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Nitrogen and irrigation effects on grain β-glucan content of oats (*Avena sativa* L.)

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Abstract

Oats (*Avena sativa* L.) with high grain β-glucan content may be useful for both human nutrition and animal feeding. The objective of this study was to determine the effects of nitrogen and irrigation levels on oat grain β-glucan content. In this study, higher levels of nitrogen increased oat grain β-glucan content in both years. Nitrogen levels at 100 kg ha^{-1} (N_2) gave the greatest β-glucan content. Increased levels of irrigation tended to decrease grain β-glucan content in oats. Cultivar effect on oat grain β-glucan content was significant. Generally, the "804" line had the highest grain β-glucan content in all treatments. Significant and positive correlations between grain β-glucan content and grain yield, protein content, 1000-grain weight and test weight were observed while a negative correlation between β-glucan content and hull percentage was significant in both years. The results of this study indicated that cultivars and increased nitrogen amounts had a major effect on grain β-glucan content, whereas irrigation had no effect on grain β-glucan content in oats.

Key words: *Avena sativa*; grain quality; grain yield; nutrition status; soil moisture.

Introduction

Oats (*Avena sativa* L.) have been a major crop for human nutrition and animal feeding throughout the world. The use of oats grain as an animal feed has declined steadily (Defra, 2003). However, due to the high dietary fiber content of oats, it has great importance in human nutrition at present. As a major source of dietary fiber, oat grains had much rich β-glucan content (Aman and Graham, 1987). Oat β-glucan is a viscous and soluble dietary fiber component (Anttila et al., 2004). The most important role of β-glucan in human health and nutrition was its cholesterol lowering effect. Maier et al. (2000) reported that fiber supplementation with oat bran in diet caused a lowering of cholesterol levels in humans. Studies with human subjects receiving three grams per day or more of soluble fiber (β-glucan) from oat products demonstrated fivefold greater reductions in total cholesterol than those whose subjects received smaller amounts (Ripsin et al., 1992). In addition, deficiency of dietary fiber causes gastrointestinal and cardiovascular diseases in human (Wisker et al., 1985). For this reason, oats and oat products might be used for preventing such diseases in humans. The quantity and quality of β-glucan of oat grain are primarily associated with genotype and environment. Standard oat (*Avena sativa* L.) cultivars contain 4.5-5.0 % of β-glucan (Chernyshova et al., 2007). Ajithkumar et al (2005) showed that the extractable β-glucan content was a heritable trait whereas Doehlert et al (2001) reported β-glucan was almost equally influenced by environment and by genotype. In addition, β-glucan content appeared to be mainly determined by genotype (Sgrulletta et al., 2002; Peterson et al., 2005). Brunner and Freed (1994) reported genotype × environment interactions in oats. It is known that N amount in soil and N fertilization affect β-glucan content. In particular, N levels in soil and high N fertilizer amounts significantly increased β-glucan contents in oats and barley (Brunner and Freed, 1994; Baur and Geisler, 1996; Weightman et al., 2004). Güler (2010) reported that higher nitrogen levels generally increased durum wheat grain β-glucan content. The other major factor which affects β-glucan content is irrigation. It is reported that increased levels of irrigation tended to decrease grain β-glucan content of barley (Güler, 2003a). Similarly, Güler (2003b) found that irrigation decreased β-glucan content of wheat grain. On the other hand, the β-glucan content of oats was not only dependent on irrigation or rainfall but also on other environmental factors (Peterson et al., 1995). The major findings related to relationships between grain β-glucan content and some traits in cereals were reported in several studies. Many positive correlations were determined between grain β-glucan concentration and grain yield, test weight, and kernel weight (Saastamoinen et al., 1992). Brunner and Freed (1994) generally found low or non-significant correlations between grain β-glucan content and oat grain yield. Similarly, Peterson et al. (1995) reported low or non-significant correlations between β-glucan and grain yield in oats. A positive correlation was found between β-glucan and grain protein content in oats (Brunner and Freed, 1994; Peterson et al., 1995); while Saastamoinen et al. (1992) reported a negative correlation between β-glucan content and grain protein content. No significant correlations between β-glucan and 1000-grain weight were observed in oats (Aman, 1987). On the other hand, Brunner and Freed (1994) and Peterson et al. (1995) generally found low but non-significant correlations between β-glucan content and test weight in oats. Hull percentage had no effect on grain β-glucan content and there was no correlation between β-glucan content and oat hull percentage (Brunner and Freed, 1994). Saastamoinen et al. (1992) detected a few negative correlations between β-glucan concentration and hull

Table 1. Mean grain β-glucan contents of four oat cultivars at different nitrogen and irrigation levels in Turkey

		2004			2005		
		Irrigation treat.			Irrigation treat.		
Cul.	Nit.	I_0	I_1	I_2	I_0	I_1	I_2
C_1	N_0	2.996±0.067	2.900±0.060	2.813±0.077	2.873±0.014	2.803±0.020	2.696±0.053
	N_1	3.016±0.084	2.970±0.046	2.983±0.012	3.003±0.020	2.923±0.024	2.853±0.044
	N_2	3.150±0.062	2.986±0.043	3.033±0.035	3.106±0.020	2.886±0.075	2.870±0.025
C_2	N_0	2.940±0.079	2.963±0.042	2.826±0.031	2.866±0.067	2.873±0.037	2.740±0.028
	N_1	3.140±0.090	3.000±0.103	2.963±0.068	3.050±0.070	2.906±0.061	2.843±0.086
	N_2	3.303±0.073	3.100±0.037	3.026±0.028	3.193±0.046	3.053±0.023	2.950±0.036
C_3	N_0	3.050±0.052	2.980±0.045	2.956±0.055	2.966±0.043	2.910±0.017	2.810±0.017
	N_1	3.210±0.036	3.060±0.058	2.900±0.047	3.120±0.036	2.990±0.055	2.790±0.028
	N_2	3.376±0.063	3.190±0.046	3.056±0.046	3.263±0.050	3.100±0.036	2.970±0.052
C_4	N_0	3.053±0.037	2.946±0.056	2.920±0.043	2.973±0.020	2.923±0.044	2.830±0.023
	N_1	3.230±0.066	3.136±0.057	2.996±0.061	3.116±0.046	3.033±0.038	2.903±0.040
	N_2	3.996±0.014	3.853±0.132	3.757±0.125	3.820±0.066	3.643±0.075	3.446±0.080

C_1=Ankara 76, C_2= Ankara 84, C_3=803, and C_4=804. N_0=no nitrogen; N_1=50 kg ha^{-1}nitrogen; and N_2= 100 kg ha^{-1} nitrogen. I_0=no irrigation;I_1=50 mm irrigation; and I_2=100 mm irrigation.

Table 2. Mean squares from the analysis of variance for grain β-glucan content of oats at different nitrogen and irrigation levels (2004)

Source	df	Mean square
Total	107	-
Rep.	2	0.005
Irrigation (I)	2	0.316
Error *a*	4	0.014
Nitrogen (N)	2	1.336
I × N	4	0.012
Error *b*	12	0.041
Cultivar (C)	3	0.608
I × C	6	0.007
N × C	6	0.340**
I × N × C	12	0.007
Error *c*	54	0.011

df=degrees of freedom. * Significant at $P<0.05$; ** Significant at $P<0.01$

percentage. However, the objectives of this study were to determine the effect of different levels of N and irrigation on grain β-glucan content and to evaluate the relationships between grain β-glucan content and some agronomic and quality traits in oat.

Materials and methods

Experimental design

An experiment was conducted in Ankara, Turkey (39° 52' N 32° 52' E) from 2003 through 2005 in order to investigate the effect of nitrogen and irrigation on oat grain β-glucan content. Soil properties of the location were as follows:soil moisture 17.34%, pH 7.79, $CaCO_3$ 5.9 % and organic matter 1.37%. Planting was done by hand on October 11, 2003 and October 16, 2004. The experiment was laid out with a randomized block, split-split plot design with three replications. Irrigation treatments were the main plots and consisted of three irrigation levels (0, 50 and 100 mm). Three different N levels (0, 50 and 100 kg ha^{-1}) were applied to the subplots. The sub-subplots consisted of two oat cultivars and two lines. Each plot was five m in length and consisted of 12 rows. Diammonium phosphate fertilizer of 150 kg ha^{-1} was given prior to planting for both P and N requirement. The rest of N was given as ammonium nitrate fertilizer in early spring. Nitrogen rates were 0 (N_0), 50 (N_1) and 100 (N_2) kg ha^{-1} N. Each irrigation was made at three growth stages: sowing, jointing and heading.

Plant materials

The two cultivars and two lines used in the study were Ankara 76 (C_1), Ankara 84 (C_2), 803 (C_3) and 804 (C_4) respectively.

Measurements and chemical analysis

In this study, test weight was measured using a 1-L volumeter (Özkaya and Kahveci, 1990). Grain protein content was determined by the Kjeldahl method given by AACC (American Association of Cereal Chemists 1969) on a dry weight basis. For β-Glucan analysis, the McCleary Enzymic Method (McCleary and Codd, 1991) was used and results of β-Glucan contents are reported on a dry basis in the study.

Table 3. Effect of different nitrogen and irrigation levels on grain β-glucan content of oats (2004)

Cultivars	N_0	N_1	N_2
C_1	2.903±0.043 a B	2.990±0.028 b AB	3.056±0.034 c A
C_2	2.910±0.034 a C	3.034±0.051 ab B	3.143±0.048 bc A
C_3	2.995±0.029 a B	3.056±0.050 ab B	3.207±0.053 b A
C_4	2.973±0.030 a C	3.121±0.046 a B	3.868±0.063 a A

C_1=Ankara 76, C_2= Ankara 84, C_3=803, and C_4=804. N_0=no nitrogen; N_1=50 kg ha^{-1}nitrogen; and N_2= 100 kg ha^{-1} nitrogen. *a-c* Lower-case letters indicate significance between cultivars at each nitrogen level at $P<0.05$ *A-C* Upper-case letters indicate significance between nitrogen levels at each cultivar at $P<0.05$

Table 4. Mean squares from the analysis of variance for grain β-glucan content of oats at different nitrogen and irrigation levels (2005)

Source	df	Mean square
Total	107	-
Rep.	2	0.014
Irrigation (I)	2	0.438
Error *a*	4	0.003
Nitrogen (N)	2	1.065
I × N	4	0.018
Error *b*	12	0.024
Cultivar (C)	3	0.455
I × C	6	0.004
N × C	6	0.209**
I × N × C	12	0.003
Error *c*	54	0.005

df=degrees of freedom. * Significant at $P<0.05$; ** Significant at $P<0.01$

Table 5. Effect of different nitrogen and irrigation levels on grain β-glucan content of oats (2005)

Cultivars	N_0	N_1	N_2
C_1	2.791±0.030 c B	2.926±0.026 b A	2.954±0.044 c A
C_2	2.826±0.032 bc C	2.933±0.047 b B	3.065±0.039 b A
C_3	2.895±0.027 ab B	2.966±0.052 ab B	3.111±0.048 b A
C_4	2.908±0.026 a C	3.017±0.037 a B	3.636±0.065 a A

C_1=Ankara 76, C_2= Ankara 84, C_3=803, and C_4=804. N_0=no nitrogen; N_1=50 kg ha^{-1}nitrogen; and N_2= 100 kg ha^{-1} nitrogen. *a-c* Lower-case letters indicate significance between cultivars at each nitrogen level at $P<0.05$. *A-C* Upper-case letters indicate significance between nitrogen levels at each cultivar at $P<0.05$

Table 6. Correlation coefficients between grain β-glucan content and grain yield, protein content, 1000-grain weight, test weight and hull percentage of oats, in 2004 and 2005

Variable	2004	2005
Grain yield	0.306**	0.230*
Protein content	0.507**	0.521**
1000-grain weight	0.296**	0.499**
Test weight	0.334**	0.327**
Hull percentage	-0.308**	-0.288**

* Significant at $P<0.05$; ** Significant at $P<0.01$

Statistical analysis

Analysis of variance (ANOVA) was done separately for each year. Duncan's Multiple Range Test was used at the 5% level of probabilty to test differences between treatment means. Correlation coefficients were calculated between grain β-Glucan content and yield and other grain characteristics.

Results and discussion

Grain β-glucan content in 2004

Mean grain β-glucan content values for both years were presented in Table 1 and mean grain β-glucan content in oats in 2004 was greater than in 2005. Significant differences were observed between treatments in grain β-glucan content in both years. The effect of both nitrogen and cultivar was significant and the nitrogen × cultivar interaction was significant for β-glucan content in 2004 (Table 2). The differences between N levels were separately evaluated for each cultivar. Higher N amounts generally increased grain β-glucan content of oats (Table 3). For Ankara 76 (C_1), the greatest grain β-glucan content was determined by the N_2 and N_1 treatments. Similarly, high N levels (N_2) produced the greatest grain β-glucan contents for the other three cultivars. Non-nitrogen treatment (N_0) had the lowest β-glucan contents in all cultivars. No significant differences were observed among cultivars at the N_0 level in grain β-glucan content of oats. The highest grain β-glucan content was generally obtained from 804 line (C_4) for N_1 and N_2 treatments (Table 3).

Grain β-glucan content in 2005

In the second year, nitrogen × cultivar interaction was significant (P<0.01) (Table 4). The differences between treatments are presented in Table 5. Significant differences between N levels were found for each cultivar. The N_2 and N_1 treatments gave the best results in grain β-glucan content for Ankara 76 (C_1). For the other three cultivars or lines (C_2, C_3 and C_4), the highest values of grain β-glucan content were achieved by N_2. The lowest grain β-glucan content was obtained from the N_0 level for all cultivars. There were significant differences between cultivars at N_0 nitrogen level and the C_4 and C_3 lines had the greatest grain β-glucan contents at N_0. Similarly, the greatest grain β-glucan contents were obtained from the C_4 and C_3 lines for the N_1. 804 line (C_4) produced the best grain β-glucan content at the N_2 treatment while Ankara 76 (C_1) had the lowest value of grain β-glucan content at N_2. The values of grain β-glucan content in this study varied depending on cultivar and N between years. Significant differences were determined among cultivars in grain β-glucan content in both years. These findings are similar to the reports of several authors (Ajithkumar et al., 2005; Sgrulletta et al., 2002; Peterson et al., 2005). The response of grain β-glucan content to N was highly significant. Increased N levels positively affected grain β-glucan content at three irrigation levels for all cultivars. Our results are in agreement with the findings of Brunner and Freed (1994), Baur and Geisler (1996), Weightman et al. (2004) and Güler (2010). Higher irrigation levels usually decreased grain β-glucan content in oats though irrigation effect on β-glucan content was statistically non-significant. These findings are similar to the results of Güler (2003a,b). Consistent correlations between grain β-glucan content and some traits must be known for higher grain yield and quality in oats. Correlation coefficients

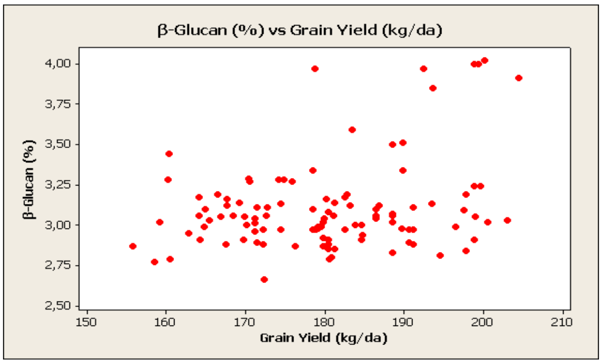

Fig 1. Correlation coefficient between grain β-glucan content and grain yield in oats (2004)

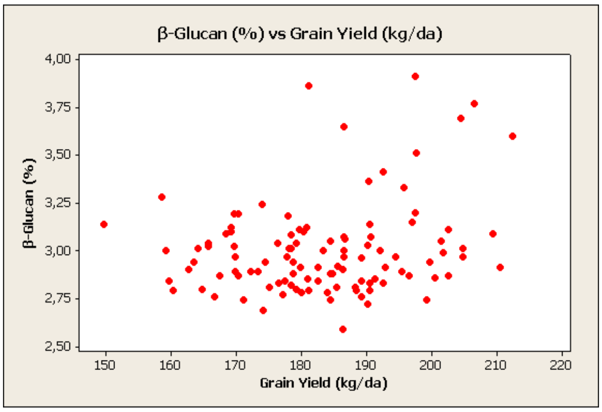

Fig 2. Correlation coefficient between grain β-glucan content and grain yield in oats (2005)

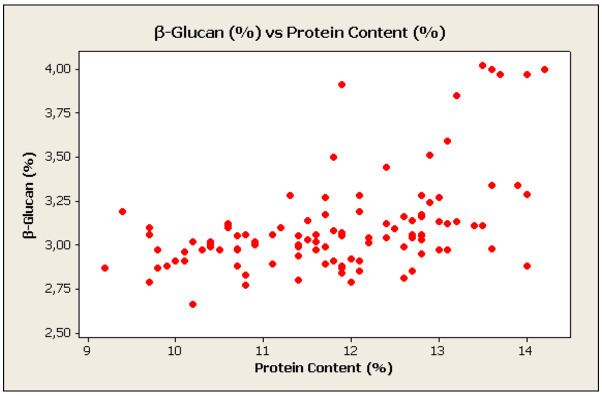

Fig 3. Correlation coefficient between grain β-glucan content and protein content in oats (2004)

between grain β-glucan content and some important traits are presented in Table 6. Significant and positive correlations were found between grain β-glucan content and grain yield in 2004 (P<0.01) and 2005 (P<0.05) (Fig 1 and fig 2). Our grain yield correlations differed with the results of Brunner and Freed (1994) and Peterson et al. (1995). Positive and significant correlations (P<0.01) between grain β-glucan content and protein content were observed in both years (Fig 3 and fig 4). These findings are similar to the results of Brunner and Freed (1994) and Peterson et al. (1995) but are not in agreement with those of Saastamoinen et al. (1992). 1000- grain weight had positive and significant correlation with grain β-glucan content (Fig 5 and fig 6). Our correlation coefficients related to 1000 - grain weight are not in

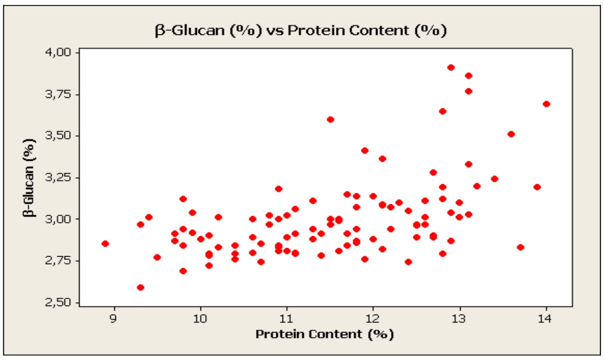

Fig 4. Correlation coefficient between grain β-glucan content and protein content in oats (2005)

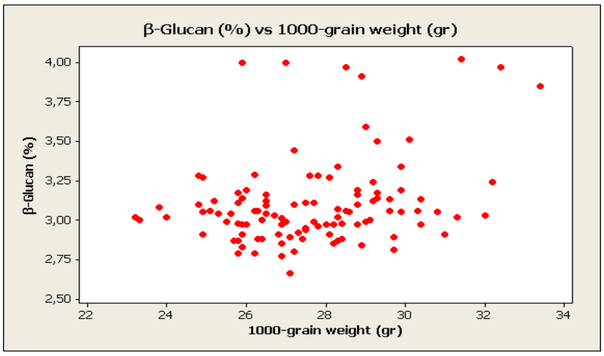

Fig 5. Correlation coefficient between grain β-glucan content and 1000-grain weight in oats (2004)

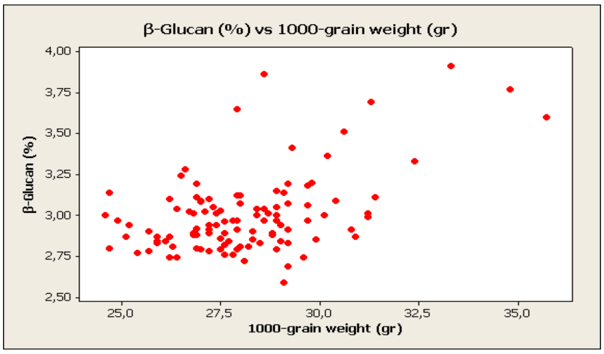

Fig 6. Correlation coefficient between grain β-glucan content and 1000-grain weight in oats (2005)

agreement with Aman (1987). Positive and significant correlations between grain β-glucan content and test weight were found for both years (Fig 7 and fig 8). These results are similar to the findings of Saastamoinen et al. (1992), but are not in agreement with several studies (Brunner and Freed, 1994; Peterson et al., 1995). For hull percentage, negative and significant correlations ($P<0.01$) between grain β-glucan content and hull percentage were detected in 2004 and 2005 (Fig 9 and fig 10), while Brunner and Freed (1994) reported that there are no significant correlations between hull percentage and grain β-glucan content. Saastamoinen et al. (1992) also found negative correlations between β-glucan concentration and hull percentage. Since significancy of correlation coefficients depended on samples ranges (Lentner, 1982) the values of correlation coefficients between

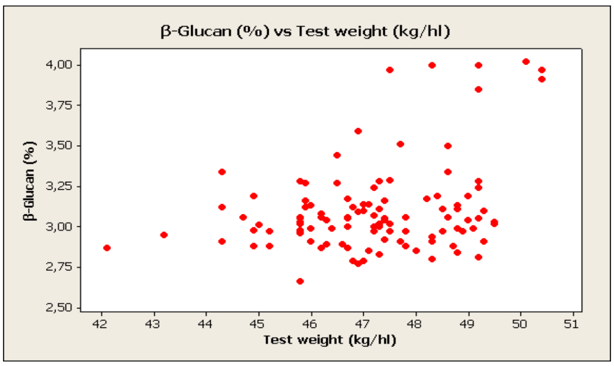

Fig 7. Correlation coefficient between grain β-glucan content and test weight in oats (2004)

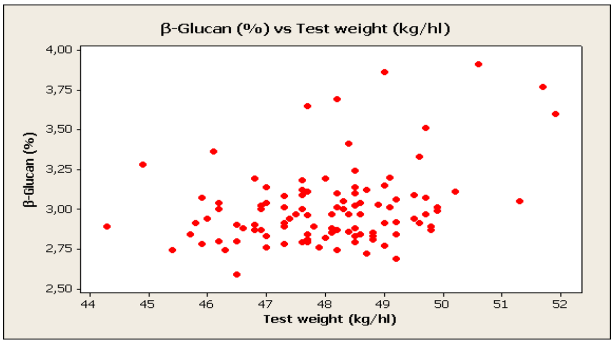

Fig 8. Correlation coefficient between grain β-glucan content and test weight in oats (2005)

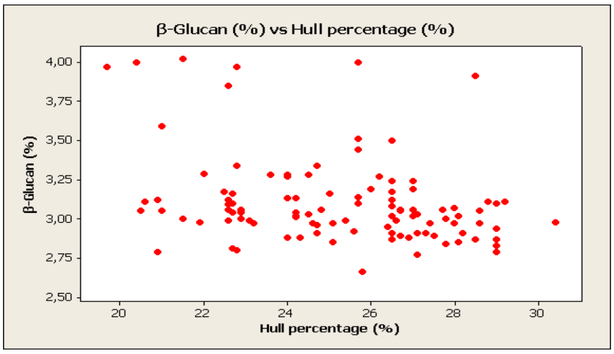

Fig 9. Correlation coefficient between grain β-glucan content and hull percentage in oats (2004)

grain β-glucan content and some important traits were varied between $r=-0.308^{**}$ and $r=0.521^{**}$ in both years.

Conclusion

Oat genotypes and N levels affected grain β-glucan content in oats. No irrigation effect was statistically deteched in this study. However, increased irrigation levels decreased oat grain β-glucan content and the greatest β-glucan values were determined by non-irrigated treatments. Grain β-glucan contents of cultivars varied depending on years. Higher N levels positively affected grain β-glucan content, and the greatest grain β-glucan contents were generally obtained from 100 kg ha^{-1} N application. Higher nitrogen rates (> 50 kg ha^{-1} N) should be recommended for increased grain β-glucan content in oats for hum an nutrition. Since high irrigation

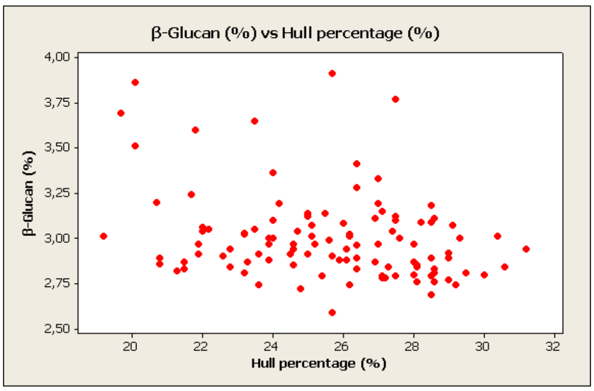

Fig 10. Correlation coefficient between grain β-glucan content and hull percentage in oats (2005)

levels decreased grain β-glucan content in oats, excessive irrigations should be avoided at the generative growth stage in oat cultivation. In addition, the relationships between grain β-glucan content and some agronomic and quality traits should be considered for oat breeding programs.

References

Ajithkumar A, Andersson R, Aman P (2005) Content and molecular weight of extractable β- glucan in American and Swedish oat samples. J Agric Food Chem 53: 1205-1209.

Aman P (1987) The variation in chemical composition of Swedish oats. Acta Agric Scand 37: 347-352.

Aman P, Graham H (1987) Analysis of total and insoluble mixed-linked (1→3), (1→4)-ß-D- glucans in barley and oats. J Agric Food Chem 35: 704-709.

American Association of Cereal Chemists (1969). AACC Standard No, 46-10.

Anttila H, Sontag-Strohm T, Salovaara H (2004) Viscosity of β-Glucan in oat products. Agric and Food Sci 13: 80-87.

Baur SK, Geisler G (1996) β-Glucan content in caryopses of oat varieties with regard to cultivation year and nitrogen level. J Agron Crop Sci 176: 5-14.

Brunner BR, Freed RD (1994) Oat grain β-glucan content as affected by nitrogen level, location, and year. Crop Sci 33: 473-476.

Chernyshova AA, White PJ, Scott MP, Jannink JL (2007) Selection for nutritional function and agronomic performance in oat. Crop Sci 47: 2330-2339.

Defra (2003) DEFRA, Department for Environment, Food and Rural Affairs, Statistics on Raw Materials Usage in the Production of Animal Feedstuffs by GB Retail Compounders http://www.defra.gov.uk/esg/Excel/hstcomps.xls.

Doehlert DC, McMullen M, Hammond JJ (2001) Genotypic and environmental effects on grain yield and quality of oat grown in North Dakota. Crop Sci 41: 1066-1072

Güler M (2003a) Barley grain β-glucan content as affected by nitrogen and irrigation. Field Crops Res 84: 335-340.

Güler M (2003b) Nitrogen and irrigation effects on β-glucan content of wheat grain. Acta Agric Scand Sect B Soil and Plant Sci 53: 156-160.

Güler M (2010) The effect of different nitrogen and irrigation levels on grain β-glucan content in some durum wheat cultivars. Turk J Agric For 34: 101-108.

Lentner C (1982) Introduction to statistics, statistical tables, mathematical formulae. *In*: Lentner, C. (Ed.), Geigy Scientific Tables, vol. 2. Ciba-Geigy Limited, Basle, Switzerland. p.63.

Maier SM, Turner ND, Lupton JR (2000) Serum lipids in hypercholesterolemic men and women consuming oat bran and amaranth product. Cereal Chem 77: 297-302.

McCleary BV, Codd R (1991) Measurement of (1→3), (1→4)-ß-D-glucan in barley and oats: a streamlined enzymic procedure. J Sci Food Agric 55: 303-312.

Özkaya H, Kahveci B (1990) Tahıl ve ürünleri analiz yöntemleri. Gıda Teknolojisi Derneği Yayınları 11, 152s., Ankara.

Peterson DM, Wesenberg DM, Burrup DE (1995) β-glucan content and its relationship to agronomic characteristics in elite oat germplasm. Crop Sci 35: 965-970.

Peterson DM, Wesenberg DM, Burrup DE, Erickson CA (2005) Relationship among agronomic traits and grain composition in oat genotypes grown in different environments. Crop Sci 45: 1249-1255.

Ripsin CM, Keenan JM, Jacobs DR, Elmer PJ, Welch RR, Van Horn L, Liu K, Thurnbull WH, Thye FW, Kestin M, Hegsted M, Davidson DM, Davidson MH, Dugan LD, Demark-Wahnefried W, Beling S (1992) Oat products and lipid lowering. J Am Med Assoc 267: 3317-3325.

Saastamoinen M, Plaami S, Kumpulainen J (1992) Genetic and environmental variation in β-glucan content of oats cultivated or tested in Finland. J Cereal Sci 16: 279-290.

Sgrulletta D, De Stefanis E, Redaelli R, Biancolatte E, Berardo N (2002) β-glucan and hull fibre content in oat cultivars grown under different agronomic conditions. *In* W Pfannhaueser et al (Ed), Biologically active phytochemicals in food Royal Soc of Chemistry, London. pp. 36-39.

Weightman RM, Heywood C, Wade A, South JB (2004) Relationship between grain (1→3), (1→4)-beta-D-glucan concentration and the response of winter-sown oats to contrasting forms of applied nitrogen. J Cereal Sci 40: 81-86.

Wisker E, Feldheim W, Pomeranz Y, Meuser F (1985) Dietary fiber in cereals. *In*: Pomeranz, Y. (Ed.), Advances in Cereal Science and Technology, vol. 7. Am Assoc Cereal Chem, Inc., Minnesota, USA. pp. 169-238.