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Evaluation of relative water content in winter wheat

Lugojan C.[1*], Ciulca S.[1]

USAMVB Timisoara, Faculty of Horticulture and Sylviculture

*Corresponding author. Email: alexcrstn@yahoo.com

Abstract Drought stress is a major limiting factor to crop production worldwide. An improved understanding of drought related characters and genetics thereof may lead to the use of these characters as selection criteria in breeding for drought resistance. Leaf relative water content (RWC) has been proposed as more important indicator of water status than other water potential parameters under drought stress conditions. The objective of the present study was to evaluate the RWC for characterization of drought tolerance as an early stage screening criterion. The studied biological material consisted of seven wheat varieties with different genetic and ecologic origin, along with their 21 one-way crosses. Combined analysis of variance indicated considerable variation for studied genotypes, parents and crosses. Hybrid combinations: Turda 2000 x Apullum, GKKapos x Apache si Xenon x Turda 2000, showed the highest values of "trans" heterosis for this character. In comparison with the experience mean is observed that approximately 24% of the hybrids (Turda 2000 x Apullum; Alex x Apache; Turda 2000 x Alex; Xenon x Turda 2000; GKKapos x Apache) have recorded a minimum 10% increase of relative water content of leaves. Xenon variety transmit with great fidelity at descendants' high value of this character.

Key words

winter wheat, relative water content, drought tolerance

Drought tolerance is considered as a valid breeding target in the stabilization of crop performance, by breeders and molecular biologists, at the moment there is a lack of information to be able to measure with precision the plant resistance under drought stress conditions [1]. Plant response to drought can be studied by identification of traits that are related to drought tolerance

Drought stress is a decrease of soil water potential so plants reduce their osmotic potential for water absorption by congestion of soluble carbohydrates and proline and in other words osmotic regulation is performed [9]. Therefore osmotic regulation will help to cell development and plant growth in water stress [10]. It is defined that decrease of relative water content close stomata and also after blocking of stomata will reduce photosynthesis rate [5]. It is reported that high relative water content is a resistant mechanism to drought, and that high relative water content is the result of more osmotic regulation or less elasticity of tissue cell wall [11].

RWC is closely related with cell volume, it may more closely reflect the balance between water supply to the leaf and transpiration rate [12; 7]. This influences the ability of the plant to recover from stress and consequently affects yield and yield stability [8].

Leaf relative water content (RWC) has also been proposed as a more important indicator of water status than other water potential parameters under drought stress conditions [3; 6]. The method is simple. It estimates the current water content of the sampled leaf tissue relative the maximal water content it can hold at full turgidity. It is a measure of water deficit in the leaf. Normal values of RWC range between 98% in turgid and transpiring leaves to about 40% in severely desiccated and dying leaves. In most crop species the typical RWC at about wilting is around 60% to 70%, with exceptions.

Material and Method

Seven wheat varieties with different genetic and ecologic origin, along with their 21 one-way crosses, were studied in a randomized block design with three replications.

To determine RWC the flag leaves were sampled. The leaves were placed in polythene bags and transported to the laboratory as quickly as possible in order to minimize water losses due to evaporation. The samples were also weighed immediately as fresh weight (FW), then sliced into 2 cm sections and floated on distilled water for 4 h. The turgid leaf discs were then rapidly blotted to remove surface water and weighed to obtain turgid weight (TW). The leaf discs were dried in the oven at 60 ^{0}C for 24 h and then dry weight (DW) obtained. The RWC was calculated by the formula given by Barrs (1968): RWC (%) = [FW-DW)/(TW-DW] * 100

The determination of differences significance between the studied cultivars and crosses, the processing of obtained experimental data was performed using variance analysis and *t* test according to Ciulca, 2006.

Results and Discussions

In terms of relative water content of leaves for F_1 hybrids (table 1), 38% of the hybrids were superior to both parents and approximately 24% were inferior to both parental forms. Among the crosses intermediate to the parental forms, about 24 % have achieved higher values of this trait, and 14% lower values comparing to mid parent. Compared with the parents mean the crosses of this generation showed an amplitude of 43.47%, while the average values of "cis" heterosis were very low (1.27%) and the "trans" heterosis were 6.54%. Hybrid combinations: Turda 2000 x Apullum, GKKapos x Apache si Xenon x Turda 2000, showed the highest values of “trans” heterosis for this character.

Table 1

Express manner of the leaf relative water content in F_1 hybrids

Number of studied hybrids	Number and proportion (%) of F_1 hybrids				Range to parents mean (%)	Mean Heterosis (%)	
	Superior to parents	Intermediary between parents		Inferior to parents			
		Above the mean	Below the mean			“cis”	“trans”
21	8 (38.09%)	5 (23.81%)	3 (14.29 %)	5 (23.81%)	74.81 – 118.28	101.27	106.54

The highest values of heterosis index have achieved by the hybrids GKKapos x Turda 2000 (18.50), Fundulea 4 x Apache (3.76), combinations in which there were no significant differences between the parental forms in terms of this character. The lowest values of heterosis index, correlated with low water retention capacity, were registered in hybrids: Alex x Apullum (-2.58), GKKapos x Apullum (-1.60), GKKapos x Alex (-1.48).

Table 2

Heterosis index for leaf relative water content in F_1 hybrids

Genitors	Fundulea 4	Xenon	GKKapos	Turda 2000	Alex	Apache	Apullum
Fundulea 4	-	0.54	0.14	-1.26	0.14	3.76	-0.90
Xenon		-	-0.29	1.98	-0.20	0.01	-0.38
GKKapos			-	18.50	-1.48	1.36	-1.60
Turda 2000				-	0.41	0.64	1.18
Alex					-	0.51	-2.58
Apache						-	0.30
Apullum							-

Variance analysis presented in table 3a shows that there are real differences between the studied hybrid combinations in terms of relative water content of leaves. Reduced heterogeneity of experimental conditions between repetition does not significantly influence the results of measurements for this character at studied hybrid combinations.

Table 3

a) Variance analysis of leaf relative water content in F_1 hybrids

Variability source	SS	DF	MS	F Test
Total	6443.04	65		
Repetitions	188.78	2	94.39	F = 2.51
Hybrids	4677.48	21	222.74	F = 5.93**
Erorr	1576.78	42	37.54	

b) Estimative values and the significance of differences between F_1 hybrids concerning leaf relative water content

No.	Hybrids	RWC (%)		Relative value (%)	Difference/ Signifficance
		$\bar{x} \pm s_{\bar{x}}$	s %		
1	Hybrids Mean	70.38±1.20	2.94	100.00	Control
2	Fundulea 4 x Xenon	74.23±6.42	14.98	105.48	3.86
3	Fundulea 4 x GKKapos	65.40±2.14	5.66	92.93	-4.98
4	Fundulea 4 x Turda 2000	48.50±2.53	9.04	68.91	-21.88^{000}
5	Fundulea 4 x Alex	71.32±2.22	5.39	101.33	0.94
6	Fundulea 4 x Apache	71.08±0.94	2.29	100.99	0.70
7	Fundulea 4 x Apullum	50.28±1.58	5.44	71.44	-20.10^{000}
8	Xenon x GKKapos	70.51±2.22	5.45	100.18	0.13
9	Xenon x Turda 2000	79.15±1.45	3.17	112.46	8.77
10	Xenon x Alex	75.23±3.66	8.42	106.89	4.85
11	Xenon x Apache	67.38±6.46	16.61	95.74	-3.00
12	Xenon x Apullum	74.09±8.54	19.97	105.27	3.71
13	GKKapos x Turda 2000	76.11±0.89	2.03	108.14	5.73
14	GKKapos x Alex	60.54±5.47	15.64	86.03	-9.83
15	GKKapos x Apache	77.21±1.53	3.44	109.70	6.83
16	GKKapos x Apullum	61.95±4.69	13.11	88.02	-8.43
17	Turda2000 x Alex	78.12±1.22	2.71	111.00	7.74
18	Turda2000 x Apache	71.22±2.21	5.37	101.20	0.85
19	Turda2000 x Apullum	81.13±0.55	1.18	115.28	10.75*
20	Alex x Apache	79.12±3.64	7.96	112.43	8.75
21	Alex x Apullum	71.86±3.99	9.61	102.11	1.48
22	Apache x Apullum	73.53±2.53	5.95	104.48	3.16

$LSD_{5\%}$ = 10.09 $LSD_{1\%}$ = 13.49 $LSD_{0,1\%}$ = 17.70

The studied hybrids have recorded values of this character ranging from 48.50 % in Fundulea 4 x Turda 2000 to 81.13 % for Turda2000 x Apullum, with variation amplitude of 32.63%, against a low inter-genotypic variability. Intra-genotypic variability was generally low for most combinations except hybrids: Xenon x Apullum, Xenon x Apache, GKKapos x Alex, Fundulea 4 x Xenon si GKKapos x Apullum, where a medium variability was observed.

In comparison with the experience mean is observed that approximately 24% of the hybrids (Turda 2000 x Apullum; Alex x Apache; Turda 2000 x Alex; Xenon x Turda 2000; GKKapos x Apache) have recorded a minimum 10% increase of relative water content of leaves, but only for the combination Turda 2000 x Apullum the increases were statistically assured. Because the water retention capacity of these genotypes is increased, the yield could be increased or at least stabilized.

A low drought tolerance associated with values of relative water content of leaves significantly below the mean were observed in the case of hybrids: Fundulea 4 x Turda 2000, Fundulea 4 x Apullum. As such, in the case of these combinations the variety Fundulea 4 show a high general combining ability to transmit to offspring low values of relative water content of leaves.

Table 4

The significance of differences between groups of F_1 hybrids with the same recurrent parent concerning leaf relative water content

No.	Reccurent parent	F_1Mean	Fundulea 4	Xenon	GKKapos	Turda 2000	Alex	Apache	Apullum
			63.47	73.43	68.62	72.37	72.70	73.26	68.80
1	Fundulea 4	63.47		-9.96	-5.15	-8.90	-9.23	-9.79	-5.33
2	Xenon	73.43			4.81	1.06	0.73	0.17	4.63
3	GKKapos	68.62				-3.75	-4.08	-4.64	-0.18
4	Turda 2000	72.37					-0.33	-0.88	3.58
5	Alex	72.70						-0.56	3.90
6	Apache	73.26							4.46
7	Apullum	68.80							

$LSD_{5\%}$	$LSD_{1\%}$	$LSD_{0,1\%}$
10.17	13.65	17.99

Taking into account the groups of hybrids with the same recurrent parent is observed that the highest water retention capacity shows the hybrids of varieties: Xenon and Apache, while the hybrids of variety Fundulea 4 exhibit a low water retention potential in the leaves. The differences observed between the groups of hybrids of the different varieties, have not reached the level of statistical assurance.

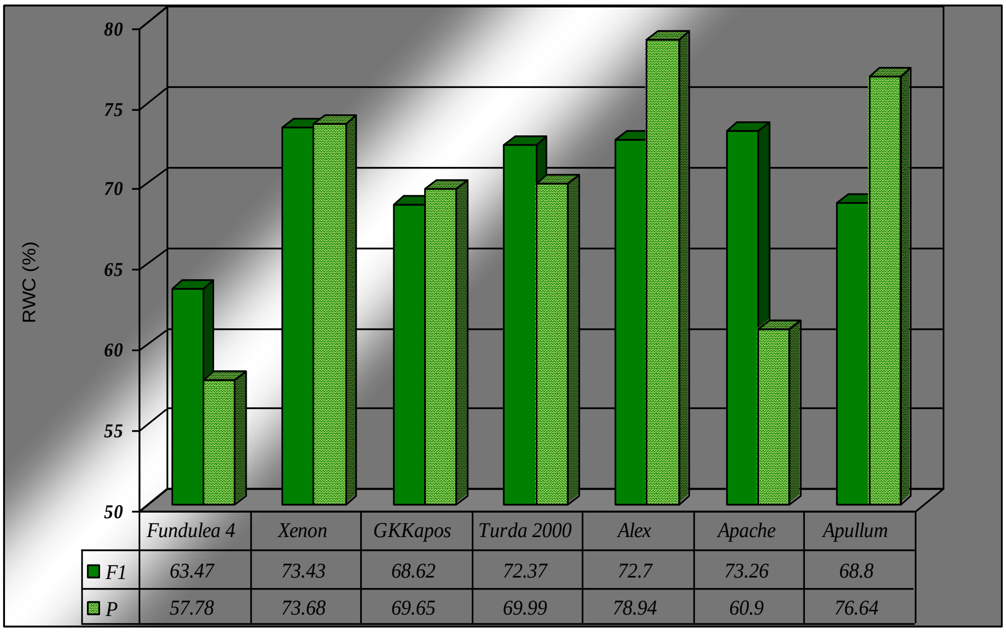

Fig .1. Leaf relative water content for groups of F_1 hybrids with the same recurrent parent

In comparison with the recurrent parent, the hybrids of varieties Apache and Fundulea 4 showed a significantly higher value of relative water content of leaves. The hybrids of Xenon variety did not show differences from the recurrent parent, suggesting that this variety transmit with great fidelity at descendants' high value of this character.

At the hybrids of the varieties which showed high values of this character, such as Apullum, Alex GKKapos, is observed a decrease of relative water content of leaves on a background of low combinative abilities of those parental forms.

Conclusions

Combined analysis of variance indicated considerable variation for studied genotypes, parents and crosses. Hybrid combinations: Turda 2000 x Apullum, GKKapos x Apache si Xenon x Turda 2000, showed the highest values of "trans" heterosis for this character.

In comparison with the experience mean is observed that approximately 24% of the hybrids (Turda 2000 x Apullum; Alex x Apache; Turda 2000 x Alex; Xenon x Turda 2000; GKKapos x Apache) have recorded a minimum 10% increase of relative water content of leaves, but only for the combination Turda 2000 x Apullum the increases were statistically assured. Because the water retention capacity of these genotypes is increased, the yield could be increased or at least stabilized.

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