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The Influence of Dual-purpose Production on Triticale Grain Quality

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Triticale is a high yielding cereal grain which performs well as a dual-purpose crop (both mid-season biomass and end-season grain harvests), however, is usually inferior to wheat under the requirements of a high-value milling grain market. There is potential to increase the profitability of dual-purpose triticale by improving grain quality for food products. Currently the ash content of triticale grain is above acceptable limits and protein content is usually below the requirement for a milling market. This research compared the yield, test weight, ash and protein content of four winter triticale genotypes in replicated grain only and dual-purpose treatments over five year-site environments, based on a previously reported hypothesis that removal of triticale biomass reduces grain ash content.

Cutting had a highly variable influence on yield and protein content between genotypes. Ash content was either unaffected or increased by cutting, again depending on the genotype. Ash content was negatively correlated with both stage of plant development when cut (explaining 82% of the variation) and amount of dry matter removed (explaining 65% of the variation). The results suggest that ash content in dual-purpose triticale grain may be reduced by combining suitable cultivars with later cutting; however, this may also decrease the grain protein content. It is unlikely that grazing or cutting is a suitable strategy to reduce ash content in triticale to the level required by wheat milling markets.

Keywords: dry matter, mineral content, grazing, hay, silage

Introduction

Triticale (× *Triticosecale* Whittmack) is a vigorous wheat-rye cross which produces a high yield of both green biomass and grain throughout the world's cereal-growing regions, particularly on acidic soils. Triticale performs significantly better than dual-purpose wheat and can produce similar dry matter and grain yields to oats over a winter season (Matthews and McCaffery 2011). However, unlike either of its parental species, triticale grain is rarely used in processed flour products such as loaf bread, flat bread, pasta and biscuits. Reasons quoted by various authors include poor gluten strength, low milling yield, high *alpha*-amylase activity, sticky dough, unsatisfactory colour and high ash content (Peña 2004;

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McGoverin et al. 2011). If product quality could be improved, triticale may become an alternative to bread wheat with high yielding dual-purpose (biomass and grain) production.

Ash content is defined as the total mineral content (inorganic residue) of flour, with around 97% found in the bran layer (AACC 1996). High ash content in wheat flour is associated with poor baking properties, low milling yield and darker colour (Rasper and Walker 2000) and is one of the key constraints to the adoption of triticale in processed food products (Peña 2004). Ash content in triticale is generally significantly higher than wheat (Peña and Amaya 1992; Leon et al. 1996; Klopfenstein 2000; Cyran et al. 2002; Boros 2006; USDA 2011), although the study of Roux et al. (2006) was an exception. The ash content of white triticale flour depends on the milling conditions relative to the variety and thus some studies reported ash content within acceptable limits (Peña and Amaya 1992) while others exceeded the standard (Dennett et al. 2009) set by the AACC for yeast breads (Halverson and Zeleny 1988).

In a study from Bangladesh, grain ash content was significantly lower in triticale which had been cut for hay compared to grain from an uncut crop (Haque et al. 2006). Furthermore, the grain protein content for both cut and uncut plots was high and did not decrease significantly following cutting. This raised questions regarding a possible benefit to flour quality when triticale biomass is removed, thus increasing the potential economic return from mixed livestock/cropping production.

The aim of this study was to investigate the influence of cutting on triticale flour quality, specifically considering the influence on ash content. This trial presents preliminary results from a larger study into the bread-making potential of Australian triticale varieties and breeding lines.

Materials and Methods

Field experiments

Preliminary trials were conducted at Greendale and Narrabri in 2009 and 2010, respectively (sites JP09 and NARR10, Table 1). Dual-purpose varieties Tobruk and Endeavour were sown at 60 kg ha^{-1} seed density in 6 m^2 plots and either cut with shears to approximately 5 cm plant height (phenology, plant development stage when cut, and dry matter removed from cutting + grain treatments is given in Table 2), or left to produce a grain crop only. Green biomass was oven dried at 70ºC for 5 days before weighing. Growing degree days were calculated with baseline temperature of 4ºC (Schwarte et al. 2005).

Long-season trials with two dual-purpose breeding lines (labelled 141014 and 145004) plus Tobruk and Endeavour were sown at Greendale in 2010, and Greendale and Cowra in 2011 (sites JP10, JP11 and COW11, Table 1). Plots were arranged in completely randomised blocks with 6 m^2 plots at Greendale and 13.125 m^2 plots at Cowra at 100 kg ha^{-1} seed density and fertilised with Granulock 15 at sowing and Urea shortly after cutting. Biomass was cut and dried as above, with only 1 m^2 retained for weighing in 2011. The grain harvest in 2010 and 2011 at all sites was delayed due to rainfall and the degree of grain

Table 1. Description of field sites and growing seasons

Site name	Year sown	Latitude/longitude	Season length (days)	Growing degree days	In-season rainfall (mm)	Soil description
Greendale (JP09)	2009	–33° 56’ 32.25”/150° 40’ 2.50”	169	1968	168.4	Heavy clay, nutrient depleted
Narrabri (NARR10)	2010	–30° 16’ 55.90”/149° 48’ 20.86”	172	1830	211.4	Black Vertosol, high fertility
Greendale (JP10)	2010	–33° 56’ 32.2512”/150° 40’ 2.5026”	231	1774	626.4*	Heavy clay, nutrient depleted
Greendale (JP11)	2011	–33° 56’ 32.2512”/150° 40’ 2.5026”	230	1764	420.0*	Heavy clay, nutrient depleted, soil often waterlogged
Cowra (COW11)	2011	–33° 48’ 19.7346”/148° 41’ 52.0224”	250	2076	368.0*	Brown Chromosol, hardsetting surface

* sites with wet harvest

Table 2. Age, phenology and dry matter removed in the cutting treatments and sprouting for all genotypes and sites

Trial	Genotype	Age of crop at cutting (days)	Phenology at cutting (Zadok score)	Dry matter cut per plot (kg ha^{-1})	Grains sprouted at harvest (%)
JP09	Endeavour	83	29	744.2	0.0
	Tobruk	83	28	705.8	0.0
NARR10	Endeavour	90	–	2380.8	0.0
	Tobruk	90	–	2140.8	0.0
JP10	141014	129	29	1277.4	35.9
	145004	129	30	1213.7	72.0
	Endeavour	129	29	1198.9	0.0
	Tobruk	129	29	1332.4	25.7
JP11	141014	119	23	341.0	35.0
	145004	119	20	329.5	64.6
	Endeavour	119	19	275.0	5.8
	Tobruk	119	20	362.0	20.6
COW11	141014	114	48	2037.1	35.9
	145004	114	42	1033.3	42.7
	Endeavour	114	28	507.2	37.8
	Tobruk	114	28	668.3	10.6

sprouting was assessed was based on a random sample of at least 25 grains, with sprouting defined as the breaking of the pericarp over the embryo.

Quality analysis

Grain protein and moisture content was analysed by NIR on a FOSS Infratec 1241 Grain Analyzer using triticale calibration TR260180 developed by FOSS. Final protein content was adjusted to 11% moisture basis. Test weight was measured on the FOSS Infratec using the test weight module.

Wholemeal flour was ground on a Newport Scientific 600 Hammer Mill with 0.5 mm screen. Moisture content was determined by weighing 5 g of wholemeal flour and heating at 135ºC for at least 1.5 h. The sample was then covered, cooled to room temperature and weighed. Ash content was assessed on wholemeal flour using AACC standard methods 08-01 (AACC 1996). Wholemeal was used in preference to white flour to prevent results being confounded by variable milling yield.

Statistical analysis

Results were analysed on Genstat 14th ed. using REML, multiple linear regression and the correlation function at a 5% significance level. The REML model used was

$$Constant + Line + Treatment + Line.Treatment + Sprouting$$

with sprouting as a covariate representing percentage of grains sprouted. Variates were also analyzed excluding the rain-affected sites JP11 and COW11 and appropriate results from the restricted data sets are presented.

Results

Grain yield was influenced by high environmental variability among sites, the incidence of sprouting at JP10, JP11 and COW11 (Table 2, correlation of –0.700) (thus sprouting was included as a covariate in the model), high late-season biomass production at sites with late season rain, and disease pressure (rust was particularly prevalent at JP10 and JP11). Tobruk out-yielded other lines on average ($P < 0.001$, Table 3); however, there was no clear influence of cutting on grain yield for any variety ($P = 0.175$). High rainfall late in the 2010 and 2011 growing seasons not only induced some sprouting but also increased the biomass and grain yield of vigorous lines. When rain-affected sites COW11 and JP11 are excluded from analysis, the influence of biomass cutting on grain yield becomes statistically stronger ($P = 0.078$). The degree of sprouting (defined as simply the breaking of the pericarp) was significantly different among genotypes but did not vary between cut and grain only plots ($P < 0.001$and $P = 0.317$, respectively), and had no detectable influence on test weight ($P = 0.151$).

Table 3. Mean grain yield and test weight of cut and uncut plots

Genotype	Treatment	Grain yield ($t\ ha^{-1}$)	Test weight ($kg\ hL^{-1}$)
141014	Grain only	2.83	66.7
	Cutting + grain	2.76	67.2
	Average	2.79	66.9
145004	Grain only	2.70	63.6
	Cutting + grain	2.71	64.9
	Average	2.71	64.2
Endeavour	Grain only	3.17	63.5
	Cutting + grain	3.09	63.8
	Average	3.13	63.7
Tobruk	Grain only	4.24	67.0
	Cutting + grain	3.30	66.7
	Average	3.77	66.9

No correlation was observed between phenology or plant development stage and grain yield (Table 4). This is despite the fact that plots cut later in development (particularly after tillering) were expected to have lower yield (Matthews and McCaffery 2011). Grain protein and yield ($P = 0.5827$) were also not significantly correlated. Test weight was not significantly influenced by cutting ($P = 0.47$), however, clear differences were found among lines ($P < 0.001$). Tobruk and 141014 reached the marketing target of 65 kg hL^{-1} test weight for triticale in Australia (Matthews and McCaffery 2011); however, all plots were well below the Australian wheat milling standard of 76 kg hL^{-1} (Honey 2010).

Table 4. Correlation between features of growing conditions and grain quality

	Ash (11% mb)	Ash (kg hL^{-1})	Yield (t ha^{-1})	Protein (11% mb)	Age at cutting (days)	Zadok at cutting	DM removed (kg ha^{-1})	Moisture (%)	Grains sprouted (%)
Ash (kg hL^{-1})	0.675[a]	–							
Yield (t ha^{-1})	0.421[a]	0.505[a]	–						
Protein (11% mb)	0.577[a]	0.445[a]	0.115	–					
Age at cutting (days)	–0.678[a]	–0.571[a]	–0.181	–0.522[a]	–				
Zadok at cutting	–0.204	–0.037	–0.267	0.103	–0.092	–			
DM removed (kg ha^{-1})	–0.145	0.013	0.042	0.175	0.129	0.837[a]	–		
Moisture (%)	–0.289	–0.238	–0.115	–0.593[a]	0.198	–0.575[a]	–0.617[a]	–	
Grains sprouted (%)	–0.589[a]	–0.520[a]	–0.695[a]	–0.237	0.301	0.032	–0.131	0.347[a]	–
Test weight (kg hL^{-1})	–0.151	0.446[a]	0.293	–0.076	0.101	0.003	0.094	–0.069	–0.236

[a] significant at 5% level (two–sided test)

Overall, grain protein content was not significantly influenced by cutting (P = 0.204, Fig. 1). However, amongst the cut plots only, the age of cutting was negatively correlated with protein content i.e. the more developed the plants at cutting, the lower the protein content of the grain (R^2 = 0.273, P = 0.0074).

The response of ash content to cutting differed among genotypes. Ash content of Endeavour and Tobruk was higher in cut plots, whereas no significant effect of cutting was detected on 141014 and 145005 (Fig. 1). Amongst cut plots, just under half the ash content was explained by plant development stage when cutting occurred (R^2 = 0.459); similar to protein, the later the crop was cut the lower the ash content recorded. If the rain-affected 2011 results are excluded, the correlation between ash content and development stage when cut increases to –0.9029, explaining 82% of ash content in cut plots. Ash content amongst cut plots was also negatively correlated with the amount of dry matter removed (–0.8048, P = 0.0089).

Grain yield was positively correlated to ash content, explaining 18% of the variation. Protein content was also positively correlated with ash content, explaining 33% of the variation (P = 0.0025) (Feil and Fossati 1995).

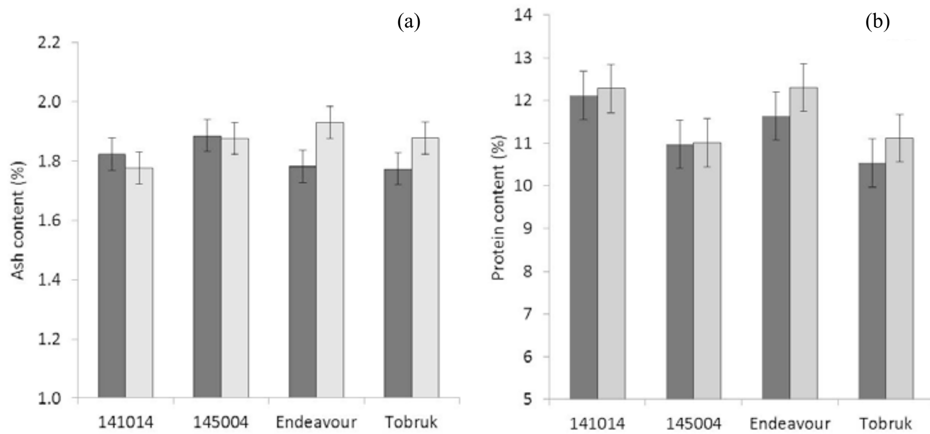

Figure 1. Grain characters in response to cutting. (a) Ash content; (b) Protein content, both corrected to 11% moisture basis. Dark columns represent grain only treatment, light columns represent the cutting + grain treatment. Error bars indicate the 5% LSD for the cut treatment

Discussion

It would be of considerable financial and environmental benefit to farmers to have a high yielding alternative to wheat or oats for biomass with at least the same level of grain quality as dual-purpose wheat. In Australia, grain from dual-purpose wheat varieties can be classed up to Australian Standard White or Noodle quality (Matthews and McCaffery 2011).

Haque et al. (2006) found that grain ash content decreased after removing biomass. However, in this study the average ash content of wholemeal flour was either equal or greater under a dual-purpose system. The trend may be the result of reduced photosynthate accumulation in developing grains (Dann et al. 1983) which increases ash and protein concentration by default (Ohm et al. 1998). The situation may be different in white flour, where the influence of the pericarp and its deep crease is removed and only endosperm minerals are considered (and thus carbohydrates per seed is irrelevant).

Furthermore, despite the fact that later cut plots had less ash than earlier cut plots (particularly lines 141014 and 145004), later cutting still did not reduce ash content to a commercially acceptable level. Indeed, triticales in this study produced ash contents 30% higher than the usual range for ash in Australian milling wheat of 1.4 to 1.5% (GrainCorp 2010). Therefore at best cutting can be used to partially reduce ash content in triticale, not as the sole technique.

Studies on winter wheat usually conclude cutting or grazing green biomass has little or no influence on grain quality in fertile environments (Royo and Tribo 1997; Khalil et al. 2002; Holman et al. 2009).

The grain yield in this study was influenced by unusually wet springs in 2010 and 2011 in south-eastern Australia. However, no observed influence of sprouting on ash content was detected. Most minerals remain in the grain in the early stages of germination unlike starch, which is converted to sugar then to carbon dioxide. The cause of minor changes in ash content in the first stage of germination is likely to be indirect, via starch hydrolysis and reduction in total grain weight, and unlikely to significantly influence the results of the barely germinated grain samples from this trial.

High ash content in triticale compared to wheat is partially due to grain morphology – triticale has a deep crease and in the past had a reputation for shrivelled grain (Peña 2004). There has been little or no selection for ash content in triticale, however, selecting for plump grains with a shallower crease in dual-purpose varieties would have had an indirect effect on ash content by improving the ratio of pericarp to endosperm. Along with continual improvement in grain appearance, variability in other grain quality characters should be exploited in triticale breeding over the next few decades to improve farm productivity and potential profitability. When combined with appropriate dual-purpose management, milling-quality triticale varieties have the potential to improve the profitability of mixed farming systems.

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