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β-Glucan contents of groats of different oat cultivars in official variety, in organic cultivation, and in nitrogen ferilization trials in Finland

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β-Glucan is a beneficial chemical compound in the diet of humans by decreasing the levels of serum cholesterol and blood glucose. The β-glucan contents of oat groats were studied in official variety trials (1997–1999), nitrogen fertilization trials (1997–1999) and organic variety trials (1997–1998) in Finland. Eight cultivars were studied in the organic variety trials. Two of them, cultivars Puhti and Veli, were cultivated also with a conventional method at the same fields. The years 1997 and 1999 were very warm and dry and 1998 very cool and rainy. The effects of year and cultivar on β-glucan content were significant in all three trial series. The Kolbu oat cultivar had a significantly lower β-glucan content than other cultivars in all trials. N fertilization did not increase the β-glucan contents of oats in Finland. The effect of cultivation method (traditional vr organic cultivation) had no significant effect on the β-glucan content. The year x cultivar interaction significantly affected the β-glucan contents of oat groats in N fertilization trials. The reaction of different cultivars to weather conditions was different. Kolbu oat cultivar had significantly lower β-glucan contents in 1998 than in warm years in all three trial series.

Key words: β-glucan, oats, *Avena sativa*, groat, organic farming, nitrogen fertilization, cultivars

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Introduction

β-Glucans, mixed-linked (1–3)(1–4)-β-D-glucans, are nonstarch polysaccharides that are typical for the genus Poacea (Nevins et al. 1978, McNeil et al. 1984). β-glucans are cell wall constituents that are found especially in grains of oats (*Avena sativa* L.) and barley (*Hordeum vulgare* L.). β-Glucan is concentrated in the cell walls of the subaleurone layer of oat grains, from which it is easy to concentrate to the bran in the oat-milling process (Wood 1986). There are also patented processing methods by which the β-glucan contents of oat bran can be increased.

β-Glucan is beneficial in the diet of human beings, because it decreases and stabilizes the levels of serum glucose and insulin (Wood et al. 1990, Jenkins et al. 2002), and decreases the level of blood cholesterol (Anderson et al. 1984, Klopfenstein 1988, Pomeroy et al. 2001). It has been found that oat β-glucan is as effective in reducing the postprandial glucose response in healthy human beings as guar gum (Wood 1994). Special high-β-glucan products are more effective in reducing the glycaemic index than normal oat bran breakfasts (Jenkins et al. 2002). Oat β-glucan has also been found to decrease infections; it increases resistance to the bacteria *Eimeria vermiformis* and *Staphylococcus aureus* in mice by increasing the amount of immunoglobulins in serum and enhancing phagocytic activity (Yun et al. 1997, 2003).

β-Glucan decreases growth in monogastric animals when incorporated in animal feed (Hesselman and Åman 1986, Pettersson and Åman 1992). β-Glucan is an antinutritional compound present in the feeds of pigs, hens and battery hens, when present in pet foods, however, yeast β-(1–3)(1–6)-glucan is beneficial, because it increases the health and welfare of animals by supporting their immune systems (Rosenhaugh 2002).

The objective here was to study the β-glucan contents of oat cultivars cultivated in Finland with conventional and organic cultivation methods. The β-glucan contents of oat cultivars were studied in official variety trials and in nitrogen fertilization trials during a 3-year period and in organic variety trials during a 2-year period throughout the oat cultivation area in Finland.

Material and methods

Oat field trials

The trials have been described previously (Eurola et al. 2003). The map of trial locations is seen in Figure 1. The material consisted of grain samples of oat cultivars undergoing official variety and organic variety trials in various locations and nitrogen fertilization trials in 2 locations of MTT Agrifood Research Finland. The official variety trials were held in 1997–1999 at Jokioinen, Mietoinen, Tuusula (Hyrylä), Pälkäne, Mikkeli, Maaninka, Laukaa, Ylistaro, Vihti (1998–1999) and Ruukki (1998–1999). The organic variety trials were held in 1997–1998 at Jokioinen, Mietoinen, Laukaa, Juva, Ylistaro and

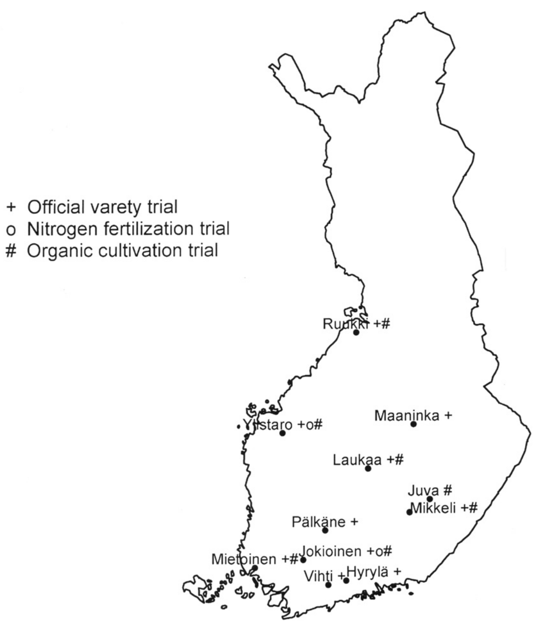

Fig. 1. The map of trial locations.

Ruukki. The N fertilization trials were established in 1997–1999 at 2 locations: Jokioinen and Ylistaro. The variety trials were conducted using the lattice designs of Cochran and Cox (1957) with 3–4 replications. The plot size varied according to locations between 10.00 and 13.00 m^2.

Official variety trials

The varieties studied were Leila, Salo, Veli, Kolbu, Roope and Belinda. Kolbu and Roope have yellow hulls, and the other varieties white hulls. Roope and Veli are Finnish, Leila and Kolbu are Norwegian, and Belinda and Salo are Swedish cultivars. The detailed information of the trials is given in Table 1.

Organic variety trials

Organic variety trials were conducted as two types of trials: organic trials and conventional trials at the same field location. In the conven-

Table 1. Dates of sowing and average dates of yellow ripening, precipitation and effective temperature sums of locations of official variety trials.

Location	Year	Precipitation May–Aug mm	Effective temperature sum May–Aug	Soil pH	Soil type	Date of sowing	Average date of yellow ripening
Jokioinen	1997	302	1217	6.3	sandy clay	17.5.1997	19.8.1997
	1998	318	1011	5.8	clay	16.5.1997	1.9.1998
	1999	146	1184	5.7	sandy clay	11.5.1999	3.8.1999
Mietoinen 1	1997	232	1285	5.3	clay	13.5.1997	9.8.1997
	1998	245	1036	5.9	sandy clay	15.5.1998	1.9.1998
	1999	92	1236	5.8	sandy clay	7.5.1999	2.8.1999
Mietoinen 2	1999	92	1236	6.3	clay	13.5.1999	5.8.1999
Tuusula. Hyrylä	1997	n.a.	n.a.	6.3	sandy clay loam	16.5.1997	14.8.1997
	1998	n.a.	n.a.	6.0	coarse silt	18.5.1998	8.9.1998
	1999	n.a.	n.a.	6.3	sandy clay	12.5.1999	29.7.1999
Pälkäne	1997	253	1250	5.7	fine silt	19.5.1997	17.8.1997
	1998	339	1043	6.0	fine silt	19.5.1998	5.9.1998
	1999	141	1231	5.9	fine silt	14.5.1999	6.8.1999
Mikkeli/Juva	1997	115	1150	6.9	fine sand	21.5.1997	18.8.1997
	1998	337	976	6.0	fine sand	20.5.1998	7.9.1998
	1999	243	1133	6.0	fine sand	20.5.1999	13.8.1999
Maaninka	1997	177	1153	5.8	coarse silt	30.5.1997	16.8.1997
	1998	340	938	6.1	coarse silt	20.5.1998	9.9.1998
	1999	183	1134	5.5	coarse silt	19.5.1999	8.8.1999
Laukaa	1997	182	1146	6.0	coarse silt	22.5.1997	24.8.1997
	1998	345	916	6.0	coarse silt	19.5.1998	12.9.1998
	1999	175	1112	6.0	coarse silt	19.5.1999	17.8.1999
Ylistaro 1	1997	155	1143	6.0	sandy clay loam	9.5.1997	5.8.1997
	1998	372	937	6.2	silty clay	11.5.1998	10.9.1998
	1999	120	1062	6.1	silty clay	4.5.1999	7.8.1999
Ylistaro 2	1997	155	1143	5.3	mould	20.5.1997	12.8.1997
	1998	372	937	5.7	mould	20.5.1998	16.9.1998
	1999	120	1062	5.5	mould	11.5.1999	12.8.1999
Ruukki 1	1998	439	850	5.9	coarse silt	20.5.1998	18.9.1998
	1999	182	952	5.4	coarse silt	20.5.1999	31.8.1999
Ruukki 2	1999	182	952	5.4	mould	20.5.1999	6.9.1999
Vihti	1998	389	997	5.9	coarse silt	20.5.1998	10.9.1998
	1999	132	1173	6.2	clay	14.5.1999	29.7.1999

n.a. not available

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tional trials there were only two varieties, Puhti and Veli. Two oat cultivars Puhti and Veli in the organic variety trials were both cultivated using organic and conventional methods in the same field as all other locations except Juva, so that these cultivation methods could be compared. Puhti and Veli were also in the organic trials as standard varieties. The trials were established at 6 locations. In organic cultivation 6 additional cultivars were also studied: Aarre, Katri, Kolbu, Leila, Roope and Yty. Leila and Kolbu are Norwegian, and Aarre, Katri, Puhti, Roope, Veli and Yty are Finnish cultivars. The conventional and organic farming system trials were carried out on the same field: conventional in the middle and organic on both sides, 6-year rotation of crops was used. In organic cultivation the preceding crop was clover to improve the nitrogen status of the soil, and in conventional systems cereal crops preceded the trial. Organic and conventional cultivation trials were held on the main plots and cultivars on subplots with 3–4 replications. In all experimental fields, organic cultivation was initiated during the early 1990s. More detailed information of the trials is found in Table 2.

N fertilization trials

Nitrogen fertilization trials were established at 2 locations: in Jokioinen and in Ylistaro in the years 1997, 1998 and 1999. Soil types, sowing data, average dates of yellow ripening and fertilization and climate conditions are given in Table 2. N fertilization was given before sowing as calcium ammonium nitrate (0, 40, 80, 120 and 160 kg N ha^{-1}) with 4 oat cultivars (Aarre, Katri, Kolbu and Salo) at 2 locations. The experimental design was split-plot with 4 replications (Cochran and Cox 1957). Rates of N uptake were determined in main plots and oat cultivars in subplots.

Table 2. Dates of sowing and average dates of yellow ripening and precipitation and effective temperature sums of locations of organic and N fertilization trials.

Type of trial	Location	Year	Precipitation May–Aug mm	Effective temperature sum May–Aug	Soil pH	Soil type	Date of sowing	Average date of yellow ripening
Organic variety trials	Jokioinen	1997	302	1217	6.2	sandy clay	26.5.1997	14.8.1997
		1998	318	1011	6.2	sandy clay	20.5.1998	21.9.1998
	Mietoinen	1997	232	1285	6.1	sandy clay	16.5.1997	7.8.1997
		1998	245	1036	5.6	sandy clay	21.5.1998	8.9.1998
	Mikkeli/Juva	1997	115	1150	6.5	fine sand moraine soil	16.5.1997	13.8.1997
		1998	337	976	6.6	fine sand moraine soil	18.5.1998	1.9.1998
	Laukaa	1997	182	1146	6.3	loam	27.5.1997	25.8.1997
		1998	345	916	n.a.	loam	22.5.1998	7.9.1998
	Ylistaro	1997	155	1143	5.7	finer fine sand	22.5.1997	12.8.1997
		1998	372	937	5.7	finer fine sand	25.5.1998	21.9.1998
	Ruukki	1997	292	1152	6.6	fine sand	4.6.1997	12.9.1997
		1998	439	850	6.8	fine sand	25.5.1998	18.9.1998
N fertilization trials	Jokioinen	1997	302	1217	5.8	heavy clay	19.5.1997	19.8.1997
		1998	318	1011	5.6	heavy clay	16.5.1998	12.9.1998
		1999	146	1184	5.7	heavy clay	12.5.1999	4.8.1999
	Ylistaro	1997	155	1143	6.1	loam	14.5.1997	7.8.1997
		1998	372	937	6.1	loam	13.5.1998	9.9.1998
		1999	120	1062	6.1	loam	4.5.1999	7.8.1999

n.a. not available

Weather conditions

Weather conditions varied widely in different test years. The weather in 1997 and 1999 was warm and dry and very rainy and cool in 1998. The precipitation data and effective temperature sums for these periods, and the average dates of yellow ripening of the trials are given in Tables 1 and 2.

Pretreatment of samples and chemical analyses

Grain samples of the trial members from different replications from the oat trials were united after weighing the yields of the plots of replications. Grain samples of the oat trial members were first sorted using a 2.0-mm sieve. Oat grains > 2.0 mm were hulled with a BT 459 oat-hulling device using air pressure at Boreal Plant Breeding. Broken groats were discarded. Oat groats were then milled with a falling-number hammer mill using a 1.0-mm sieve. The β-glucan contents of oat groats were analysed using the method of McCleary (McCleary and Glennie-Holmes 1985, McCleary and Codd 1991).

Statistical methods

The LSMeans (least square means) of the cultivars and statistical differences between the cultivars over trials, locations and years were calculated as described previously (Eurola et al. 2003). The data from different trials were analyzed in 4 separate parts: In the first part the differences between the varieties (data from variety trials) were analyzed, using mixed linear models. In the model year, location and trial were analyzed as the random factor and cultivars as the fixed factor (Öfversten and Nikander 1996). In the second part differences between 6 additional cultivars in organic cultivation were analyzed as in part 1. In the third part the main effects of farming systems (organic and conventional), cultivars (Veli and Puhti) and their interactions were determined by analyses of variance according to the split-plot design. In the analyses the farming system (as the main plot factor) and cultivar (as the split-plot factor) were analyzed as the fixed and location (as block factor) and year as the random factor. In the fourth part the main effects of N fertilization, cultivars and their interactions were determined by analyses of variance according to the split-plot design. In the analyses the N fertilization (the main plot factor) and cultivars (subplot factor) were analyzed as the fixed-effects factor and replications, year and location as random effects. In general, when multiple-comparison procedures were needed in all parts, Tukey's HSD method or t-type contrast examination with 95% confidence intervals was used.

Before performing analysis of variance, assumptions of group variances were checked in Box-Cox diagnostic plots. In addition the normality assumption of errors was assessed with stem-and-leaf display and normal probability plot. Analyses were performed by means of the SAS statistical package. The MIXED, UNIVARIATE and GPLOT procedures were used.

The effects of year, location, and cultivar were tested with analyses of variance using the Statistica programme. The effects of year were tested also separatetely for different cultivars using the analyses of variance.

Results and discussion

The β-glucan contents of the cultivars in the official variety trials are shown in Table 3. Significant differences ($P < 0.0001$) were found between the cultivars tested with analysis of variance. The highest average β-glucan contents (LSMeans) were found in cultivars Leila and Roope. 'Kolbu' had significantly lower β-glucan contents than other oat cultivars. The rather high β-glucan content of 'Roope' and the low content of 'Kolbu' were also reported previously (Saastamoinen 1999). There were significant differ-

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ences in the average β-glucan contents of oats between the years (Table 3). The effect of year was greater in some cultivars; e.g. Kolbu and Veli had significantly lower β-glucan contents during the cool rainy weather of 1998 than in the warm years of 1997 and 1999 (Table 3). Location significantly affected the β-glucan contents, when shown with one-way analyses of variance, as did the year x location x trial interaction when tested with analyses of covariance.

The β-glucan contents of the cultivars in the N fertilization trials during 1997–1999 are shown in Table 4. In these trials 'Kolbu' had significantly lower β-glucan contents than 'Aarre', 'Katri' and 'Salo', as shown by analyses of variance (Table 4). N fertilization did not significantly affect the β-glucan contents (Table 5). The cultivars significantly affected the β-glucan contents, but the cultivar vs. N-level interaction did not, as shown with two-way analyses of variance (Table 5). Year, location and cultivar significantly affected the variation in β-glucan content of oats (Table 5), as did the year x location and year x cultivar interactions (Table 5). 'Kolbu' had significantly lower β-glucan contents in 1998 than in 1997 and 1999.

N fertilization increased the oat yields (unpublished results), but not the β-glucan contents, probably due to the northern climate of Finland. N fertilization has likewise been seen to have no effect on β-glucan content of oats in Finland (Saastamoinen 1995) or in Canada (Humphreys et al. 1994). N fertilization increases the β-glucan contents of cultivated and wild oats under greenhouse conditions (Welch et al. 1991). Foliar feeding of urea was found to increase the β-glucan content of oats by 0.17%, giving an average β-glucan yield increase of 20 kg ha^{-1} in the United Kingdom (Weightman et al. 2001). N fertilization increases the β-glucan contents of barley in Denmark (Sorensen and Truelsen 1985) and the β-glucan contents of wheat in Turkey (Guler 2003). Heavy N fertilization causes later maturity of oats in Finland where weather conditions are often more favourable earlier in the summer.

The differences in β-glucan content between cultivars were shown to be significant in organic variety trials tested by analyses of variance (Table 6). 'Kolbu' had significantly lower β-glucan contents than other oat cultivars. The differences between the other cultivars were not significant, although they were more so in official variety trials than in organic variety trials (Tables 3 and 6). 'Aarre', 'Yty' and 'Puhti' had higher β-glucan contents than 'Leila' and 'Roope' in the organic variety trials. It was also shown that the β-glucan content of 'Yty' is rather high (Saastamoinen et al. 1992b, Saastamoinen 1999). The rather high β-glucan content of 'Roope' and 'Aarre' and the low content of 'Kolbu' have also been reported (Saastamoinen 1999). There were no significant differences in β-glucan contents of 'Puhti' and 'Veli' in conventional trials of the organic trial series (Table 6). The cultivation method did not significantly affect the β-glucan contents of oats (Table 6).

The relative amounts of the β-glucan contents of the oat cultivars were in general constant for different years, cultivation methods and locations, which is an indication of the extensive genetic regulation of β-glucan synthesis in oats. It has been widely reported that the effect of genotype on β-glucan content of oats is significant (Lim et al. 1992, Saastamoinen et al. 1992a, b, Doehlert et al. 2001) and that the β-glucan content of cultivated oats (*Avena sativa* L.) is a quantitatively inherited trait influenced by several genes (Baur and Geisler 1996, Kianian et al. 2000, Cervantes-Martinez et al. 2001). Extremely high β-glucan contents (up to 11.3%) have been found in wild oat species (Welch et al. 2000).

In the organic trial series, cultivation practice did not significantly affect the β-glucan contents of Puhti and Veli cultivars, which were cultivated by conventional and organic systems (Table 7). The effect of cultivar was significant, but the cultivar x cultivation method interaction resulted in no significant effects (Table 7). The average β-glucan content in organic cultivation was, however, slightly higher than that seen in conventional cultivation (Table 6), but the effect of cultivation method was not significant (Tables 6 and 7). The year significantly affected the

Table 3. β-Glucan contents (% from d. m.) of groats of oat cultivars in official variety trials.

Cultivar	Year 1997					Year 1998					Year 1999					LSMeans	SEM	Significance P < 0.0001	Year difference F-test (P-value)
	n	Mean	Max	Min	s.d.	n	Mean	Max	Min	s.d.	n	Mean	Max	Min	s.d.				
Leila	9	5.21	5.96	3.57	0.75	11	5.24	6.14	4.61	0.44	13	5.16	5.81	4.67	0.39	5.28	0.085	a	0.932
Roope	8	5.51	5.94	5.06	0.33	7	5.32	6.40	4.46	0.65	6	4.92	5.46	4.27	0.46	5.27	0.096	a	0.109
Belinda	9	5.25	5.87	4.36	0.52	10	5.10	5.75	4.60	0.39	6	4.99	5.43	4.55	0.34	5.12	0.091	ab	0.523
Salo	9	5.38	6.64	4.42	0.59	10	5.05	5.97	4.54	0.46	13	4.91	5.75	3.58	0.61	5.07	0.085	ab	0.165
Veli	9	5.32	6.17	4.88	0.39	11	4.83	5.45	4.43	0.33	13	4.84	5.96	4.20	0.54	4.98	0.084	b	0.032
Kolbu	8	4.38	4.57	4.14	0.18	6	3.44	3.92	3.03	0.31	8	4.02	4.73	3.62	0.38	4.06	0.095	c	0.000
Year mean		5.18					4.91					4.84							0.011

F-test (2-way)	F-value	P value	F-test (1-way)	F-value	P value	Covariance:	Z-value	P value
Year	9.79	0.0001	Location	3.18	0.0015			
Cultivar	24.08	0.0000				Year x Location x Trial	3.38	0.0004
Year x Cultivar	1.44	0.1693						

n = number of trials
LSMeans = least square means
SEM = standard error of means
Significance: a, b, c cultivars marked with different letters differ significantly from each others

Table 4. β-Glucan contents of oat cultivars in nitrogen fertilization trials.

Cultivar	n	Year 1997 N fertilization, kg/ha					Year 1998 N fertilization, kg/ha					Year 1999 N fertilization, kg/ha					LSMeans	SEM	Year Difference F-test P-value
		0	40	80	120	160	0	40	80	120	160	0	40	80	120	160			
Aarre	2	5.15	5.20	5.15	5.20	5.35	5.26	5.11	5.13	5.13	5.38	5.04	5.25	5.32	5.13	5.38	5.19	0.092 a	0.966
Katri	2	4.92	4.92	5.11	4.96	5.17	5.17	5.06	5.30	5.42	5.00	5.05	5.00	5.33	5.42	5.00	5.11	0.092 a	0.409
Salo	2	5.16	5.09	5.15	5.22	5.21	4.92	4.99	5.10	4.77	4.93	5.34	5.06	5.18	4.77	4.93	5.11	0.092 a	0.145
Kolbu	2	4.17	4.27	4.20	4.24	4.17	3.70	3.69	3.53	3.79	3.73	4.41	4.38	4.23	3.79	3.73	4.08	0.092 b	0.000
Year mean		4.85	4.87	4.90	4.90	4.97	4.76	4.71	4.76	4.77	4.76	4.96	4.92	5.01	4.77	4.76			0.440

n = number of trials
LSMeans = least square means
SEM = standard error of means
Significance: a, b cultivars marked with different letters differ significantly from each others

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Table 5. Average calculated β-glucan contents (LSMeans) of oat groats for N fertilization levels over 4 cultivars and 3 years and effects of year, cultivar, N fertilization and location on β-glucan content of oat groats.

	β-Glucan content, % N fertilization, kg/ha				
	0	40	80	120	160
LSMeans	4.85	4.82	4.89	4.87	4.91
SEM	0.094	0.094	0.094	0.094	0.094

Effects: F-test (2-way) Factors:	P-value
Cultivar	<0.0001
N level	0.790
Cultivar x N level	0.940

Effects: F-test (3-way) Factors:	d.f.	F-value	P-value
Year	2	4.267	0.017
Location	1	5.605	0.020
Cultivar	3	153.989	0.000
Year x Location	2	3.277	0.042
Year x Cultivar	6	3.828	0.002
Location x Cultivar	3	0.600	0.616
Year x Location x Cultivar	6	1.454	0.202

LSMeans = least square means
SEM = standard error of means

β-glucan content of oat cultivars in both organic and conventional trial series (Table 7) and in most cultivars under organic cultivation (Table 6). The year effect was significant on the β-glucan content of 'Puhti' in conventional trials of the organic trial series (Table 6). The year x location interaction was statistically significant in organic trials tested by analyses of covariance (Table 6).

The effect of year was greater in organic trials than in the official trials; e.g. in the rainy year 1998 the average β-glucan contents were much lower than in the warm year of 1997 (Tables 3 and 6). The Puhti and Veli cultivars differed, however, in their reaction to the year effect: in the former the effect was significant in conventional trials and in the latter it was significant in the organic trials (Table 6). The year x cultivar interactions were not significant, however (Table 7). It was found that the β-glucan content is dependent on the mean temperature of the growing period for oats in Finland (Saastamoinen 1995). High growth period temperature increases (Saastamoinen et al. 1992b, Miller et al. 1993, Saastamoinen 1995) and high precipitation decreases the β-glucan content of oats (Miller et al. 1993). It was also found in barley that high precipitation decreases several factors, especially viscosity, which correlates positively with the water-soluble β-glucan content (Aastrup 1979). Accumulated temperatures to 25°C and 30°C and precipitation and days with rain during seed development were significant factors influencing the β-glucan content of barley (Zhang et al. 2001). In some studies the effect of year on β-glucan content of oats was significant (Saasta-

Table 6. β-Glucan contents of oat cultivars in organic and conventional trials in 1997 and 1998.

Cultivar	1997					1998					LSMeans	SEM	Significance (P-value)	Year effect F-test (P-value)
	n	Mean	Max	Min	s.d.	n	Mean	Max	Min	s.d.				
Conventional trials														
Puhti	5	5.87	6.23	5.64	0.24	5	4.82	5.55	3.27	0.91	5.37	0.391	n. s.	0.038
Veli	5	5.13	5.91	4.48	0.63	5	4.42	5.08	3.04	0.82	4.94	0.391	n. s.	0.157
Year mean		5.50						4.62						
Organic variety trials													P < 0.0001	
Aarre	5	5.87	6.6	5.12	0.54	5	5.15	5.47	4.49	0.40	5.52	0.161	a	0.044
Yty	5	5.75	6.41	5.20	0.47	5	5.37	5.72	4.97	0.28	5.50	0.161	a	0.165
Puhti	6	5.61	6.43	5.04	0.49	6	5.20	5.94	3.83	0.72	5.40	0.156	a	0.271
Leila	6	5.58	6.23	5.00	0.43	6	5.12	5.40	4.93	0.22	5.35	0.156	a	0.040
Roope	6	5.68	5.92	5.33	0.22	6	4.85	5.52	4.41	0.40	5.26	0.156	a	0.001
Katri	6	5.51	5.93	5.20	0.29	5	4.82	5.31	4.09	0.47	5.16	0.158	a	0.016
Veli	6	5.49	5.96	5.19	0.28	6	4.76	5.37	3.83	0.58	5.12	0.156	a	0.019
Kolbu	6	4.52	4.68	4.43	0.10	6	3.51	3.89	3.07	0.32	4.01	0.156	b	0.000
Year mean		5.49						4.94						
Effects:														
Conventional											5.06	0.392	n. s.	
Organic											5.24	0.392	n. s.	

n = number of trials
s.d. = standard deviation
LSMeans = least square means
SEM = standard error of means
a, b = differences between cultivars marked by different letters are statistically significant
n.s. = not significant

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Table 7. Effects of cultivation method, year, cultivar and location in organic trials.

Test	Type of cultivation	Factor	d.f.	F-value	P- value
F-test (3-way)	Organic/ Conventional	Year	1	15.25	0.000
		Cultivar	1	5.22	0.028
		Cultivation method	1	1.17	0.287
		Year x Cultivar	1	0.00	0.996
		Year x Cultivation method	1	0.69	0.413
		Cultivar x Cultivation method	1	0.60	0.444
		Year x Cultivar x Cultivation method	1	0.75	0.393
F-test (2-way)	Organic	Year	1	56.16	0.000
		Cultivar	7	16.46	0.000
		Year x Cultivar	7	0.83	0.568
F-test (1-way)	Organic	Location	5	1.41	0.230
Covariance test	Organic			Z-value	
		Year x Location		2.22	0.013

moinen et al. 1992b, Miller et al. 1993) in contrast to other studies (Lim et al. 1992). The genotype x environment interaction significantly affected the β-glucan content of oats in many studies (Cervantes-Martinez et al. 2001, Doehlert et al. 2001).

The average β-glucan contents of oat cultivars in the organic cultivation trials were much lower in 1998 compared with 1997 than in the official variety trials (Tables 3 and 6). The significantly lower average β-glucan content of oats during the organic cultivation trials in 1998 compared with 1997 may be partially explained by the normally lower availability of N in the organic cultivation compared with conventional cultivation methods, the high leaching of N from the soil during periods of heavy rain and the later maturation of oats in the organic cultivation compared with conventional cultivation methods.

In conclusion, β-glucan content of oat is very much dependent on the genotype. The differences between oat cultivars are small but consistant. 'Kolbu' has lower β-glucan content than other cultivars studied. 'Kolbu' is more suitable for feed than for human consumption. N fertilization had no significant effect on β-glucan content of oats in Finland. Cultivation method, traditional vs. organic farming, had no significant effect on β-glucan content of oats in Finland. β-Glucan contents of oat cultivars were dependent on year and location.

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SELOSTUS

Kauran ytimen β-glukaanipitoisuus

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Kauran β-glukaani on terveyttä edistävä ravintokuituyhdiste, joka alentaa veren kolesterolia ja alentaa ja tasaa veren sokeria. Kauran ytimen β-glukaanipitoisuuden vaihtelua tutkittiin kauran virallisissa lajikekokeissa ja N-lannoituskokeissa vuosina 1997–1999 sekä luomulajikekokeissa vuosina 1997–1998 useilla lajikkeilla.

Luomulajikekokeissa kasvatettiin kahta lajiketta, Puhtia ja Veliä, myös ns. tehokokeissa normaalilla viljelymenetelmällä samoilla lohkoilla luomukokeiden kanssa. Vuodet 1997 ja 1999 olivat kuivia ja lämpimiä, ja vuosi 1998 viileä ja sateinen.

Vuosi ja lajike vaikuttivat β-glukaanipitoisuuteen kaikissa koetyypeissä. Kolbu-lajikkeen β-glukaanipitoisuus oli pienempi kuin muiden kauralajikkeiden kaikissa kokeissa. Suurimmat β-glukaanipitoisuudet olivat virallisissa lajikekokeissa Leilalla ja Roopella, luomulajikekokeissa Aarteella, Ytyllä ja Puhdilla sekä N-lannoituskokeissa Aarteella ja Katrilla. Typpilannoitus ei vaikuttanut kauran β-glukaanipitoisuuteen. Myöskään viljelymenetelmä (perinteinen/luomu) ei vaikuttanut merkitsevästi β-glukaanipitoisuuteen.

Johtopäätöksenä voitiin todeta, että kauran β-glukaanipitoisuus on voimakkaasti riippuvainen lajikkeesta, vuodesta ja kasvupaikasta. Viljelytapa (perinteinen/luomu) ja typpilannoitus eivät vaikuttaneet kauran β-glukanipitoisuuteen.