Effect of seeding date and rate on malting barley (*Hordeum vulgare* L.) quality

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SHORT COMMUNICATION

**Effect of seeding date and rate on malting barley (*Hordeum
vulgare* L.) quality**

Short title: Malting barley quality as affected by date and rate of seeding

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A western Canada field study investigated the effects of seeding date and rate on malting barley quality. Seeding date had little effect on quality. Increasing the seeding rate up to 300 seeds m⁻² resulted in higher germination and Kolbach indices, lower β -glucan, and better endosperm modification without compromising malt extract.

Key words: Germination index, Kolbach index, β -glucan, α -amylase, endosperm modification.

For Review Only

Barley (*Hordeum vulgare* L.) growers in western Canada often have difficulty achieving malting grade. Annually, only 20 to 25% of malting barley produced is deemed acceptable for malting with the rest sold as feed for livestock. This can result in reduced revenues for growers (Smith et al. 2012). The main acceptance criteria for malting grade include low protein concentration (110 to 125 mg g⁻¹) and plump kernels of uniform size.

While poor quality can often be due to adverse climatic factors, suboptimal agronomic practices can also be a factor (Edney et al. 2012). Previous research conducted on the Great Plains of North America focussed mainly on agronomic practices that influence malting barley yield and protein concentration. These practices included N fertilizer application (Therrien et al. 1994; McKenzie et al. 2005; O'Donovan et al. 2011; Edney et al. 2012), cultivar selection (O'Donovan et al. 2011; Edney et al. 2012), seeding dates and rates (McKenzie et al. 2005), previous crop residue (Turkington et al. 2012; Sainju et al. 2013), and tillage systems (Sainju et al. 2013; Carr et al. 2014).

A study conducted at eight locations in western Canada over three years found that delayed seeding often resulted in negative effects on malting barley including lower yield and higher protein concentration (O'Donovan et al. 2012). The study also found that seeding barley at 300 seeds m⁻² was usually optimal in terms of increasing kernel yield, resulting in more uniform kernels, and decreasing protein concentration compared to seeding barley at lower rates. Traditionally, growers have not been encouraged to seed malting barley above 200 seeds m⁻² since quality may be reduced (McKenzie et al. 2005). This is largely due to the perception that the resulting reduction in kernel plumpness will produce less malt extract and negatively impact acceptability of barley for malting. Very few studies, however, have examined the direct effects of seeding date and rate or other agronomic practices on malt extract or other end-quality parameters. This may be due to the expense and time required for malt analysis (Edney et al. 2012).

The present study was an extension of the study of O'Donovan et al. (2012). In that study, the effect of seeding date on grain yield was variable while the effect of seeding rate was generally parabolic. Yield increased from approximately 3800 kg ha⁻¹ at 100 seeds m⁻² to 4200 kg ha⁻¹ at 300 seeds m⁻², but declined to 4120 kg ha⁻¹ at 500 seeds m⁻². The objective of this study was to determine the effects of seeding date and rate and their interaction on malting barley quality.

A no-tillage field experiment was conducted at Fort Vermilion, Beaverlodge, Lacombe, and Lethbridge AB, Canora, Scott and Indian Head, SK and Brandon MB in 2006, 2007 and 2008. The experiment was designed as a randomised split-plot with four replicates. Early (late April to mid-May) and late (mid-May to early June) time of seeding was allocated to main plots and five barley (AC Metcalfe) seeding rates (100, 200, 300, 400 and 500 seeds m⁻²) to sub-plots randomized within the main plots. Soil types, actual seeding dates and other agronomic practices at the various locations are described by O'Donovan et al. (2012).

Constraints on capacity for malting and quality analysis limited the number of environments (location-year combinations) that could be malted and analysed each year. Barley samples from all environments were tested for plumpness, germination energy and protein content to determine suitability for malting. Based on these criteria, a total of 28 samples spread across 13 environments were malted. All eight locations were represented in the study. Germination energy and micro-malting analysis was determined according to the standard methods of the American Society of Brewing Chemists (2004). Germination index was calculated from the germination energy results according to the method of Riis and Bang-Olsen (1991). Samples were malted in a Phoenix Automated Micromalting machine (Adelaide, SA, Australia) using the following malting schedule: steeping (8 h wet, 16 h air, 8 h wet, 12 h air at 13 °C), germination (96

h at 15 °C) and kilning (12 h at 55 °C, 6 h at 65 °C, 2 h at 75 °C, 4 h at 85 °C – 24 h total). Malt analyses included: fine grind malt extract, which is a measure of a malt's beer production potential; Kolbach index, the ratio of soluble to total malt protein which is an indicator of the extent of protein modification; wort β -glucan which indicates the extent to which cell walls were degraded during malting; diastatic power and α -amylase, enzymes that produce fermentable sugars from malt during mashing; friability modification, an indicator of how well the endosperm was broken down during malting; and friability homogeneity, an indicator of the number of individual kernels that were well-modified.

Data were analyzed using PROC MIXED of SAS (Littell et al. 2006). Times of seeding and seeding rate were considered as fixed effects. Environments, replicates within environments, and the environment interaction with the applied treatments (fixed effects) were considered as random effects. Contrast statements were used to test for linear and quadratic responses to seeding rate. P values in Table 1 indicate the significance of the linear and quadratic responses to seeding rate as determined by PROC MIXED. Where responses were significant, regression equations were fitted to describe the relationship between the dependent variables and seeding rate. Differences were deemed significant at $P < 0.05$.

Seeding date had few significant effects on malting barley quality parameters, and none of the seeding date by seeding rate interactions was significant (Table 1). There was a slight increase in germination energy with late (92%) compared to early (89%) seeding. There was also a very slight difference in α -amylase concentration between early and late seeding (70 and 71 DU, respectively). It is unlikely, however, that these minor differences in kernel germination or enzyme production would have a significant impact on the malting process. There was a strong but non-significant ($P = 0.068$) trend towards higher β -glucan at the late (205 mg l⁻¹) compared to the early (167 mg l⁻¹) seeding date.

However, this did not affect overall endosperm modification (Table 1). In spite of the apparent lack of effects of seeding date on malting barley quality, previous studies have shown that seeding barley relatively early in the growing season can often lead to positive outcomes including higher yields, plumper seed, lower protein concentration and less lodging (McKenzie et al. 2005; O'Donovan et al. 2012). In terms of acceptability for malting grade, there may therefore be greater risk associated with late seeding especially if protein concentration increases. Greater protein concentrations at later seeding dates may have been due to higher temperatures later in the growing season (O'Donovan et al. 2012).

Seeding rate significantly affected most of the malting barley quality parameters (Table 1). Exceptions were germination energy, fine extract and diastatic power. All of the effects of increasing seeding rate were positive in terms of malting barley quality (Fig. 1). The germination index increased with increasing seeding rate up to 300 seeds m^{-2} (Fig. 1A) indicating greater potential for rapid initiation of germination at the higher seeding rates. In addition, endosperm modification improved with increasing seeding rate as indicated by higher Kolbach indices (Fig. 1B), lower levels of wort β -glucan (Fig. 1C), and higher values for both friability modification (Fig. 1E) and friability homogeneity (Fig. 1F). The effect of seeding rate on enzyme levels was variable. Overall diastatic power was unaffected (Table 1), but α -amylase levels increased with increasing seeding rate (Fig. 1D).

O'Donovan et al. (2012) found that while kernel weight and plumpness decreased somewhat as seeding rate increased, protein concentration also decreased and kernel uniformity increased. Results from the present study suggest that the smaller more uniform kernels resulted in a quicker start to germination, better overall modification due to lower protein and β -glucan, and more uniform kernel modification as indicated by the higher friability homogeneity values. In spite of the reduction in kernel plumpness at

higher seeding rates, malt extract levels were unaffected. This suggests that kernel uniformity may be more important than kernel plumpness when selecting barley for malting grade.

These results are in general agreement with those of Edney et al. (2012) who found that improved endosperm modification occurred when barley was seeded at 400 compared to 200 seeds m^{-2} . However, increasing the seeding rate to 400 or 500 seeds m^{-2} was shown to sometimes reduce yield, possibly due to increased lodging (O'Donovan et al. 2012), and this resulted in lower economic returns for growers (Smith et al. 2012). In most cases, in the present study, responses to seeding rate were quadratic, and the positive effects on quality were most evident when the seeding rate was increased from 100 to 300 seeds m^{-2} with only slight improvements in quality when seeding above this rate (Fig. 1). Conclusions from both studies indicate that seeding malting barley relatively early at 300 seeds m^{-2} has the potential to optimize both quality and yield, and thus increase the amount of barley deemed acceptable for malting grade.

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Fig.1. Response of malting barley quality parameters to increasing seeding rate.

Regression equations were fitted when linear or quadratic responses were significant ($P < 0.05$) as determined by PROC MIXED (see Table 1).

Table 1. P values from the analysis of variance for the effects (fixed) of barley time of seeding and barley seeding rate on malting barley quality parameters. Environments (location and year), and their interaction with fixed effects, and replicates within environments were considered random effects. Significant effects ($P < 0.05$) are indicated in bold type

Effects	Germination energy (%)	Germination index	Fine extract (mg g^{-1})	Kolbach index (mg g^{-1})	β -glucan (mg l^{-1})	Diastatic power ($^{\circ}\text{L}$)	α -amylase (DU)	Friability modification (mg g^{-1})	Friability Homogeneity (mg g^{-1})
P values									
Seeding date (D)	0.043	0.218	0.634	0.371	0.068	0.533	0.028	0.155	0.393
Seeding rate (S)	0.546	<0.001	0.678	<0.001	<0.001	0.638	<0.001	<0.001	<0.001
D x S	0.109	0.101	0.350	0.603	0.269	0.612	0.847	0.659	0.303
S linear ^a	0.480	<0.001	0.243	<0.001	<0.001	0.262	<0.001	<0.001	<0.001
S quadratic ^a	0.192	0.005	0.415	0.018	0.005	0.917	0.020	0.045	0.058

^aP values indicate the significance of linear and quadratic responses to seeding rate as determined by PROC MIXED.

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