Rutherglen)</th>
<th>Field stripe rust (Camden)</th>
<th>Stripe rust</th>
<th>Field Stem rust</th>
<th>Aluminiu</th>
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<td>MR</td>
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Barley Mean 4.42 138 64.70 1.48 42.20
Kariet® Mean 1.34 138 78.00 0.84 79.20
Tricale Mean 3.05 133 Yes 68.77 0.75 49.87
Wheat Mean 3.77 138 Yes 75.10 2.52 38.40

Grand Mean 2.02806 LSD(5%) 0.33217

2. P response and grain yield:

There was no significant interaction between Line and fertiliser P for grain yield. Tiller number increased linearly with P; however this interaction was not translated into greater grain yield. Differentiation of lines by grain yield was not very precise; however, the mean yields of three lines in Group 1, (Lines 2, 22 & 29) appear to be particularly low. The main cause of the low yields may be the longer length to anthesis among these lines. The wheat varieties, to the contrary, appear relatively high yielding. Lines 10, 18, 19 & 40 were within 80% of the mean yield (6.67 g/pot) of the wheat varieties; Lines 10, 18 & 19 had a dry matter & P uptake pattern similar to the wheats. Line 40 has high dry matter, yet comparatively good yield possibly as it commits less to tillering. In relation to grain yield per unit uptake of P, there was no evidence that spelt was more efficient at converting P to grain than wheat cultivars.

3. P response in field trials (Yanco and Rutherglen)

Field analysis of critical P concentration revealed that spelt lines sown at Yanco were adequate for P; whilst at Rutherglen lines 20 and 19 (from Group 3) were deficient, suggesting yields of these lines may have been compromised. Lines that performed well in the glasshouse study (10, 18, 19 and 40) generally yielded well in the field.

Figure 1. Arbitrary classification of spelt and wheat lines into three groups according to relationship between dry matter (DM) production and uptake of phosphorus (P). Responses are forced through the nil, nil origin.

![Figure 1](image)

Line 41 was not a ‘high performer’ in the glasshouse but performed well at both Yanco and Rutherglen. Lines 2 & 29 performed better at Yanco than in the glasshouse and at Rutherglen. These lines had long maturation time in the field, as was also observed in the glasshouse, and may have constrained their yield performance in the field. Irrigation at Yanco appears to have contributed to longer-maturing lines fulfilling yield. A correlation appears to exist between high tillering and lower yield, however, this trend was not evident for lines 40 and 41.

**Conclusion**

**Agronomic and quality attributes**

There was a trend towards later maturing genotypes of spelt wheat yielding less than earlier maturing genotypes. The yields of all lines tested generally increased under irrigation. Increased tillering appeared to be correlated with lower yield in spelt lines (except for Lines 40 and 41) suggesting that the common practice of grazing spelt lines during the growing season should be carefully weighed up against the potential for grain yield loss. Line 40 could potentially be a suitable candidate for a grain and graze option. Lines 2, 7, 16, 18, 19, 29, 40, 41 and 54 will undergo further agronomic evaluations in 2008. A range of aluminium tolerances were scored indicating some spelt lines may be useful on acidic soils. Preliminary quality data suggests whilst most spelt lines had higher test weights and lower grain size relative to wheat; significantly greater % screenings could ultimately result in lower milling yields.

**Phosphorus response**

As there was no interaction between line and applied P level, there was no evidence to suggest that any spelt line was more or less efficient in converting applied P into grain as compared to the wheat cultivars. Lines 10, 18, 19, 40, will be included in field trials in 2008.

**Disease response**

For stripe rust, seedling resistance observed in the glasshouse remained resistant in the field. Intermediate resistant lines (Lines 23 & 39) remained resistant in the field. Susceptible lines grown in the field showed a range of responses from resistant to susceptible in the glasshouse. It was concluded that spelt genotypes 33 and 43 pose an unacceptable stripe rust risk, whilst 9a and 10ab should not be recommended for their stem rust susceptibility. Further field and glasshouse evaluations for disease response and an analysis of the genetic basis of resistance are being undertaken in 2008/09.
References


