THE EFFECTS OF DROUGHT ON THE GRAIN YIELD OF SOME WHEAT GENOTYPES (*TRITICUM AESTIVUM* L.) UNDER THE AGROECOLOGICAL CONDITIONS OF SOUTH SERBIA

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Abstract. The paper aimed at identifying wheat genotypes tolerant to drought stress. The study repeated in three consecutive years was done on the alluvial soil of the Southern Morava river valley in South Serbia. The average wheat grain yield was higher by 124.5% under irrigation conditions than without irrigation. Over the experimental period, the average water consumed on wheat evapotranspiration under irrigation conditions was higher by 38.9% than without irrigation. Based on correlation statistical results and principal component analysis (PCA), in the case of stress resistant wheat genotypes, stress susceptibility index (SSI), tolerance index (TOL), mean productivity (MP), geometric mean productivity (GMP), stress tolerance index (STI), yield index (YI), yield stability index (YSI) as well as the LSD test was proved to be invariably efficient for determining the stress-tolerant genotypes. The result of tolerance index concerning drought and LSD test denoted that the Pobeda variety had a superior tolerance to stress due to drought than the other genotypes. Considering a comparatively low percentage of irrigated wheat fields in Serbia, it seemed to be outstandingly significant to identify the wheat genotypes tolerant to drought stress so that stable yields could be obtained.
Keywords: *winter wheat, drought stress, irrigation, water utilization efficiency, evapotranspiration*

Introduction

Crop production has been exposed to stress recently due to climate changes which have brought about extremely high temperatures with rather long dry periods. Drought stress takes place when soil and atmospheric humidity is low and the ambient air temperature is high. This condition is the result of an imbalance between the evapotranspiration flux and water intake from the soil (Lipiec et al., 2013). Namely, the stress caused by drought has a significantly negative effect on the crop yields. Implementation of crop management practices can potentially alleviate the harmful effects of drought and heat stresses and includes: soil management and culture practices, irrigation, crop residues and mulching and selection of more appropriate crop varieties (Lamaoui et al., 2018).

Wheat (*Triticum aestivum* L.) is said to be the most important crop in human nutrition with 728.1 million tons produced worldwide (FAO, 2018). However, Lizumi et al. (2018) found out that climate changes from 1981 to 2010 had decreased the wheat grain yield globally by 1.8%. In their research, Liu et al. (2016) foresaw that the wheat yield would

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fall by 4-6% per each degree of temperature rise. Having analysed the temperatures and rainfalls in Europe over the last three decades, Moore and Lobell (2015) established the wheat yield to have dropped by 2.5%.

Thus, the extreme drought in Spain and Portugal in 2005 led to a lower yield by 50-60% (Isendahl and Schmidt, 2006) while in Serbia, according to Dragović and Maksimović (2000), it caused yield to drop even by 81%. Jovanović et al. (2013) also reported decreased crop yield by 10-50% depending on the intensity of drought.

Further, Hall (1993) defined drought as a relative yield of a genotype when compared to that under stress conditions. Thus, researchers had to select the genotypes prone to stress in order to use genetic variation for improving stress-tolerant varieties (Clarke et al., 1984). The authors who suggested the indices for establishing stress-tolerant genotypes, were numerous (Fischer and Maurer, 1978; Rosielle and Hamblin, 1981; Bouslama and Schapaugh Jr, 1984; Fernandez, 1992; Gavuzzi et al., 1997). In contrast, the wheat varieties of a high genetic potential for grain yield selected under optimal growing conditions were reported as non-resistant to drought (Blum, 1979; Ceccarelli and Grando, 1991). Richards (1996) also stressed that wheat selection should be made under stress and optimal growing conditions.

The research aimed to determine drought stress resistant wheat varieties grown in Serbia, based on the effect of drought stress on their grain yield, in order to provide information on which varieties are less susceptible to climate change.

Materials and methods

Experimental location

The study lasted for three years in the experimental field, in Batušinac (43º15′24″ N and 21º49′13″ E, altitude: 201 m asl), municipality of Merošina, not far from the city of Niš in South Serbia (*Fig. 1*). The study location is approximately 240 km away from Belgrade.

Experimental design

The trials were set up in a random block system in three repetitions. Drought tolerance of the seven varieties Pobeda, Zvezdana, Rapsodija, Renesansa, Evropa 90, Simonida and NS Rana 5, created at the Institute of Field and Vegetable Crops in Novi Sad (the National Institute of the Republic of Serbia) and that of the two varieties (KG 56 and Takovčanka), selected at the Institute for Small Grains – Kragujevac, were studied. In the experimental field, winter wheat sowing was carried out from the 10th to 25th October. Seeding rate was 500 germinative seeds per m^2. The areas of elementary plots were 6 m^2 and, during vegetation, usual agrotechnical measures for wheat were used. The total amount of nutrients deposited to soil was: N - 130 kg ha^{-1}, P_2O_5 - 85 kg ha^{-1}, K_2O - 110 kg ha^{-1}. Irrigation was done by drip irrigation method and its term was determined by observing dynamics of soil moisture down to 60 cm of depth, pre-irrigation soil moisture amounted to 70% of the field water capacity (FWC). Soil moisture content was measured by thermogravimetric analysis in the oven at 105-110ºC.

Rainfall was measured at the experimental field by rain gauge. The mean monthly air temperatures and monthly amount of rainfall for the study period and multi-annual average for the city of Niš (*Table 1*) were taken from the website of RHS (2019).

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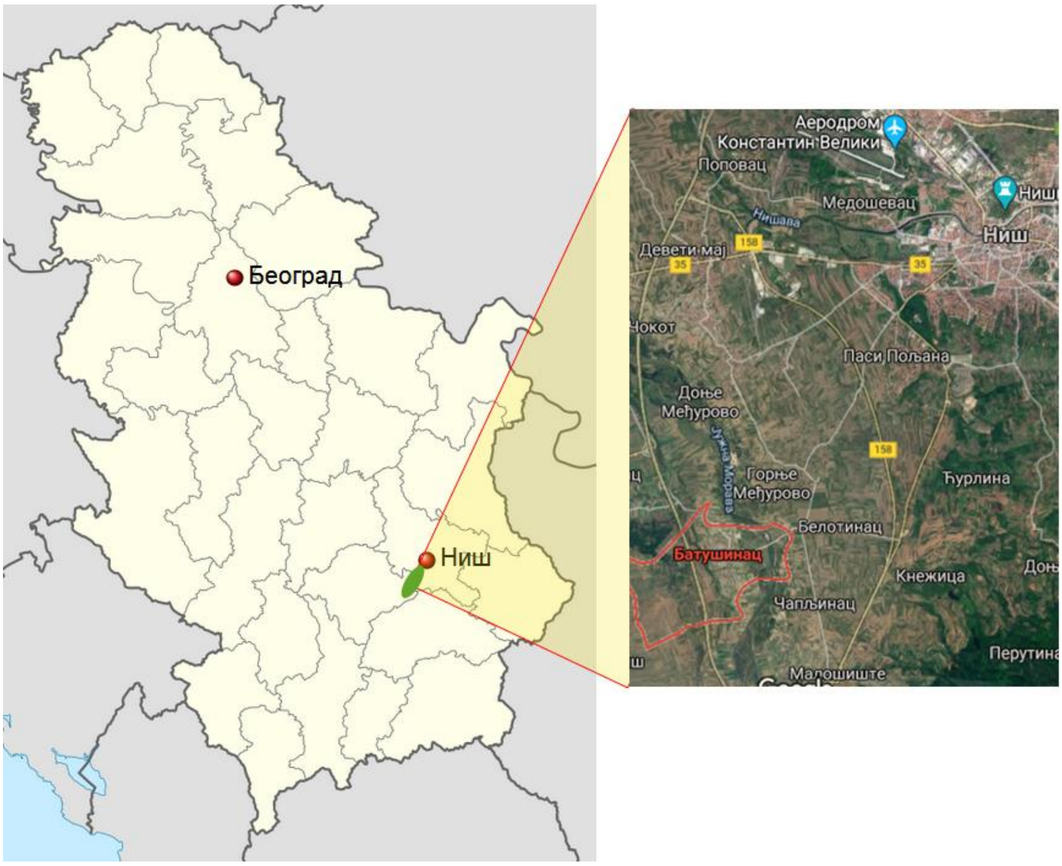

Figure 1. *Study location map (Niš, South Serbia)*

Table 1. *Mean monthly air temperatures (°C) and monthly amount of rainfall (mm)*

Year	**2014/15**		**2015/16**		**2016/17**		**1961-1990**		**1981-2010**	
Month	**T_{mean} (°C)**	**Rainfall (mm)**	**T_{mean} (°C)**	**Rainfall (mm)**	**T_{mean} (°C)**	**Rainfall (mm)**	**T_{mean} (°C)**	**Rainfall (mm)**	**T_{mean} (°C)**	**Rainfall (mm)**
X	12.3	56.8	12.1	81.3	11.1	89.5	11.9	34.1	12.3	45.5
XI	9.1	47.2	7.7	60.2	7.1	129.6	6.4	56.8	2.6	54.8
XII	2.8	87.3	2.9	1.7	-0.5	9.1	1.7	53.6	-0.8	51.5
I	2.1	60.0	0.5	101.3	-4.3	16.6	-0.2	41.3	0.6	38.8
II	3.6	45.2	9.1	45.1	4.9	32.9	2.5	40.3	2.4	36.8
III	6.9	79.5	8.3	62.5	10.8	37.5	6.7	45.3	7.0	42.5
IV	11.5	33.8	14.9	31.2	11.5	69.4	11.9	51.3	12.2	56.6
V	18.4	40.0	15.9	65.6	17.0	68.0	16.6	66.7	17.1	58.0
VI	20.2	53.4	22.5	37.3	22.9	26.0	19.5	69.7	20.4	57.3
VII	25.3	7.5	23.4	64.2	24.7	21.8	21.3	43.6	22.5	44.0
X-VII	11.2	510.7	11.7	550.4	10.5	500.4	9.8	502.7	9.6	485.8
IV-VII	18.8	134.7	19.2	198.3	19.0	185.2	17.3	231.3	18.0	215.9

Winter wheat evapotranspiration (ET) was calculated using the water balance method (*Eq. 1a, b, c*; Simsek et al., 2005):

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$$ETm = R + I \pm \Delta S - D - Ro \quad \text{(Eq.1a)}$$

$$ETa = R \pm \Delta S - D - Ro \quad \text{(Eq.1b)}$$

$$\pm \Delta S = R + I - D - Ro - ET \text{, } (ETm \text{ or } ETa) \quad \text{(Eq.1c)}$$

where:
ETm = evapotranspiration determined in irrigation treatment for the growing season;
ETa = evapotranspiration determined in treatment without irrigation for the growing season;
±ΔS = change in root zone water storage over a given time interval;
R = rainfall;
I = irrigation water applied;
D = drainage water (percolation);
Ro = surface runoff which was set to zero.

Water utilization efficiency of winter wheat (WUE) has been calculated as the observed wheat grain yield divided by water consumption for evapotranspiration (*Eq. 2*):

$$WUE = \frac{GY}{ET} \quad \text{(Eq.2)}$$

where:
WUE = water utilization efficiency (kg ha^{-1} mm^{-1});
GY = wheat grain yield (kg ha^{-1});
ET = evapotranspiration (mm).

Drought resistance indices were calculated as below:

- Stress Susceptibility Index (*Eq. 3*; Fischer and Maurer, 1978):

$$SSI = \frac{1 - \left(\dfrac{Y_s}{Y_p}\right)}{1 - \left(\dfrac{\overline{Y_s}}{\overline{Y_p}}\right)} \quad \text{(Eq.3)}$$

- Tolerance Index (*Eq. 4*; Rosielle and Hamblin, 1981):

$$TOL = Y_p - Y_s \quad \text{(Eq.4)}$$

- Mean Productivity (*Eq. 5*; Rosielle and Hamblin, 1981):

$$MP = \frac{(Y_s + Y_p)}{2} \quad \text{(Eq.5)}$$

- Geometric Mean Productivity (*Eq. 6*; Fernandez, 1992):

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$$GMP = \sqrt{Y_p \times Y_s} \quad \text{(Eq.6)}$$

- Stress Tolerance Index (*Eq. 7*; Fernandez, 1992):

$$STI = \frac{(Y_s + Y_p)}{(\overline{Y}_p)^2} \quad \text{(Eq.7)}$$

- Yield Index (*Eq. 8*; Gavuzzi et al., 1997):

$$YI = \frac{Y_s}{\overline{Y}_s} \quad \text{(Eq.8)}$$

- Yield Stability Index (*Eq. 9*; Bouslama and Schapaugh Jr, 1984):

$$YSI = \frac{Y_s}{Y_p} \quad \text{(Eq.9)}$$

where:
Y_s - yield of cultivar under stress condition;
Y_p - yield of cultivar under irrigation condition;
$\bar{Y}_s$ - total yield mean under stress condition;
$\bar{Y}_p$ - total yield mean under irrigation condition.

Statistical analysis

Data reported for the wheat yield were assessed by the analyses of variance (ANOVA) and Fisher's LSD test was used for all the significant differences at the $P < 0.05$ levels between the means. The relationship between crop yield and water used by evapotranspiration was evaluated using regression analysis. All the statistical analyses were made using software package JMP 15, Copyright SAS Institute Inc.

Results and discussion

The average wheat grain yield was higher by 124.5% with irrigation than without it (*Table 2*). Similarly, the effect of yield increased by 118.3% was established by Dutta et al. (2017) for the approximate values calculated for wheat ET. The highest irrigation during the season of 2014/15 exerted yield increase by 133.3%. The highest percentage of yield increase over the production year probably resulted from the rainfall deficiency in the period from April to July (134 mm) with longer dry periods.

The water used for wheat evapotranspiration with irrigation over the three years of the experiment amounted to 356.9 mm whereas ET amounted to 256.8 mm, being lower by 38.9% under stress conditions. The highest ET value (377.7 mm) with irrigation was recorded in 2015/16 when the highest mean monthly temperature of 19.2ºC was reported for the period from April to July (*Table 1*). The lowest ET value (227.4 mm) was recorded in the production year of 2014/15, during which the lowest amount of 134.7 mm rain fell.

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Table 2. *Grain yield, evapotranspiration and WUE of winter wheat under stress and irrigation conditions*

Year	Conditions	Soil water supplies (mm)	Rainfall (mm)	Irrigation (mm)	Grain yield (t ha^{-1})	ET (mm)	WUE (kg ha^{-1} mm^{-1})
2014/15	Irrigation	63.6	134.7	150	5.89	348.3	16.9
	Stress	92.7	134.7	-	2.68	227.4	11.8
2015/16	Irrigation	59.4	198.3	120	6.25	377.7	16.5
	Stress	77.9	198.3	-	2.85	276.2	10.3
2016/17	Irrigation	69.4	185.2	90	6.37	344.6	18.5
	Stress	81.8	185.2	-	2.73	267.0	10.2
Average	Irrigation	64.2	172.7	120	6.17	356.9	17.3
	Stress	84.1	172.7	-	2.75	256.8	10.8

Note: ET - evapotranspiration, WUE - water utilization efficiency

The ET values calculated for wheat throughout the research with irrigation (344.6-377.7 mm) were similar to those cited by Vučić (1976) and Bošnjak (1999) in the environmental conditions of South Serbia. The ET value determined with irrigation was similar to those from 345 to 385 mm evidenced by Luchiari et al. (1997). In addition, Balwinder-Singh et al. (2011) reported the plant requirements for water to range from 345 to 404 mm. Cui et al. (2018) reported wheat ET to be 402 mm at the invariable value of 70% of FWC being the same as that in the current research. Different ET values of wheat were due to differences in wheat varieties, irrigation regime and pedo-climatic conditions pertained to the area studied.

The WUE of winter wheat irrigation along with optimal soil humidity averaged 17.3 kg ha^{-1} mm^{-1} whereas it averaged 10.8 kg ha^{-1} mm^{-1} without irrigation (*Table 2*). The rational irrigation regime used resulted in significantly higher WUE values, complying with results of numerous authors (Kang et al., 2002; Huang et al., 2005; Sun et al., 2006; Mahamed et al., 2011; M'hamed et al., 2015).

The inter-relation of the linear regression of wheat yield with water consumption on ET (*Fig. 2*) was determined with a positive high significant correlation (r = 0.95**) displayed between the yield and the total water consumption on ET over the three years of the experiment.

All the nine wheat genotypes showed considerably lower mean values (86.6-204.7%) under stress conditions than when irrigated (*Table 3*). Thus, the average wheat yield with irrigation proved to be the highest with Renesansa (6.55 t ha^{-1}) and the lowest with Simonida (5.75 t ha^{-1}). The genotype Pobeda achieved the highest (3.95 t ha^{-1}) and NS Rana 5 the lowest yield (1.92 t ha^{-1}) under stress conditions without irrigation.

Further, the linear regression (*Fig. 3*) confirmed a high percentage of variation between Yp and Ys whereas the correlation coefficient between the wheat yield with irrigation and stress was insignificant (r = 0.61).

The variance analysis showed a noticeable difference in wheat yield as an interaction between the genotype and agroecological conditions with or without irrigation. LSD test also revealed a significant difference in the yield between the genotypes with irrigation conditions (*Table 4*). However, no significant difference in yield could be reported between the following genotypes: Pobeda - Zvezdana, Rapsodija - Renesansa, Renesansa - Evropa 90, KG 56 - Evropa 90, Takovčanka - Simonida and Simonida - NS Rana 5, respectively (*Table 4*).

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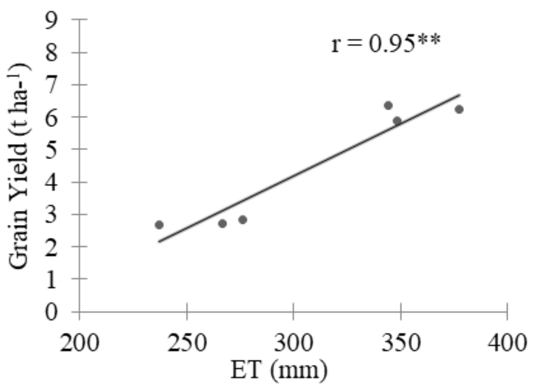

Figure 2. *Regression of grain yield by ET*

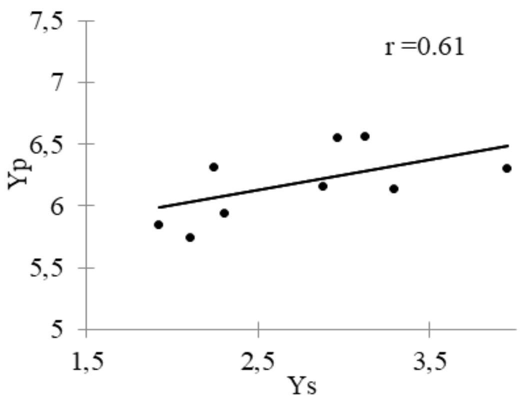

Figure 3. *Regression of Y_p by Y_s*

Table 3. *Mean grain yield of 9 winter wheat genotypes under stress and irrigation conditions (t ha^{-1})*

Genotypes (A)	Conditions (B)							
	2014/15		**2015/16**		**2016/17**		**Average (A)**	
	Irrigation	**Stress**	**Irrigation**	**Stress**	**Irrigation**	**Stress**	**Irrigation**	**Stress**
Evropa 90	6.31	2.81	5.97	3.26	6.19	2.56	6.16	2.88
KG 56	5.83	2.20	5.64	2.42	6.34	2.28	5.94	2.30
NS Rana 5	5.58	1.83	6.06	1.92	5.92	2.02	5.85	1.92
Pobeda	5.66	3.94	6.51	3.88	6.73	4.02	6.30	3.95
Renesansa	5.96	2.95	6.73	2.77	6.95	3.16	6.55	2.96
Simonida	5.34	1.99	6.06	2.16	5.85	2.14	5.75	2.10
Zvezdana	5.79	2.97	6.16	3.56	6.47	3.36	6.14	3.29
Takovčanka	6.06	2.14	6.25	2.54	6.55	2.03	6.32	2.24
Rapsodija	6.45	3.26	6.87	3.14	6.35	2.97	6.56	3.12
Average (B)	5.89	2.68	6.25	2.85	6.37	2.73	6.17	2.75

Table 4. *Irrigation by genotypes - Fisher's LSD test (2014/15-2016/17)*

Genotypes	**Pobeda**	**Zvezdana**	**Rapsodija**	**Renesansa**	**Evropa 90**	**KG 56**	**Takovčanka**	**Simonida**	**NS Rana 5**
Pobeda	-0.124	-0.112	0.135*	0.147*	0.270*	0.295*	0.496*	0.577*	0.683*
Zvezdana	-0.112	-0.124	0.123*	0.135*	0.257*	0.283*	0.484*	0.565*	0.671*
Rapsodija	0.135*	0.123*	-0.124	-0.112	0.010*	0.035*	0.236*	0.317*	0.423*
Renesansa	0.147*	0.135*	-0.112	-0.124	-0.002	0.023*	0.224*	0.305*	0.411*
Evropa 90	0.270*	0.257*	0.010*	-0.002	-0.124	-0.098	0.102*	0.183*	0.289*
KG 56	0.295*	0.283*	0.035*	0.023*	-0.098	-0.124	0.076*	0.157*	0.263*
Takovčanka	0.496*	0.484*	0.236*	0.224*	0.102*	0.076*	-0.124	-0.043	0.062*
Simonida	0.577*	0.565*	0.317*	0.305*	0.183*	0.157*	-0.043	-0.124	-0.018
NS Rana 5	0.683*	0.671*	0.423*	0.411*	0.289*	0.263*	0.062*	-0.018	-0.124

Note: *significantly different at LSD 0.05

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The variety Pobeda exposed to stress achieved a positive significant difference in its yield compared to the remaining varieties, meaning its best tolerance to stress due to water deficit (*Table 5*). In addition to Pobeda, Zvezdana and Evropa 90 also exhibited a significant tolerance to stress with no significant variations found in yield between the following wheat genotypes: Zvezdana - Rapsodija, Rapsodija - Renesansa, Renesansa - Evropa 90, KG 56 - Takovčanka, Takovčanka - Simonida, Simonida - NS Rana 5.

Table 5. *Genotypes under stress conditions - Fisher's LSD test (2014/15-2016/17)*

Genotyps	Pobeda	Zvezdana	Rapsodija	Renesansa	Evropa 90	KG 56	Takovčanka	Simonida	NS Rana 5
Pobeda	-0.175	0.472*	0.645*	0.812*	0.856*	1.456*	1.533*	1.670*	1.844*
Zvezdana	0.472*	-0.175	-0.002	0.164*	0.208*	0.808*	0.885*	1.023*	1.196*
Rapsodija	0.645*	-0.002	-0.175	-0.009	0.035*	0.635*	0.712*	0.849*	1.023*
Renesansa	0.812*	0.164*	-0.009	-0.175	-0.131	0.468*	0.545*	0.683*	0.856*
Evropa 90	0.856*	0.208*	0.035*	-0.131	-0.175	0.424*	0.500*	0.638*	0.812*
KG 56	1.456*	0.808*	0.635*	0.468*	0.424*	-0.175	-0.099	0.038*	0.212*
Takovčanka	1.533*	0.885*	0.712*	0.545*	0.500*	-0.099	-0.175	-0.038	0.135*
Simonida	1.670*	1.023*	0.849*	0.683*	0.638*	0.038*	-0.038	-0.175	-0.002
NS Rana 5	1.844*	1.196*	1.023*	0.856*	0.812*	0.212*	0.135*	-0.002	-0.175

Note: *significantly different at LSD 0.05

The lower values of SSI and TOL showed susceptibility and tolerance of the genotypes affected by stress. Based on the values calculated for SSI (0.67) and TOL (2.35), Pobeda expressed a more superior tolerance to stress than the other genotypes did (*Table 6*). It is worth mentioning that Zvezdana (SSI-0.84; TOL-2.85), Rapsodija (SSI-0.94; TOL-3.44) and Evropa 90 (SSI-0.95; TOL-3.28) expressed a better tolerance to drought than the remaining wheat genotypes did (Clarke et al., 1992; Golabadi et al., 2006; Talebi et al., 2009; Ilker et al., 2011). Guttieri et al. (2001) stressed that when the SSI values were higher than one, wheat varieties were manifested as extremely susceptible to stress caused by drought.

Table 6. *Drought tolerance indices and mean yield of 9 wheat genotypes under stress and irrigation conditions*

Genotypes	Y_p	Y_s	SSI	TOL	MP	GMP	STI	YI	YSI
Evropa 90	6.16	2.88	0.95	3.28	4.52	4.21	0.46	1.04	0.47
KG 56	5.94	2.30	1.09	3.64	4.12	3.69	0.36	0.84	0.39
NS Rana	5.85	1.92	1.20	3.93	3.89	3.35	0.30	0.70	0.33
Pobeda	6.30	3.95	0.67	2.35	5.12	4.98	0.65	1.44	0.63
Renesansa	6.55	2.96	0.98	3.59	4.75	4.40	0.51	1.08	0.46
Simonida	5.75	2.10	1.14	3.65	3.92	3.47	0.32	0.76	0.36
Zvezdana	6.14	3.29	0.84	2.85	4.75	4.49	0.53	1.20	0.53
Takovčanka	6.32	2.24	1.16	4.08	4.28	3.76	0.37	0.81	0.35
Rapsodija	6.56	3.12	0.94	3.44	4.84	4.52	0.54	1.13	0.46

Note: Y_p - yield of cultivar under irrigation condition, Y_s - yield of cultivar under stress condition, SSI - stress susceptibility index, TOL - tolerance index, MP - mean productivity, GMP - geometric mean productivity, STI - stress tolerance index, YI - yield index, YSI - yield stability index

The values of indices MP-5.12, GMP-4.98, STI-0.65 calculated for Pobeda favoured stress-tolerance of this genotype along with the similar values found for the yield under irrigation and stress conditions of MP-4.84, GMP-4.52, STI-0.54 for Rapsodija, MP-4.75, GMP-4.49, STI-0.53 for Zvezdana and MP-4.75, GMP-4.40, STI-0.51 for Renesansa, respectively, thereby expressing their high tolerance to stress due to water deficit. Fernandez (1992) claimed STI index to have probably altered the genotypes having a high yield and withstanding stress due to drought. Numerous authors (Talebi et al., 2009; Dadbakhsh et al., 2011; Khodarahmpour et al., 2011; Mohammadi et al., 2011; Sareen et al., 2012) pointed out STI, GMP and MP efficiency with the stress-tolerant genotypes. Khayatnezhad et al. (2010) pointed out that none of these indices could distinctly determine high yielding genotypes under the optimal and stress conditions.

The analysis of calculated results YI (1.44) and YSI (0.63) denoted that Pobeda exhibited a higher stress tolerance than the remaining eight wheat genotypes did. In addition to Pobeda as stress-tolerant to drought, the values of YI and YSI reported for Zvezdana (1.20; 0.53), Rapsodija (1.13; 0.46), Renesansa (1.08; 0.46) and Evropa 90 (1.04; 0.47), respectively, also confirmed their good stress tolerance to drought.

In addition, wheat yield attained with irrigation showed no significant correlation with SSI and TOL indices but it did with MP, GMP and STI (*Table 7*). Thus, when irrigated, the wheat yield achieved a negative with SSI and TOL but a positive significant correlation with MP, GMP and STI. These results comply with those reached by: Fernandez (1992), Shafazadeh et al. (2004), Golabadi et al. (2006), Talebi et al. (2009), Boussen et al. (2010), Anwar et al. (2011), Sarren et al. (2012) and Abdolshahi et al. (2013).

Table 7. *Correlation between drought tolerance indices with yield under irrigation and drought stress conditions*

Variables	Yp	Ys	SSI	TOL	MP	GMP	STI	YI	YSI
Yp	**1**	0.60	-0.47	-0.20	**0.78***	**0.72***	**0.70***	0.49*	0.46
Ys	0.60	**1**	**-0.98***	**-0.90***	**0.96***	**0.98***	**0.97***	0.28*	**0.98***
SSI	-0.47	**-0.98***	**1**	**0.95***	**-0.91***	**-0.94***	**-0.95***	-0.22*	**-0.99***
TOL	-0.20	**-0.90***	**0.95***	**1**	**-0.76***	**-0.82***	**-0.84***	-0.08	**-0.96***
MP	**0.78***	**0.96***	**-0.91***	**-0.76***	**1**	**0.99***	**0.99***	0.39	**0.90***
GMP	**0.72***	**0.98***	**-0.94***	**-0.82***	**0.99***	**1**	**0.99***	0.37	**0.94***
STI	**0.70***	**0.99***	**-0.95***	**-0.84***	**0.99***	**0.99***	**1**	0.32	**0.95***
YI	0.49	0.28*	-0.22	-0.08*	0.39	0.37	0.32*	**1**	0.20
YSI	0.46	**0.98***	**-0.99***	**-0.96***	**0.90***	**0.94***	**0.95***	0.20	**1**

Note: *significantly different at $p < 0.05$; Y_p - yield of cultivar under irrigation condition, Y_s - yield of cultivar under stress condition, SSI - stress susceptibility index, TOL - tolerance index, MP - mean productivity, GMP - geometric mean productivity, STI - stress tolerance index, YI - yield index, YSI - yield stability index

Based on PCA made for the three years of studies, the first two factors accounting for 93.9% data deviation were differentiated (*Table 8*). The first component accounted for 79.3% variation of the calculated indices. This component had a highly negative correlation with SSI and TOL, but a highly positive with Yp, Ys, MP, GMP, STI and YSI and a barely positive one with YI. The second component accounted for 14.6% index

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deviation and was positively correlated with Yp, SSI, TOL and YI but barely correlated with the remaining indices embraced by the current studies.

Table 8. *Principal Component Analysis (PCA) - Correlations between variables and components*

Factor	Total	% of variance	Yp	Ys	SSI	TOL	MP	GMP	STI	YI	YSI
1	7.14	79.35	0.66	0.99	-0.97	-0.87	0.98	0.99	0.99	0.35	0.96
2	1.31	14.58	0.63	-0.08	0.21	0.44	0.14	0.06	0.03	0.77	-0.23

Note: Y_p - yield of cultivar under irrigation condition, Y_s - yield of cultivar under stress condition, SSI - stress susceptibility index, TOL - tolerance index, MP - mean productivity, GMP - geometric mean productivity, STI - stress tolerance index, YI - yield index, YSI - yield stability index

The biplot, resulting from the two basic factors for the genotypes and indices, is presented in *Fig. 4.* Fernandez (1992) denoted to the angles and directions of the vectors indicating the strength and correlation between either one of the two attributes. Thus, a significantly positive correlation was revealed between YI and Yp, Yp and MP, MP, GMP and STI. A significantly positive correlation was also noticed between STI and TOL but solely due to the impact of the second component whereas a significantly negative correlation resulted from that of the first component, which is in agreement with the correlation results outlined in *Table 7*. Therefore, in order to efficiently identify the stress-tolerant genotypes, STI, GMP and MP should be used, which is corroborated by the findings of Fernandez (1992), Talebi et al. (2009), Nouri et al. (2011) as well as by those of Mollasadeghi et al. (2011), Sareen et al. (2012).

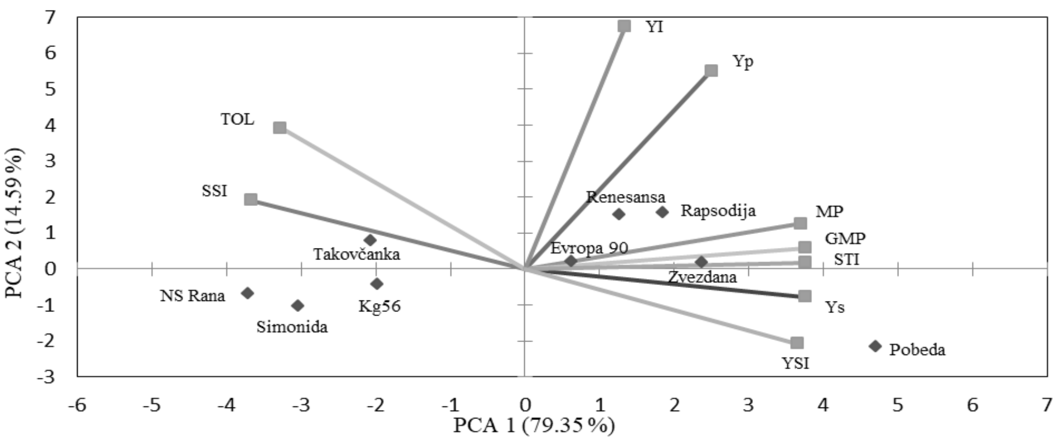

Figure 4. *PCA of drought tolerance indices*

Based on everything mentioned above as well as on the observations about the wheat genotypes within biplot, it may be inferred that Pobeda had a noticeably high tolerance to stress caused by drought along with Renesansa, Rapsodija, Evropa 90 and Zvezdana resisting the stress conditions quite satisfactorily, too.

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Conclusion

Climate changes were the major reason for identifying stress-tolerant wheat genotypes, which would simultaneously lead to their stable yields. Drought led to a significant decrease in the average yield (124.5%). The average water used for wheat evapotranspiration under irrigation conditions over the study period amounted to 356.9 mm and that used for ET under stress conditions to 256.8 mm. The stress tolerance indices of STI, MP and GMP helped to differentiate adequately and efficiently the wheat genotypes of a high yield, both in optimal and in stress conditions. YSI, TOL and SSI values clearly indicated the stress-tolerant genotypes. As confirmed by Fisher's LSD test, the YSI, TOL and SSI proved to be invariably efficient for revealing the stress-tolerant wheat genotypes. The variety Pobeda exhibited a more superior tolerance to stress than it did with the remaining genotypes. Renesansa, Rapsodija, Evropa 90 and Zvezdana also displayed a considerably good tolerance to stress. The study results will, therefore, pave the way for high and stable wheat yields provided that modern farming techniques and adequate agroecological management are used.

Overall, climate changes will pose a grave threat to agricultural production in the future and that´s all the more reason to keep on making long-term experiments of the crop stress tolerance caused by climate extremes so that stable yields can be achieved.

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