Beta-Glucans Deposition in Malting Barley as Affected by Nitrogen Supply

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Introduction

Barley grain is a source of soluble dietary fiber and other bioactive constituents. Approximately 75% of the non-starch polysaccharide family (1-3)(1-4) mixed linked β-glucans (β-glucans) occurs in the endosperm, the remaining 25% in the aleurone layer. Beta-glucans-rich foods may help prevent type-2 diabetes (*Dickin et al., 2011*). Conversely, β-glucans reduce extract yields in the brewhouse and may cause poor filtration during mashing (*Bamforth, 1982*).

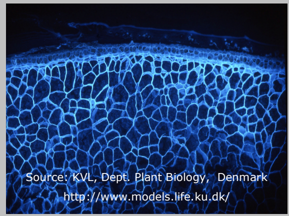

Figure 1. *Distribution of β-glucans in a kernel cross-section. The β-glucan has been stained with calcofluor and appears blue.*

A direct effect of N supply on β-glucans in field-grown barley is debatable (*Güler, 2003*). Due to trade-offs between grain yield and malting quality, new information about β-glucans evolution in grains could improve malting barley N management.

Objective

To evaluate the effect of N level on grain β-glucans in winter-type malting barley.

Methods

Two field experiments were run on a superficial soil (Chromi-Skeletic Cambisol; FAO, 1998) in Udine, Italy (46°03' lat. N). A total of 6 barley varieties were sown in early November at 350 viable seeds m^{-2}. In 2006 & 2007 (*Exp. 1*) three malting varieties (Orchidea, Regina and Sunbeam) were used, while one feed barley (Aldebaran) and two malting barleys (Nure and Pariglia) were tested in 2011 (*Exp. 2*). Nitrogen (as ammonium nitrate) was supplied within a split-plot design at 0, 50, 100, 150 kg ha^{-1} with varieties in subplots and 3 reps. Throughout post-anthesis stages, total N (NA-1500 Elemental Analyzer, Carlo Erba) and β-glucans (McCleary Streamlined Method, Megazyme®, Ireland) concentrations were measured in 30-40 developing kernels taken from 10-12 heads per plot. Statistical analysis (GLM univariate and Graph procedures) was performed using SPSS 15.0 package (SPSS Inc., Chicago, IL). For simplicity's sake, only effects of applied N are discussed.

Results

Typically for our soil environment, crop yields and N uptake were rather low (**table 1**). Nitrogen supply increased grain yield and grain protein. Any specific effect of N on β-glucans accumulation remains elusive. Averaged across years and cultivars, grain β-glucans concentration at harvest was significantly increased (*Exp. 1*), albeit in a different manner between years (**Figure 2**). Conversely, N supply had no effect on another set of cultivars (*Exp. 2*).

Nitrogen applied *kg ha^{-1}*	Grain yield *Mg ha^{-1}*	Thousand kernels *No. m^{-2}*	TKW *g*	Nitrogen uptake *kg ha^{-1}*	Grain protein *g kg^{-1}*	Grain beta-glucans *g kg^{-1}*	Beta-glucans yield *kg ha^{-1}*
Experiment 1 - 2006 / 2007							
0	2.60 c	7.7 d	47.8 a	43.2 d	83.9 c	34.6 c	92.1 c
50	4.24 b	10.8 c	49.9 a	74.2 c	85.7 c	36.8 b	156.6 b
100	4.53 a	13.8 b	47.8 a	113.3 b	101.2 b	40.8 a	182.9 a
150	4.08 b	17.5 a	48.8 a	154.2 a	120.9 a	42.2 a	172.4 ab
Experiment 2 - 2011							
0	1.44 c	6.8 b	43.5 a	42.9 b	86.7 c	41.1 a	59.0 c
50	2.40 b	8.5 b	44.4 a	56.8 b	81.3 c	40.2 a	96.1 b
100	3.60 a	13.6 a	45.9 a	104.0 a	94.7 b	42.1 a	149.0 a
150	3.66 a	13.7 a	46.7 a	114.2 a	102.0 a	41.5 a	154.8 a

Table 1. *Effect of applied N on yield and quality traits, averaged across years and cultivars (Exp. 1) or cultivars (Exp. 2). Within each experiment, means followed by the same letter are not significantly different based on Scheffé test (Alpha = .05 level).*

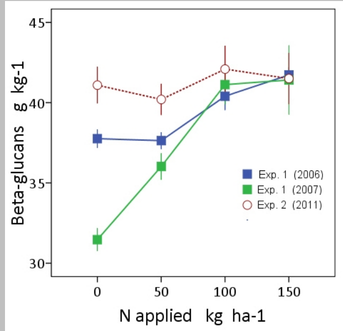

Figure 2. *Beta-glucans concentration at harvest as affected by N supply, measured in 2006/2007 (Exp. 1) and 2011 (Exp. 2). Bars are standard error of the mean.*

From *Exp. 1* data, distinct linear relationships were found between the number of kernels per m^2 and β-glucans concentration (**Figure 3**). If the final crop sink size depends upon kernels per m^2 only (no major compensation from TKW, see Table 1) and the average number of cells per kernels is fixed, the total cell wall volume accommodating β-glucans basically depends upon the number of kernels per m^2 at harvest. A low number of kernels per m^{-2} observed in 2007 could have driven the response of β-glucans to N supply.

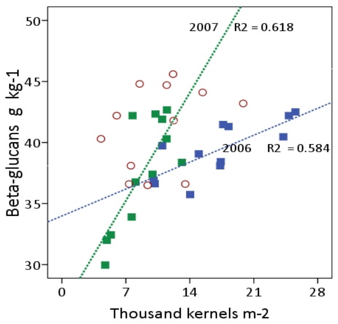

Figure 3. *Linear relationships observed between kernels per m^2 and grain β-glucans concentration in 2006 and 2007 (solid squares). No relationship found in 2011 (open circles).*

Figure 4 shows the post-anthesis β-glucans accumulation in developing kernels. The model includes a lag, then a linear phase up to 26-28 DAA and a final plateau. The time course is coherent with detailed deposition studies on wheat endosperm (Philippe et al., 2006). Again, 2007 data show distinct plateaux in response to different N supply. Conversely, a variety effect (data not shown) but no N effect have been detected in 2011.

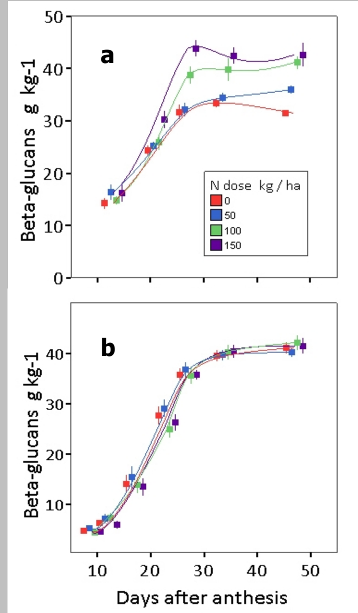

Figure 4. *Beta-glucans accumulation in maturing kernels taken from plants grown at four N doses. Panel (a) and panel (b) report 2007 and 2011 measurements respectively. Each observation comes from 30-40 developing kernels per plot. Bars are standard error of the mean.*

In summary, nitrogen supply increased β-glucans concentration in barley kernels in two out of three seasons.

Crop sink volume (kernel number per m^2 at harvest) could influence β-glucans accumulation.

References

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