POSSIBILITIES OF BREEDING WHEAT COMBINING HIGH OSMOTIC ADJUSTMENT CAPACITY AND SUITABLE BREADMAKING QUALITY

Amalia Neacşu[1], Gabriela Şerban[1], Constantina Bănică[1], Nicolae N. Săulescu[1]

ABSTRACT

High osmotic adjustment (OA) is a desirable trait for improving wheat performance under drought. Previous reports showed that the *or* allele of the gene that controls osmotic adjustment has a negative effect on dough strength, because of a difference in peroxidase activity, due to linkage between the endosperm peroxidase, *Per-A4*, locus, and the osmoregulation locus. We analyzed quality parameters of doubled haploid lines, derived from a cross between a high OA, lower quality cultivar (Izvor) and a low OA cultivar with higher quality (Jiana). A large variation, only slightly associated with the capacity for osmotic adjustment was found among lines in all quality parameters, including dough strength. Distribution of high OA and low OA lines overlapped and, although best values for all parameters were found in low OA lines, the difference between the parameters of the best low OA and the best high OA lines was relatively small. These results suggest that breeding high OA cultivars with improved quality is feasible.

Key words: osmotic adjustment (OA), breadmaking quality, mixing properties, doubled haploids (DH).

INTRODUCTION

Plant performance under drought can be improved by many potentially useful mechanisms and traits (Blum, 1996, 1998; Ginkel et al., 1998). Among them, osmotic adjustment (OA) is receiving increased recognition as a major mechanism of drought resistance in crop plants (Zhang et al., 1999).

The capacity to adjust the cell osmotic pressure is an inherited trait, which in wheat is controlled by alternative alleles at one locus on chromosome 7A, that controls primarily differences in potassium accumulation (Morgan, 1983, 1991).

Morgan (1999 b) analyzed backcross lines selected for this particular gene and found that those who had high OA had a reduction in the breadmaking quality. The negative effect on dough strength was explained by a difference in peroxidase activity, due to linkage between the endosperm peroxidase, *Per-A4*, locus, and the osmoregulation, *or*, locus. There was an expectation, from published work, that dough strength could be affected by peroxidase, and this hypothesis was confirmed by measurements of peroxidase activity. On average, lines with high OA (lower dough strength) had lower peroxidase activities than the recurrent parents (higher dough strength).

Mixing properties can be best determined by recording dough behavior during mixing, using a mixograph type device (Finney and Shogren, 1972). The Reomixer, manufactured by Reologen i Lund AB, conforms at large to the AACC Mixograph standard, and the mixing curves produced agree well with the results of the classical pen recording National Mixograph (Bohlin, 2007), providing „practical, rapid small-scale wheat protein quality measurements derived from dough mixing characteristics” (Anderson, 2004).

Mixing parameters can be used for predicting bread volume (Wikstrőm and Bohlin, 2007) and are themselves important objectives in breeding for improved wheat processing quality. A high bread volume was related to higher values for both resistance (strength) and extensibility (Antes and Wieser, 2001).

This paper is an attempt to evaluate possibilities of combining high OA with acceptable breadmaking quality, based on results on quality parameters of doubled haploid lines derived from a cross between a high OA, lower quality cultivar and a low OA cultivar with higher quality.

MATERIAL AND METHODS

Fifty six doubled haploid (DH) lines from the cross between cultivars Izvor (drought resistant) and Jiana (medium drought resistance), were obtained using the „*Zea* system” (Giura, 1993).

The osmotic adjustment capacity was estimated using the pollen test developed by Morgan (1999 a). As osmotic adjustment is a cellular mechanism it is expressed in all plant

[1] National Agricultural Research and Development Institute Fundulea, 915200 Fundulea, Călăraşi County, Romania.

cells, including pollen and this offers a convenient way to characterize germplasm for this trait (Morgan, 1999 a; Moud and Yamagishi, 2005).

Pollen grains of matured anthers, at or near the point of dehiscing, were soaked in polyethylene glycol (PEG 6000) solutions of several concentrations, over microscope slides, with or without 10 mM KCl added to the solutions. A PEG concentration of 55% with and without KCl was used to discriminate the DH lines according to their OA capacity (Bănică et al., 2008).

Grain samples of DH lines and of the parents were collected from yield trials performed on 5 square meter plots in 2008. Three replications were used for the parents.

All grain samples were analyzed with Reomixer, used ten grams flour, following manufacturer's instructions. The Reomixer measures the torque by detecting the deflection of a lever arm constrained by a pair of stiff springs, using a non-contacting sensor. The software provided by the manufacturing company allows for determining 13 mixing parameters describing specific characteristics of the mixing curve, plus three integrating (integrated height to peak - IHTP, area below and area within the mixing curve) and one calculated parameter, the estimated bread volume (BV).

Neacşu et al. (2009) found that most information contained in this large number of mixing parameters can be condensed by five parameters, which describe the basic rheological aspects of dough development and are most appropriate for use in breeding: initial slope („initslope") describing the water absorption phase**;** development time, or time to peak („peaktime"), describing the mixing requirements of the dough; peak height („peakheight") describing the dough strength or elasticity; dough breakdown („breakdown"), describing the dough stability or tolerance to over-mixing; and final width („endwidth"), describing mainly the dough extensibility.

In this study we analyzed these five parameters, and in addition the estimated bread volume (BV), areabelow and areawithin which describe the area under the curve and inside the curve respectively. We also analyzed the grain protein concentration, using a Perten Inframatic infrared analyzer and sedimentation value was determined using the Zeleny method, modified by adding sodium dodecyl sulphate.

Significance of differences between parents was calculated using ANOVA, and average and amplitude of variation were calculated for high OA and low OA lines.

RESULTS AND DISCUSSION

All quality parameters of the high OA parent Izvor were inferior to those of the low OA parent Jiana, but the difference between the two parents was significant only for the mixing parameters dough development time (peaktime) and strength (peakheight) (Table 1). Close to significance were differences between parents for grain protein concentration and sedimentation values, but differences for breakdown, extensibility (endwidth) and estimated bread volume (BV) were clearly not significant.

Table 1. Quality parameters of the parental cultivars Izvor and Jiana

Parameters	Izvor (high OA parent)	Jiana (low OA parent)	P%[a]
Protein concentration %	13.23	14.47	6.0
Sedimentation index	53.83	56.00	6.9
Estimated bread volume	1085.33	1246.67	13.2
Initial slope	5.56	5.15	8.2
Peak time	2.47	3.38	*2.4*
Peak height	5.80	6.50	*4.8*
Break down	3.59	2.58	32.8
Area below	28.9	37.95	7.5
End width	0.49	0.93	12.4

[a]) Probability that the parameters of the two parents are equal

For the DH lines grouped according to their OA, the averages of all quality parameters were very close, with only slight and not significant superiority of the low OA lines (Table 2). The variation of all parameters inside both high and low OA groups was very large, with considerable overlapping of variation among the groups. This can be easily observed from the amplitudes of variation in table 2 and from the figures 1 and 2, describing the variation of dough strength and development time in high and low OA lines.

Table 2. Quality parameters of high and low osmotic adjustment DH lines from the cross Izvor/Jiana

Parameters	High OA lines		Low OA lines	
	Average ± standard deviation	Amplitude of variation	Average ± standard deviation	Amplitude of variation
P%	13.48 ± 0.68	12.0 - 14.7	13.75 ± 0.63	12.2 - 15.0
Sedimentation index	52.00 ± 4.83	43.0 - 61.5	52.05 ± 4.77	42.5 - 65.0
Estimated bread volume	1102 ± 107.8	924 - 1305	1144 ± 127.9	919 - 1480
Initial slope	5.38 ± 0.89	4.04 - 8.36	5.15 ± 0.73	3.41 - 6.87
Peak time	2.84 ± 0.46	2.18 - 3.90	2.90 ± 0.48	1.95 - 3.98
Peak height	5.85 ± 0.69	4.76 - 7.54	5.96 ± 0.73	4.55 - 7.81
Break down	2.52 ± 0.64	1.40 - 3.86	2.62 ± 0.68	1.24 - 5.09
Area below	33.8 ± 5.1	23.7 - 44.2	34.1 ± 4.7	22.7 - 45.4
End width	0.66 ± 0.28	0.29 - 1.37	0.69 ± 0.26	0.29 - 1.58

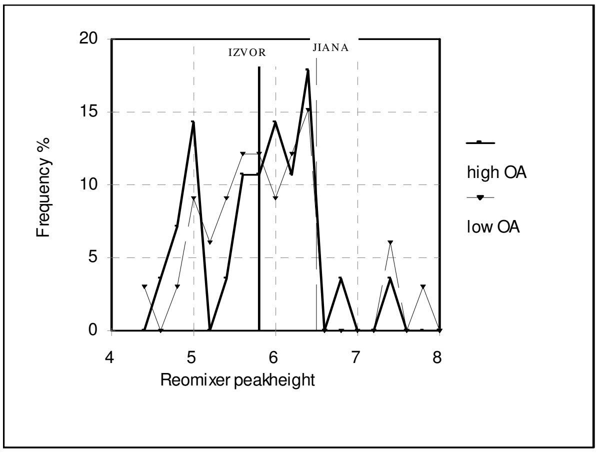

Figure 1. Gluten strength expressed as Reomixer peakheight in high and low osmotic adjustment DH lines from the cross Izvor/Jiana

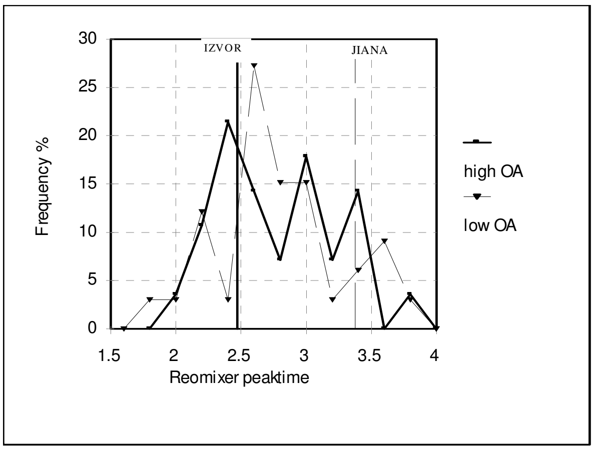

Figure 2. Dough development time, expressed as Reomixer peaktime, in high and low osmotic adjustment DH lines from the cross Izvor/Jiana

Best values for each parameter in the analyzed lines were better than the best parent and were always found in a low OA line. However the best high OA line was only slightly inferior to the best low OA line.

This suggests that analyzed quality parameters depended on the effect of a large number of genes, among which the effect of the *or* gene played a relatively minor role, dependent on the whole genetic background. Morgan (1999 b) also found that the effect of the *or* gene on dough rheological properties depended on protein content and genotype.

CONCLUSIONS

Quality parameters of DH lines, derived from a cross between a high OA, lower quality cultivar (Izvor) and a low OA cultivar with higher quality (Jiana), showed a large variation, only slightly associated with their capacity for osmotic adjustment. Distribution of high OA and low OA lines overlapped and, although best values for all parameters were found in low OA lines, the difference between the parameters of the best low OA and the best high OA lines was relatively small.

These results suggest that breeding high OA cultivars with improved quality is feasible.

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