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Araştırma Makalesi (Research Article)

β-Glucan Content and Relationships to Some Agronomical and Quality Characters in Oat (*Avena sativa* L.)

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Abstract

The β-glucan of oat is recommended for lowering cholesterol level in human nutrition. The main objective of this research is to determine the selection criteria for increased β-glucan in oat breeding. Fifty oat genotypes were evaluated for β-glucan content in two different yield trials during 2010 and 2011 growing seasons in Aegean Agricultural Research Institute (AARI).Experimental designs were completely randomized block design with four replications in both trials. The data of β-glucan and related traits were evaluated to analyze the correlation, path and stepwise regression. The correlation coefficients between β-glucan content and number of spikelet/panicle, number of grain/panicle, starch rate and hull rate were negatively significant, while β-glucan showed significant positive correlations with thousand kernel weight, plant height, harvest index, oil rate, protein rate and ash rate. The results of path analysis showed that the greatest positive direct effects were ash rate and number of grain/panicle. The stepwise regression analysis verified that ash and oil rate, test weight had marked increasing effects on β-glucan. As a result of all analysis, selection plants with higher ash rate and lower number of spikelet/panicle are needed to be increased for higher β-glucan content

Keywords: Oat, β-glucan content, yield, quality, correlation, stepwise analysis

Yulafta (*Avena sativa* L.) Bazı Agronomik ve Kalite Özellikleri ile β-Glukan İçeriği Arasındaki İlişkiler

Öz

Yulafın beta glukan içeriği insan beslenmesinde kolesterol düzeyini azaltmak için önerilmektedir. Bu araştırmanın amacı, yulaf ıslahında beta glukan oranını arttırmak için seleksiyon kriterlerini belirlemektir. Ege Tarımsal Araştırma Enstitüsünde 2010 ve 2011 yıllarında yürütülen denemelerde beta glukan ve diğer tarımsal ve kalite özeliklerini belirlemek için 50 genotip değerlendirilmiştir. Çalışmada, deneme deseni olarak dört tekerrürlü Tesadüf Blokları Deneme Deseni kullanılmıştır. İncelenen özelliklere ilişkin veriler korelasyon, path ve aşamalı regresyon analizi ile değerlendirilmiştir. Beta glukan içeriği ile salkımda başakçık sayısı, salkımda tane sayısı, nişasta ve kavuz oranı arasında önemli negatif yönde korelasyon tespit edilirken, bin tane ağırlığı, bitki boyu, hasat indeksi, yağ oranı, protein oranı ve kül oranı arasında önemli pozitif yönde korelasyon bulunmuştur. Path analizi sonuçlarında beta glukan ile doğrudan etkiler incelendiğinde kül oranı ve salkımda tane sayısı özellikleri en yüksek olumlu yönde değer göstermiştir. Kül oranı, yağ oranı ve hektolitre ağırlığının beta glukan üzerinde arttırıcı etkileri stepwise regresyon analizi ile doğrulanmıştır. Tüm analiz sonuçlarına göre, daha yüksek beta glukan içeriği için yüksek kül oranı ve salkımda düşük başakçık sayısı kriterlerinin seleksiyon ölçütü olarak kullanılabileceği bulunmuştur.

Anahtar Kelimeler: Yulaf, β-glukan içeriği, verim, kalite, korelasyon, stepwise analizi

Introduction

Oat is a type of cool-climate grain, which is used for animal forage, human food, pharmaceutical and cosmetic industry. Its most common use is for animal nutrition. Oat grain, which is very good animal forage, is especially used for feeding cattle, sheep, poultry and horses. Oats in human nutrition and other applications in-use today are becoming

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increasingly widespread. Compared with other grains, oat is reported to have high fiber content and high ratio of oil and protein content as well as being rich in terms of mineral substances. β-glucan, a viscous and soluble dietary fiber component of oat, which is polysaccharide with no starch, was found to reduce blood cholesterol and blood glucose levels (Tsikitis et al., 2004; Tiwari and Cummins 2009). For these reasons, oats with higher β-glucan ratio should be preferred for human and animal nutrition (poultry excluded).

To reach higher β-glucan content in breeding studies, the relationships among characters were determined (Kapoor et al., 2011). It was reported that β-glucan content is affected by genetic variability and environmental factors in previous studies with oat genotypes (Havrlentová et al. 2013). Redaelli et al. (2011) found that total β-glucan content was between 2.85 and 6.77% and the soluble fraction from 2.05 to 5.29% in the 658 European oat genotypes. In other study, β-glucan content of oat varieties and breeding lines ranged from 3.85 to 4.31 % for naked oats and 2.49 to 3.52 % for husked oat in grain samples of 102 oat genotypes (Zute et al. 2011).

Cervantes-Martinez et al. (2002) revealed that the presence of oat β-glucan content with yield components and other grain quality traits have high selection potential for greater β-glucan. According to Holthaus et al. (1996) and Kibite and Edney (1998), the relationships between β-glucan content and grain yield was non-significant. Similarly, β-glucan content also non-significant positive correlated with test weight (Peterson et al. 1995).Asp et al. (1992) found positive correlation coefficient between beta-glucan content and insoluble and total dietary fiber but significant negative correlations between beta-glucan content and fat content.

There are few studies about correlations and multiple regression analysis between β-glucan and other agronomical and quality characteristics. Therefore, this study was carried out to determine the relationship between β-glucan ratio with yield and yield components of oat (*Avena sativa* L.) and take these features into consideration for plant breeding by examining their effects on β-glucan ratio with path and stepwise analysis.

Material and Method

This study was carried out as two different oat yield trials (OYT-1 and OYT-2) during 2009-10 and 2010-2011 production periods at the experimental fields at AARI (Aegean Agricultural Research Institute). As research material, 25 genotypes were included in each yield trial. In OYT-1, 20 advanced lines and 5 standard oat varieties, and in OYT-2, 19 advanced lines and 6 standard oat varieties were used with different origins and backgrounds. Totally, 39 different advanced lines and 6 standard oat varieties were tested for yield trial. The source of the material was from the introduction material; imported from abroad by the Aegean Agricultural Research Institute of Plant Genetic Resources Department Headquarters through the National Gene Bank. Standard oat varieties used in this study consisted of a land race (Akyulaf) cultivated in the Aegean Region coastal zone and other registered oat varieties including Apak 2-3, Bozkır 1-5, Checota, Faikbey, Seydişehir and Yeşilköy 330.

In this study, protein, oil, starch, dietary fiber, β-glucan, hull and ash with plant height, grain size, harvest index, panicle length, number of spikelet/panicle, number of grain/panicle, thousand kernel weight, test weight and grain yield criteria were measured. Protein ratio was determined by grain-mill grinding of the post-harvest grains from each parcel and measuring the rate of protein with the Leco FP-328 devise based on Dumas combustion method (Dumas 1831). Oil ratio was found by measuring the grain oil content with the Soxhlet device on the basis of the oil solvent extraction. Starch ratio was determined by grain-mill grinding of the post-harvest grains from each parcel and using ready kits, AOAC 996.11, ratio of dietary fiber; AOAC 991.43, β-glucan ratio with the application of the method of AOAC 995.16 (AOAC 1995). Hull rate of 50 post-harvest grains from each parcel was calculated. Ash content was determined by modifying AACC Method 08-01(AOAC 1995) for oat samples. Plant height was obtained by measuring the distance from ground level to the top of bunches during maturity period whereas; seed size was obtained by calculating the percentage of remaining oats above 2.5 mm. Harvest index was determined by dividing the weight of grain to the total weight of the entire above-ground assembly during the seed maturation period. Panicle length was obtained by measuring and averaging the length of 10 randomly selected panicles from the bottom to the tip of the panicle; the number of spikelet/panicle was obtained by counting and averaging the number of spikelet from 10 panicles; the number of seed/panicle was obtained by blending the resulting particles from 10 panicles, counting and averaging; panicle grain weight was taken by blending 10 panicles and weighing them and taking the average. Thousand kernel weights were found by obtaining grain harvest from each parcel, weighing as 100-counted units with four replications and multiplying the average by 10. Test weight was determined by weighing with the Kettler-AM 600 instrument after harvesting. Grain yield was determined by converting the trial parcel yield to hectare.

The data obtained from this study were subjected to analysis of correlation and path analysis in the TARIST statistical program. The correlation between β-glucan content and other yield parameters, direct effects on β-glucan were evaluated in path analysis according to Singh and Chaudhary (1979) The stepwise regression analysis for β-glucan content was performed using MINITAB-11 software package. It was performed using β-glucan, content as the response variable and other agronomic and quality parameters as predictor variables.

Results and Discussion

For the improvement of higher β-glucan, the correlation, path and step-wise regression analysis are very important in determining indirect selection criteria. Ali et al. (2009) explained that correlation between related characteristics is mostly due to the presence of linkage and pleiotropy. β-glucan content showed positive and significant correlations with grain yield, thousand kernel weight, plant height, harvest index, oil, protein and ash content. These correlations reveal that if mentioned characteristics increases the β-glucan is also increased. β-glucan content and the number of spikelet/panicle, the number of grains/panicle, starches and hull ratio were highly negatively associated (Table 1). The results of correlations are in contradiction with Holthaus et al. (1996); Kibite and Edney (1998) for grain yield but are in accordance with Peterson et al. (1995) for test weight. They reported that the correlation between β-glucan content and grain yield and test weight were non-significant. Cervantes-Martinez et al. (2002) suggested that the selection for higher β-glucan content should be in the direction of increasing the β-glucan content without degrading the grain yield efficiency. Also, our results showed that the correlation coefficient between β-glucan content and grain yield was significantly and positive direction.

Although path coefficient analysis provides an effective way of finding out direct and indirect sources of correlations, many researchers generally evaluated direct effects. The results are given in Table 2 which reveals that the ash rate, grain weight /panicle, oil rate and test weight had the highest and positive direct effects whereas starch content, number of spikelet/panicle and dietary fiber rate showed negatively highest direct effects. Asp et al. (1992) also revealed that the β-glucan was significantly positively correlated with the fat content, and significantly negatively correlated with starch. I was concluded that to increase β-glucan selection in the segregating early population should be for plants having high

Çizelge 1. Correlation coefficients between β-glucan and other traits
Table 1. Beta glukan ve diğer özellikler arasındaki korelasyon katsayıları

	Evaluated characters[1]							
	GY	TW	TKW	PH	GS	HI	PL	NSP
βGR	.117*	.015	.250**	.181**	.018	.242**	-.066	-.236**
	Evaluated characters[1]							
	NGP	GWP	SR	OR	PR	DFR	AR	HR
βGR	-.150**	-.074	-.364**	.460**	.399**	-.037	.645**	-.216**

*,**: Significant at p< 0.05 and 0.01, respectively.

,:Sırasıyla 0.05 ve 0.01 düzeyinde önemli.*

[1]Characters: βGR: β-glucan rate, GY: Grain yield, TW: Test weight, TKW: Thousand kernel weight, PH: Plant height, GS: Grain size, HI: Harvest index, PH: Panicle length, NSP: Number of spikelet panicle, NGP: Number of grain panicle, GWP: Grain weight panicle, SR: Starch rate, OR: Oil rate, PR: Protein rate, DFR: Dietary fiber rate, AR: Ash rate, HR: Hull rate

[1]Özellikler: βGR: Beta glukan oranı, GY: Tane verimi, TW: Hektolitre ağırlığı, TKW: Bin tane ağırlığı, PH: Bitki boyu, GS: Tane iriliği, HI: Hasat indeksi, PH: Salkım boyu, NSP: Salkımda başakçık sayısı, NGP: Salkımda tane sayısı, GWP: Salkımda tane ağırlığı, SR: Nişasta oranı, OR: Yağ oranı, PR: Protein oranı, DFR: Besinsel lif oranı, AR: Kül oranı, HR: Kavuz oranı

Table 2. Direct effects (%) of related characters for βGR in path analysis.
Çizelge 2. Path analizinde beta glukan için ilgili karakterlerin doğrudan etkileri (%)

	Evaluated characters[1]							
	GY	TW	TKW	PH	GS	HI	PL	NSP
βGR	1.082	16.504	-1.353	-16.095	-11.607	-11.093	-3.424	-30.919
	Evaluated characters[1]							
	NGP	GWP	SR	OR	PR	DFR	AR	HR
βGR	-14.529	31.005	-59.046	25.831	1.841	-23.471	53.852	-6.972

[1]Characters: βGR: β-glucan rate, GY: Grain yield, TW: Test weight, TKW: Thousand kernel weight, PH: Plant height, GS: Grain size, HI: Harvest index, PH: Panicle length, NSP: Number of spikelet panicle, NGP: Number of grain panicle, GWP: Grain weight panicle, SR: Starch rate, OR: Oil rate, PR: Protein rate, DFR: Dietary fiber rate, AR: Ash rate, HR: Hull rate

[1]Özellikler: βGR: Beta glukan oranı, GY: Tane verimi, TW: Hektolitre ağırlığı, TKW: Bin tane ağırlığı, PH: Bitki boyu, GS: Tane iriliği, HI: Hasat indeksi, PH: Salkım boyu, NS P: Salkımda başakçık sayısı, NGP: Salkımda tane sayısı, GWP: Salkımda tane ağırlığı, SR: Nişasta oranı, OR: Yağ oranı, PR: Protein oranı, DFR: Besinsel lif oranı, AR: Kül oranı, HR: Kavuz oranı

Table 3. Results of stepwise analysis for β-glucan ratio.
Çizelge 3. Beta glukan oranı için stepwise analiz sonuçları

	Prediction	St. error	t value
Determination coefficient	4.37		
Ash rate	0.39	0.02	16.84**
Starch rate	-0.17	0.02	-7.83**
Oil rate	0.18	0.02	9.43**
Dietary fiber rate	-0.07	0.02	-3.54*
Number of spikelet/panicle	-0.07	0.02	-3.70*
Test weight	0.05	0.02	2.89*

*,**: Significant at p< 0.05 and 0.01, respectively.

,:Sırasıyla 0.05 ve 0.01 düzeyinde önemli*

grain weight/panicle and number of spikelet/panicle as morphological traits of plants. In further generations and selection of variety, high ash content, oil rate and test weight and low starch content and dietary fiber rate were evaluated as technological characteristics.

The results of stepwise regression analysis for the prediction of β-glucan rate are given in Table 3.For β-glucan content, effects in the rate of 62.12% are defined. According to this, the following formula was obtained:

$$\beta GR = 4,37 + 0.39\ AR + 0.18\ OR + 0.05\ TW - 0.17\ SR - 0.07\ DFR - 0.07\ NSP\ (R^2 = 62.12)$$

Based on the result of stepwise regression analysis, the ash rate, oil rate and test weight were determined to generate positive effects on β-glucan content whereas starch, dietary fiber and number of spikelet/panicle were determined to generate negative effects. These characteristics were the most effective selection criteria.

The results of correlation, path and step-wise analysis were found corroborative and consistent for ash rate, oil rate, starch rate, dietary fiber rate and number of spikelet/panicle.

Conclusions

The present study revealed that β-glucan content was significantly positive associated with ash content and oil rate in correlation, path and step-wise analysis. Similarly, starch rate, dietary fiber rate and number of spikelet/panicle had negatively effects in all methods. For higher β-glucan in the definition of genotypes or for breeding programs, it can be said that it is beneficial to select genotypes with high values of ash content, oil content and test weight while with low values of starch content and dietary fiber ratio as well as low number of spikelet/panicle. The selection criteria for high β-glucan must be easily measurable properties. Moreover, relationships between β-glucan and these traits must be significant for indirect selection in breeding. The quality laboratory parameters such as higher ash and oil rate and test weight and lower starch and dietary fiber rate were evaluated to determine the suitable parents and line at further generations. However it can be said that suitable selection criteria was low number of spikelet/panicle in the early generation of single plant selection.

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References

AOAC, 1995 Official Methods of Analysis of the AOAC International, 16th ed., supplement 1998. AOAC, Washington, DC, pp: 25–28

Asp N. G., Mattsson B. and Onning G., 1992. Variation in dietary fiber, beta-glucan, starch, protein, fat and hull content of oats grown in Sweden 1987-1989. European Journal of Clinical Nutrition. 46(1):31-37

Cervantes-Martinez C.T., Frey K.J., White P.J. and Holland J.B., 2002. Correlated responses to selection for greater β-glucan content in two oat populations. Crop Sci. 42:730-738

Dumas J.B.A., 1831 Procedes de l’ analyse organique. Ann. Chim. Phys. 247: 198-213

Havrlentova M., Hlinkova A., Zofajova A., Kovacik P., Dvoncova D. and Deakova L., 2013. Effect of fertilization on β-glucan content in oat grain (*Avena sativa* L.). Agriculture (Poľnohospodárstvo), 59, 2013 (3): 111−119

Holthaus J.F., Holland J.B., White P.J. and Frey K.J., 1996 Inheritance of β-glucan content of oat grain. Crop Sci. 36: 567-572

Kapoor R, Bajaj R.K., Sidhu N. and Kaur S., 2011. Correlation and path coefficient analysis in oat (*Avena sativa* L.). Int. Jour. of Plant Breeding. 5(2): 133-136

Kibite S. and Edney M.J., 1998.The inheritance of β-glucan concentration in three oat (*Avena sativa* L.) crosses. Can. J. Plant Sci. 78: 245-250

Peterson D.M., Wesenberg D.M. and Burrup D.E., 1995. β-glucan content and its relationship to agronomic characteristics in elite oat germplasm. Crop Sci:35:965-970

Redaelli R., Frate V.D., Bellato S., Terracciano G., Ciccoritti R., Germeier C.U. and Stefanis E., 2011. Genetic and environmental variability in total and soluble β-glucan in European oat genotypes. Journal of Cereal Science, 57(2):193-199

Singh R.K. and Chaudhary B.D., 1979. Biometrical methods in quantitative genetic analysis. Kalyani Publishers. Ludhiana-New Delhi. pp. 304

Tiwari U. and Cummins E., 2009. Simulation of the factors affecting β-glucan levels during the cultivation of oats. Journal of Cereal Science 50(2):175/183

Tsikitis V.L., Albina J.E. and Reichner J.S., 2004. β-glucan affects leukocyte navigation in a complex chemotactic gradient. Surgery 136:384-389

Zute S., Berga L. and Vicupe Z., 2011. Variability in endosperm B-Glucan content of husked and naked oat genotypes. Acta Biol. Univ. Daugav p. 11 (2): 192-200