Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 23, Issue 2, 2023
PRINT ISSN 2284-7995, E-ISSN 2285-3952

EVALUATION AND COMPARISON OF DROUGHT TOLERANCE IN SOME WHEAT VARIETIES BASED ON SELECTION INDICES

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Abstract

Continued population growth together with current climate change will threaten global food security in the near future. Wheat is a staple cereal crop for many countries, including Romania. Therefore, to obtain high yields, it is necessary to choose wheat cultivars with drought tolerance. Research has been done out during two growing seasons: 2018-2019 and 2019-2020 in the experimental field of ARDS Simnic, the purpose of this study being the evaluation of the drought tolerance of ten wheat varieties. The obtained results confirmed the strong positive relationships between the grain yields obtained both in drought (Ys) and non-stress conditions (Ys) and STI, MPI, GMP and YI indices, these selection indices expressing a high power of discrimination between varieties at a moderate level of drought stress (SI =0.53). Based on the rank sum (RS) of all selection indices, three drought tolerant varieties were identified, namely Miranda, Simnic 60 and Glosa. These varieties can be considered as the most suitable for cultivation in the study area and other areas with similar agroclimatic conditions.

Key words**:** *drought selection indices, rank sum, varieties of wheat, yield*

INTRODUCTION

Wheat (*Triticum aestivum* L.) represents the basic food for the human population in many areas of the world, therefore it occupies a significant weight in the structure of agricultural crops. In 2021, globally, wheat was cultivated on almost 221 million hectares, with production reaching 771 million tons [10].

It is an important crop for agricultural holdings, being used for industry, food, fodder, export and as a source of profit [17]. In the Romania's external cereal trade, both in export and in import, wheat and maize occupy over 40% [19].

The current climate changes determined by the lack of precipitation and the increasing temperatures together with the worsening of the eco-environment can severely reduce the yield of crops, thus compromising the nutritional security of the growing population.

According to [6], the most severe environmental stress that limits wheat productivity is drought stress. Also, drought stress in the reproduction stage is more harmful than that in the vegetative growth stage because drought during anthesis reduces photosynthesis, grain development and ultimately grain yield.

Habitat conditions (soil, climate) and genotypes are the main factors that allow obtaining high productions with superior quality.

In the Oltenia region, drought and heat are the two major stresses with a huge impact on the growth and yields of agricultural crops [5, 7, 8, 23].

Therefore, an effective approach to reduce the harmful effects of drought stress is the use of high-yielding and drought-tolerant varieties.

Considering the complexity of the plant-environmental conditions interaction, it is obvious that each set of environmental conditions (specific to a certain area) corresponds to a certain ideotype of wheat that is endowed with those properties capable of maximizing the exploitation of local conditions [20].

Based on the genotypic response to culture conditions, [12] established 4 Groups of genotypes:

- Group A: genotypes that achieve uniform performance in both conditions (stress and non-stress), having both high productivity and tolerance to stress;
- Group B: genotypes that show performance only in non-stress conditions, so they have no stress tolerance and achieve high productivity only in non-stress conditions;
- Group C: the genotypes that express performance only under stress conditions, they have tolerance to stress, but a low productivity;
- Group D: genotypes expressing a poor performance in both conditions. These genotypes have low productivity and low tolerance.

According to [24], for the comparison of changes in grain yields and the identification of genotypes from group A, various selection indices can be successfully used that are based on the mathematical relationship between yields under stress and non-stress conditions. The most used selection indices in many previous studies were GMP and STI [12], SSI [13], TOL and MPI [21]], YI [14], and DRI [16].

Also, moderate drought-stress environments are considered more suitable for selecting drought-tolerant genotypes than severe drought-stress environments [1].

The objectives of present study were to evaluate and compare grain yields based on selection indices, and to identify the most stable high-yielding varieties under both non-stress and drought conditions.

MATERIALS AND METHODS

This study was carried out in the experimental field, in two contrasting growing periods (2018-2019 and 2019-2020) at Agricultural Research and Development Station Șimnic, located 4 km North from Craiova. The 2018-2019 growing period was characterized as dry, with insufficient precipitation (429.5 mm) and an average temperature of 13.3°C. The period 2019-2020 was optimal for the wheat crop, summing up a total amount of precipitation 451.4 mm and an average annual temperature of 11.8°C (Table 1).

Trials were carried out on 10 wheat varieties in a randomized block with three repetitions. The soil in the experimental field was reddish preluvosol with a humus content of 1.8% and a pH=5.7-6.9.

To evaluate drought tolerance, seven selection indices were used: the index for stress susceptibility - SSI [13], index for stress tolerance - STI [12], index for mean productivity - MPI [21], index for geometric mean productivity - GMP [12], index for tolerance - TOL [21], index for yield - YI [14] and index for drought resistance - DRI [16].

These indices were calculated according to the following formulas:

$$SSI = [1 - (Ys/Yp)]/SI;\ SI = 1 - (Ysi/Ypi)$$

$$STI = (Yp) * (Ys)/(Ypi)^2$$

$$MPI = (Ys + Yp)/2$$

$$GMP = \sqrt{Ys * Yp}$$

$$TOL = (Yp - Ys)$$

$$YI = Ys/Ysi$$

$$DRI = Ys * (Ys/Yp)/Ysi$$

Yp and Ys are the grain yields obtained by each variety under non-stress and drought conditions (t/ha), and Ypi and Ysi are the average yields for all varieties under non-stress and drought conditions.

The rank sum (RS) for all the indices used was calculated with the formula below [11]:

$$RS = R + SDR$$

SDR is the standard deviation of rank, and R is the rank average;

The following statistical parameters were determined: average, standard deviation of the average and correlation coefficients using MS EXCEL program.

RESULTS AND DISCUSSIONS

Performance of varieties

Average grain yields and mean values of drought indices of the 10 varieties under non-stress (Yp) and drought conditions (Ys) were presented in Table 2.

The lower yields obtained in 2019 are due to the effect of the lack of precipitation in

October and the insufficient precipitation in May, months that coincided with the germination and anthesis phenophases, but also the higher average temperatures this year that amplified the effect of the drought.

The average yields under optimal conditions (non-stress) was 7.20 t/ha, and the 7 varieties that had higher yields than this average were considered varieties with high potential yield. In drought conditions, the average yields was 3.41 t/ha, and 5 varieties had higher yields than this average. The Pajura variety (8.17 t/ha) followed by the Simnic 60 variety (7.64 t/ha) recorded the highest grain yield values under non-stressed conditions, and the Miranda variety (3.85 t/ha) followed by the Otilia (3.68 t/ha) recorded the higher grain yield values under drought conditions.

Table 1. Monthly precipitation and average temperatures at ARDS Şimnic

Parameters	**Years**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Total Oct.-Sept.**
Precipitation (mm)	2018-2019	0	51	37	39.5	8.4	24	42	32	136	59	437.9
	2019-2020	32.8	46.4	4.8	23.6	20.6	64.6	4.5	71	71	90	451.4
Temperatures (°C)	2018-2019	14.3	5.5	-0.3	-1	4.1	11	11.9	16.2	22.7	22.9	13.8
	2019-2020	14.3	9.8	1.5	6.1	3.9	7.8	12	16.2	21.3	23.2	11.8

Source: Craiova meteorological station.

In non-stressed conditions, Bezostaia (5.58 t/ha) followed by Izvor (6.99 t/ha) recorded the lowest grain yield values, and in drought conditions, varieties Bezostaia (2.86 t/ha) and Ursita (3.20 t/ha) recorded the lowest values (Table 2). This variation of grain yields under drought (Ys) and non-stress (Yp) conditions suggested the existence of important genetic resources for obtaining drought-tolerant genotypes, confirming the results found by [9].

Comparison of cultivars based on tolerance indices

According to [22], under a moderate stress, the STI, MPI and GMP indices are more able to distinguish Group A genotypes (with high productivity and stress tolerance) from other groups. Therefore, high values for these indices express the higher drought tolerance and higher yield potential of the varieties.

Table 2. Average grain yields under non-stress (Yp) and drought conditions (Ys) with stress tolerance indices (SI =0.53)

Variety	**Yp**	**Ys**	**STI**	**SSI**	**MPI**	**GMP**	**TOL**	**YI**	**DRI**
Simnic 60	7.64	3.60	0.53	1.00	5.62	5.24	4.04	1.05	0.50
Adelina	7.40	3.29	0.46	1.05	5.35	4.93	4.11	0.96	0.43
Ursita	7.39	3.20	0.45	1.07	5.29	4.86	4.19	0.93	0.41
Pitar	7.33	3.36	0.47	1.02	5.34	4.96	3.97	0.98	0.45
Pajura	8.17	3.53	0.55	1.07	5.85	5.37	4.64	1.03	0.45
Otilia	7.00	3.68	0.50	0.90	5.34	5.08	3.32	1.07	0.57
Glosa	7.25	3.55	0.49	0.98	5.40	5.07	3.70	1.04	0.51
Izvor	6.99	3.21	0.43	1.02	5.10	4.74	3.78	0.94	0.43
Bezostaia	5.58	2.86	0.30	0.92	4.22	3.99	2.72	0.83	0.43
Miranda	7.25	3.85	0.54	0.88	5.55	5.28	3.40	1.12	0.60
Average	7.20	3.41	0.47	0.99	5.31	4.95	3.79	1.00	0.48

STI is the index for stress tolerance ; SSI is the index for stress susceptibility; TOL is the index for tolerance; MPI is the index for mean productivity; GMP is the index for geometric mean productivity; YI is the index for yield; DRI is the index for drought resistance

Source: Own calculation based on the experimental data obtained.

In our study, the Pajura, Miranda, Simnic 60, Otilia and Glosa varieties had the highest ITS value indicating that these could be the most suitable varieties (Tables 2 and 3).

The best varieties based on MPI index were Pajura, Simnic 60, Miranda, Glosa, Adelina, Pitar and Otilia, and the best varieties based on GMP were Pajura, Miranda, Simnic 60, Otilia, Glosa and Pitar.

According to YI, varieties Miranda, Otilia, Simnic 60, Pajura, - and by DRI, varieties Miranda, Otilia, Glosa, Simnic 60 - were the most suitable varieties (Table 3).

Low values of SSI and TOL indices indicate greater tolerance to drought [18].

Thus, the varieties Bezostaia, Otila, Miranda, Glosa and Izvor had the lowest values by the TOL index, and the varieties Miranda, Otilia, Bezostaia and Glosa had the lowest values by the SSI index (Tables 2 and 3).

Therefore, there were variations in the ranking of varieties according to different indices.

Ranking of varieties

Due to the lack of consistency of the indices used in their ability to identify the most suitable and drought tolerant wheat varieties, mean rank, standard deviation of ranks and rank sum were calculated for the ranking of these varieties (Table 3). Some previous studies by [2, 4, 11], successfully used this ranking method for drought tolerance screening.

Table 3. Ranks (R), standard deviation of ranks (SDR) and ranks sum (RS) of selection indices

Variety	Yp	Ys	STI	SSI	MPI	GMP	TOL	YI	DRI	R	SDR	RS
Simnic 60	2	3	3	5	2	3	7	3	4	3.56	1.59	5.15
Adelina	3	7	7	8	5	7	8	7	9	6.78	1.79	8.57
Ursita	4	9	8	9	8	8	9	9	10	8.22	1.72	9.94
Pitar	5	6	6	7	6	6	6	6	5	5.89	0.60	6.49
Pajura	1	5	2	10	1	1	10	5	6	4.56	3.64	8.20
Otilia	8	2	4	2	7	4	2	2	2	3.67	2.35	6.01
Glosa	6	4	5	4	4	5	4	4	3	4.33	0.87	5.20
Izvor	9	8	9	6	9	9	5	8	7	7.78	1.48	9.26
Bezostaia	10	10	10	3	10	10	1	10	8	8.00	3.50	11.50
Miranda	7	1	1	1	3	2	3	1	1	2.22	1.99	4.21

STI is the index for stress tolerance ; SSI is the index for stress susceptibility; TOL is the index for tolerance; MPI is the index for mean productivity; GMP is the index for geometric mean productivity; YI is the index for yield; DRI is the index for drought resistance

Source: Own calculation.

According to the ranking method, the lowest ranks sum were recorded for the wheat varieties Miranda (RS=4.21), Simnic 60 (RS=5.15), and Glosa (RS=5.20), therefore these varieties were found to be the most tolerant to drought, while the highest ranks sum were recorded for the Bezostaia varieties (RS=11.50).), Ursita (RS=9.94), and Izvor (RS=9.26), these being the most sensitive to drought (Table 3).

Correlations of grain yield and selection indices

Selection criteria capable of distinguishing genotypes from group A from other genotypes are considered to be the most effective [12]. Among these, the most suitable selection indices are those that achieve a high correlation with grain yields obtained in both environments [2, 22].

In our study, under a moderate drought level (SI=0.53), Yp was significantly positively correlated with Ys (r=0.608) (Table 4).

This correlation between Yp and Ys is an indication that the high yield performance under non-stressed conditions led to a relatively high yield under drought conditions. Similar results were reported by [18].

The significant positive correlations were found between Yp and STI, MPI, GMP, TOL, YI, also between Ys and STI, MPI, GMP, YI, DRI (Table 4). Therefore STI, MPI, GMP and YI indices are able to distinguish Group A varieties from other varieties. Similar results reported by [3]. The correlation of TOL with

Ys (r=0.214) was positive and non-significant, but the correlation with Yp was significantly positive (r=0.906). As a result, varieties selection based on the TOL index will lead to a significant yield reduction under non-stress conditions [25].

Table 4. Correlation coefficients between yields in non-stress (Yp) and drought conditions (Ys) and selection indices

Index	Yp	Ys	STI	SSI	MPI	GMP	TOL	YI	DRI
Yp	1								
Ys	0.608*	1							
STI	0.883**	0.908**	1						
SSI	0.561	-0.310ns	0.108ns	1					
MPI	0.965**	0.796**	0.975**	0.325ns	1				
GMP	0.907**	0.886**	0.997**	0.164ns	0.986**	1			
TOL	0.906**	0.214ns	0.602*	0.855**	0.762**	0.643*	1		
YI	0.618*	0.999**	0.912**	-0.294ns	0.804**	0.892**	0.228ns	1	
DRI	0.087ns	0.843**	0.542ns	-0.770^{00}	0.346ns	0.497ns	-0.343ns	0.833**	1

*, ** - significant positive at probability level of 5% and 1%, respectively; ^{00} - significant negative at probability level of 1%; ns - non-significant;
STI is the index for stress tolerance ; SSI is the index for stress susceptibility; TOL is the index for tolerance; MPI is the index for mean productivity; GMP is the index for geometric mean productivity; YI is the index for yield; DRI is the index for drought resistance
Source: Own calculation.

The close correlation (r=0.999) between the YI and Ys indices indicates that these two indices are identical in varieties ranking.
Positive and significant correlations were also observed between YI and STI, MPI, GMP (Table 4). Similar results were found in a previous study [15].

CONCLUSIONS

The assessment of drought tolerance in different rainfed environments allows the ranking of varieties according to their performance in each environment (with stress or non-stress). To identify drought-tolerant wheat varieties under moderate drought conditions, it is recommended to use the STI, MPI, GMP, YI indices because these indices support a stable and high yield both under non-stress and drought conditions. The screening of drought tolerant varieties by the ranking method for all selection indices used identified the varieties Miranda, Simnic 60 and Glosa as the most droughts tolerant and suitable varieties for cultivation in the agro-climatic conditions of the study area.

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