Изследвания върху полските култури, 2004, Том I - 3
Field Crops Studies, 2004, Vol. I - 3

COMBINING ABILITY FOR β-GLUCAN CONTENT OF OAT (*Avena sativa L.*) GRAIN

Galina Panayotova[1], Nikolay Tsenov[2]
[1]Institute of Agriculture and Seed Science "Obrazcov chiflik", Ruse
[2]Dobroudja Agricultural Institute, General Toshevo

Резюме

Панайотова, Г., Н. Ценов, 2004. Комбинативна способност по признака съдържание на β-глюкан в зърното на овеса (Avena sativa L.)

Направен е анализ на комбинативната способност на 6 сорта и селекционни линии пролетен овес по признака съдържание на β-глюкан в зърното. Установено е, че образците SL 7-65 и RL 5-38 са най-добри общи комбинатори. Те могат успешно да бъдат използвани в селекцията като родителски компоненти за високо съдържание на β-глюкан в зърното.

Ключови думи: Овес, Диалелен анализ, Комбинативна способност, β-глюкан

Abstract

Panayotova, G., N. Tsenov, 2004. Combining ability for β-glucan content of oat (Avena sativa L.) grain

The combining ability for β-glucan content of oat grain of six spring oat varieties and breeding lines were analyzed. The samples SL 7-65 and RL 5-38 have the best GCA (general combining ability). They can be used successfully in breeding programs as a donor for high β-glucan content of oat grain.

Key words: Oat, Diallel analysis, Combining ability, β-glucan

INTRODUCTION

Oat cultivars with high level of β-glucan content of grain are of interest because of its desirable effects on human health (Jenkins et al., 2002). Oat soluble fibre when added to daily diet has the potential to reduce low-density lipoprotein cholesterol levels which are associated with greater incidence of coronary heart disease in humans (Maki et al., 2003).

The high proportion of water soluble (1?3) (1?4) β-D-glucans (β-glucan) in oat grain has been identified as an active component primarily responsible for the effect of oat fiber on lowering blood serum cholesterol levels (Aman, 2001; Fleming, 2002;). β-glucan is a cell wall polysaccharide found in the endosperm and subaleurone layers of cereal seeds (Davidson et al., 1991; Behall et al., 1997). Among cereals, oat (*Avena sativa L.*) and barley (*Hordeum vulgare* L.) have the greatest concentrations of β-glucan (Wood, 1994; Aman & Hesselman, 1985; Prentice et al., 1980) but oat generally has a larger proportion of soluble β-glucan (Lee et al., 1997).

Development of oat cultivars with greater β-glucan content would increase the nutritional and economic value of the crop (Cervantes-Martinez et al., 2001).

While there is some information regarding the degree of inheritance of this trait, investigations on the combining ability for β-glucan content of oat grain are missing. This study was conducted to investigate the general combining ability (GCA) and specific combining ability (SCA) of some spring oat samples and to determine the relative importance of additive and non-additive gene action conditioning β-glucan content of oat grain.

MATERIAL AND METHODS

Six spring oat varieties and advanced breeding lines: Obrazcov chiflik 4, Prista 2, Drug, RL 5-38, ND 83-64 and SL 7-63 with different β-glucan content of grain were used as parents in diallel combinations without reciprocals: p (p-1)/2. The parents, F_1 and F_2 generations were grown in the field of the Institute of Agriculture and Seed Science "Obrazcov chiflik", Russe, in a randomized complete block design, with three replications. Oat seeds from each plot were dehulled to provide a sample of oat groats. β-glucan content of grain samples was determined by near infrared reflectance spectrophotometry (NIRS) (Osborne et al., 1983) at the Iowa State University, Ames, USA.

Data were collected on parents, F_1 and F_2 generations. The analysis of the combining ability was conducted according to Griffing (1956), Method II and Volf et al. (1980). The evaluation was based on parent's, F_1 and F_2's generations means.

The analysis of experimental results was done on the basis of the following scheme:

$$\mathbf{x_{IJK} = \mu + g_I + g_J + s_{IJ} + e_{IJK}}$$

x_{IJK} - value of selected trait in the cross i x j in k - th replication
μ - average value of the total set of crosses
g_I - general combining ability (GCA)of the i - th parent
g_J - general combining ability (GCA) of the j - th parent
s_{IJ} - specific combining ability (SCA) of the cross i x j
e_{IJK} – error

The genetic components of variation were determined after Hayman (1954) and the coefficient of inheritance - according to Mather & Jinks (1971).

RESULTS AND DISCUSSION

The variation assay of the combining ability shows that both the general combining ability (GCA) and specific combining ability (SCA) are significant in the studied generations (Table 1). The variances of GCA prevail significantly over these of SCA for F_1 and F_2 generations. This is a certain indication that additive gene action is important in determining this trait in the concrete diallel combinations. The presence of additive gene effects is very favorable for more effective breeding regarding β-glucan content of oat grain (Holthaus et al., 1996).

Table 1. Analysis of variation of combining ability for β-glucan content in oat grain in F_1- and F_2-generations

Year	Source of variation	F_1		dF	Ft	F_2	
		SS	F exp.			SS	F exp.
1997	GCA	17.98	76.39	5	2.45	19.79	90.54
	SCA	1.41	6.01	15	1.84	1.34	6.13
	E	0.24		40		0.22	
	GCA/SCA		16.64				15.79
1998	GCA	134.57	506.48	5	2.45	157.27	421.68
	SCA	2.68	10.08	15	1.84	7.48	20.05
	E	0.27		40		0.37	
	GCA/SCA		50.25				21.03
1999	GCA	88.84	406.82	5	2.45	97.58	84.47
	SCA	5.05	23.14	15	1.84	7.12	6.16
	E	0.22		40		1.16	
	GCA/SCA		17.58				13.70

The breeding lines SL 7-65 and RL 5-38 (Table 2) have high significant GCA effects in both generations while the rest of the lines exhibit insufficient effects. We suppose that the high level of the trait is controlled by additive genes. In the other parents the trait is determined by non-additive genes probably due to their low and negative GSA effects.

Table 2. General combining ability (GCA) effects and specific combining ability (SCA) variances for β-glucan content in oat grain

Oat samples	1997		1998		1999		Mean
	F_1	F_2	F_1	F_2	F_1	F_2	
			GCA effects				
Obrazcov chiflik	0.41	0.48	1.05	0.95	-0.02	0.39	0.54
RL 5-38	0.52	0.77	0.62	1.19	0.61	0.50	0.70
Drug	-0.72	-0.79	-0.52	-0.77	-0.95	-0.80	-0.76
SL 7-65	2.53	2.53	2.41	2.70	2.27	1.99	2.41
ND 83-64	-1.62	-1.67	-2.33	-2.57	-1.17	-1.36	-1.79
Prista 2	-1.11	-1.32	-1.23	-1.51	-0.74	-0.72	-1.11
			SCA variances				
Obrazcov chiflik	2.02	1.06	9.59	5.64	2.91	2.54	3.96
RL 5-38	1.01	1.24	3.49	2.17	2.34	0.93	1.86
Drug	3.31	2.59	5.59	2.20	2.63	1.79	3.02
SL 7-65	2.46	3.19	4.82	2.44	5.12	1.95	3.33
ND 83-64	6.12	6.98	3.70	3.36	9.76	4.28	5.70
Prista 2	3.39	3.68	9.48	7.15	5.92	2.86	5.41

Because of the high GCA effects and low SCA variances, the breeding lines SL 7-65 and RL 5-38 could be used as genetic donors for high в-glucan content of oat grain in breeding schemes. Parental line ND 83-64 and spring oat variety Prista 2 would be avoided as components as they have negative GCA effects and low trait average values. Therefore, GCA is more convenient in the case of self-pollinating crops for a basic evaluation of initial materials (parents), the importance of SCA increases in hybrid combination, the parents of which were selected on the basis of GCA. GCA + SCA rate in a certain traits can serve as criteria of its potential level, achieved by means of selection (Pixley et al., 1991).

Table 3. Components of genetic variation of F_1- and F_2-generations

Generations	Components of genetic variation						
	A	D_1	D_1/A	u	v	h^2	H^2
F_1	9.01	6.35	0.73	0.62	0.38	0.56	0.90
F_2	8.75	5.97	0.66	0.61	0.39	0.55	0.88

The additive (A) and non-additive (D) components of genetic variation of this diallel scheme are significant (Table 3). The values of D_1/A for both generations show a partial domination in the inheritance to the higher parent's means. The coefficients of heritability in broad (H^2) and narrow (h^2) sense are high.

CONCLUSION

The breeding lines SL 7-65 and RL 5-38 have to be used in new hybrid crosses because of their high general combining ability (GCA) effects and specific combining ability (SCA) variances for β-glucan content of grain. Breeding line ND 83-64 and spring oat variety Prista 2 would be avoided as components for breeding for this trait.

ACNOWLEDGMENTS

We express our sincere thanks to Dr. James B. Holland, Iowa State University, Ames, USA for his important contributions.

REFERENCES

Aman P., 2001. Starch and dietary fiber in oats products, Proc. of 3rd European Conference on Functional Properties in Oats, Uppsala, Sweden, May 17-18, 2001, 43-51

Aman, P., K. Hesselman, 1985. An enzymic method for analysis of total mixed-linkage в-glucans in cereal grains, J. Cereal Sci., 3, 231–237

Behall, K.M., D.J. Scholfield, J. Hallfrisch, 1997. Effect of в-glucan level in oat fiber extracts on blood lipids in men and women. J. Am. Coll. Nutr., 16, 46–51

Cervantes-Martinez, C.T., K.J. Frey, P.J. White, D.M. Wesenberg, J.B. Holland, 2001. Selection for Greater в-Glucan Content in Oat Grain, Crop Sci., 41, 1085–1091

Davidson, M.H., L.D. Dugan, J.H. Burns, J. Bova, K. Story, K.S. Drennan, 1991. The hypocholesterolemic effects of в-glucan in oatmeal and oat bran, JAMA, 265, 1833–1839

Fleming, S.E., 2002. Handbook of Dietary Fiber, Ed.: S.S. Cho and M.L. Dreher, 2001, M. Dekker, New York., Am J Clin Nutr, 76, 493

Jenkins, D.J.A., C.C. Kendall, V. Vuksan, E. Vidgen, T. Parker, D. Faulkner, C.C. Mehling, M. Garsetti, G. Testolin, S.C. Cunnane, M.A. Ryan, P.N. Corey, 2002. Soluble fiber intake at a dose approved by the US Food and Drug Administration for a claim of health benefits: serum lipid risk factors for cardiovascular disease assessed in a randomized controlled crossover trial, Am. J. Clinical Nutrition, 75, 834 – 839

Griffing, B., 1956. Concept of general and specific combining ability in relation to diallel crossing system, Australian J. of Biol. Sci., 9, 463 – 493

Hayman, B.I., 1954. The theory and analysis of diallel crosses, Genetics, 45, 155-172

Lee, C.J., R.D. Horsley, F.A. Manthey, P.B. Schwarz, 1997. Comparisons of в-glucan of barley and oat, Cereal Chem., 74, 571–575

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

Maki, K.C, F. Shinnick, M.A. Seeley, P.E. Veith, L.C. Quinn, P.J. Hallissey, A. Temer, M.H.

Davidson, 2003, Food Products Containing Free Tall Oil-Based Phytosterols and Oat Я-Glucan Lower Serum Total and LDL Cholesterol in Hypercholesterolemic Adults, J. Nutr., 133, 808 – 813

Mather, K., J.L. Jinks, 1971, Biometrical Genetics, Chapman Hall, London

Osborne, B.G., T. Fearn, P.G. Randall, 1983, Measurements of fat and sucrose in dry cake mixes by near infrared reflectance spectroscopy, J. Food Technol., 18, 651–656

Pixley, K.V., K.J. Frey, 1991. Combining ability for test weight and agronomic traits of oat, Crop Sci., 31, 1448-1451

Prentice, N., S. Babler, S. Faber, 1980, Enzymatic analysis of в-D-glucans in cereal grains, Cereal Chem., 57, 198–202

Volf, B.G., P.P. Litun, A.B. Havelova, P.I. Kuzmenko, 1980, Mathematical methods for analysis of the combining ability, 5-38, Harkov (Ru)

Wood, P.J., 1994, Evaluation of oat bran as a soluble fiber source; Characterization of oat в-glucan and its effect on glycogenic response, Carbohydr. Polym., 25, 331–336